# Validating a System to Monitor Motor Development of At-Risk Infants in Black Communities: A Case Study

**Katelyn Fry-Hilderbrand[1], Yu-Ping Chen[2], Ayanna Howard[3]**

1. Institute of Robotics and Intelligent Machines, Georgia Institute of Technology, Atlanta, Georgia, USA
2. Department of Physical Therapy, Georgia State University, Atlanta, Georgia, USA
3. College of Engineering, The Ohio State University, Columbus, Ohio, USA

# Motivation

- Premature birth is a leading cause of infant mortality.
- Decline in infant mortality due to advances in neonatal care.
- Increase in survivability associated with increase in infant disability (~50% of all disabilities in children).
- Disabilities include neuro-developmental abnormalities and motor development delays.

# Importance of Early Intervention

- Early intervention can improve mobility and quality of life.

- Delays in diagnosis can reduce the success of intervention programs.

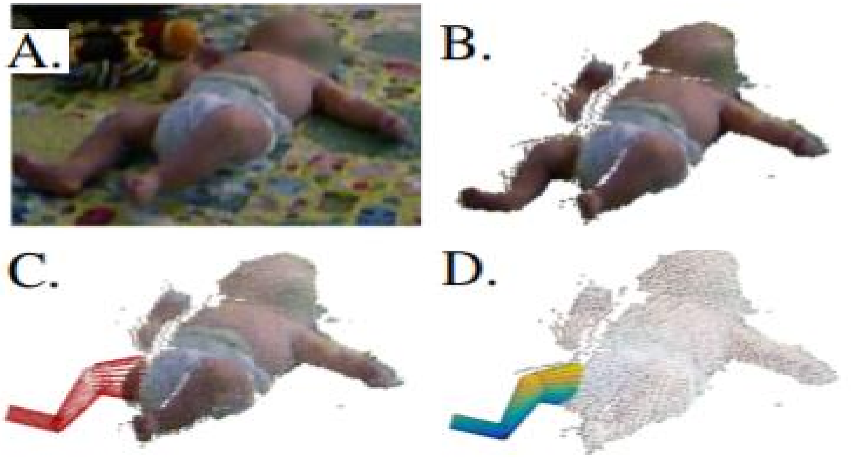
- **Automated tools needed to increase observation and detect delays sooner.**

Credit: Hyperbaric Healing Institute

# Automated Assessment:

- Marker-based motion tracking used to provide high accuracy in pose estimation.
- Camera data and depth cameras often used to determine limb coordination.
- Wearable sensing systems used to gather movement data over time.

Infant reaching for target while wearing reflective markers on wrists and shoulders[24].



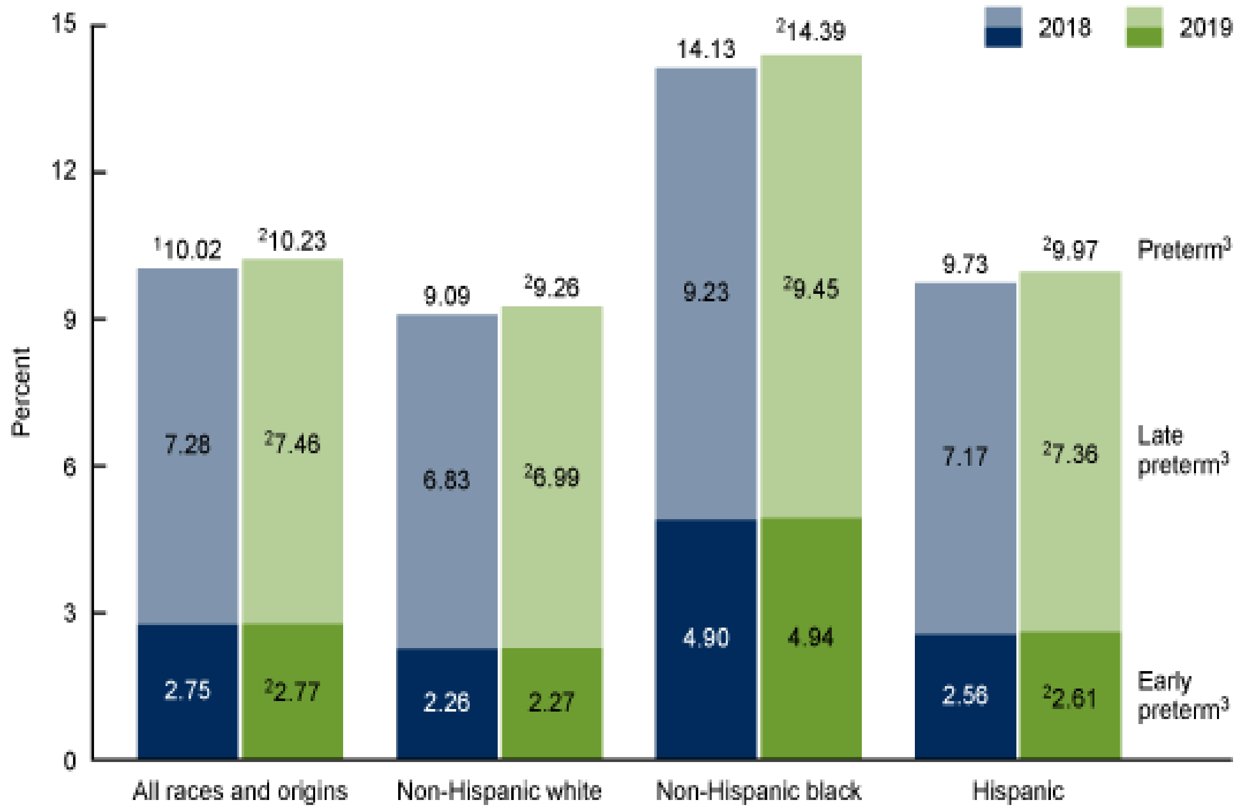

A: Input image, B: segmented point cloud, C: point cloud mixture model, and D: mesh model overlay[15].

# Limits in Current Automated Methods

- **Limited to a clinical setting due to expensive equipment and necessity for trained personnel.**
- Infants may not display their typical behavior when in an unfamiliar environment.
- Observation time still limited due to clinical setting.
- **May not be accessible for members of underserved communities.**

# Accessibility

- Additional factors associated with increased risk of preterm birth.
- Infants born to communities with elevated preterm births are at higher risk of delay and disability.

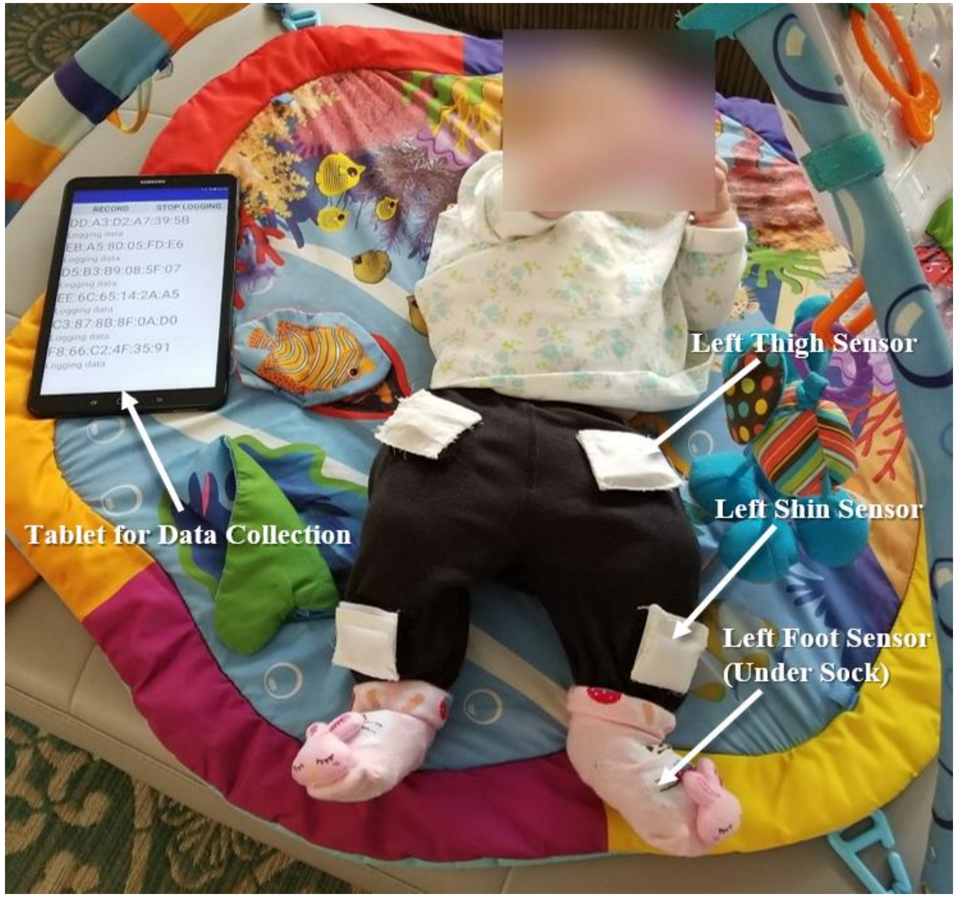



Credit: CDC.gov Births in the US, 2019

- **Accessible option to monitor infant motor development is needed.**

# Baby SmartyPants

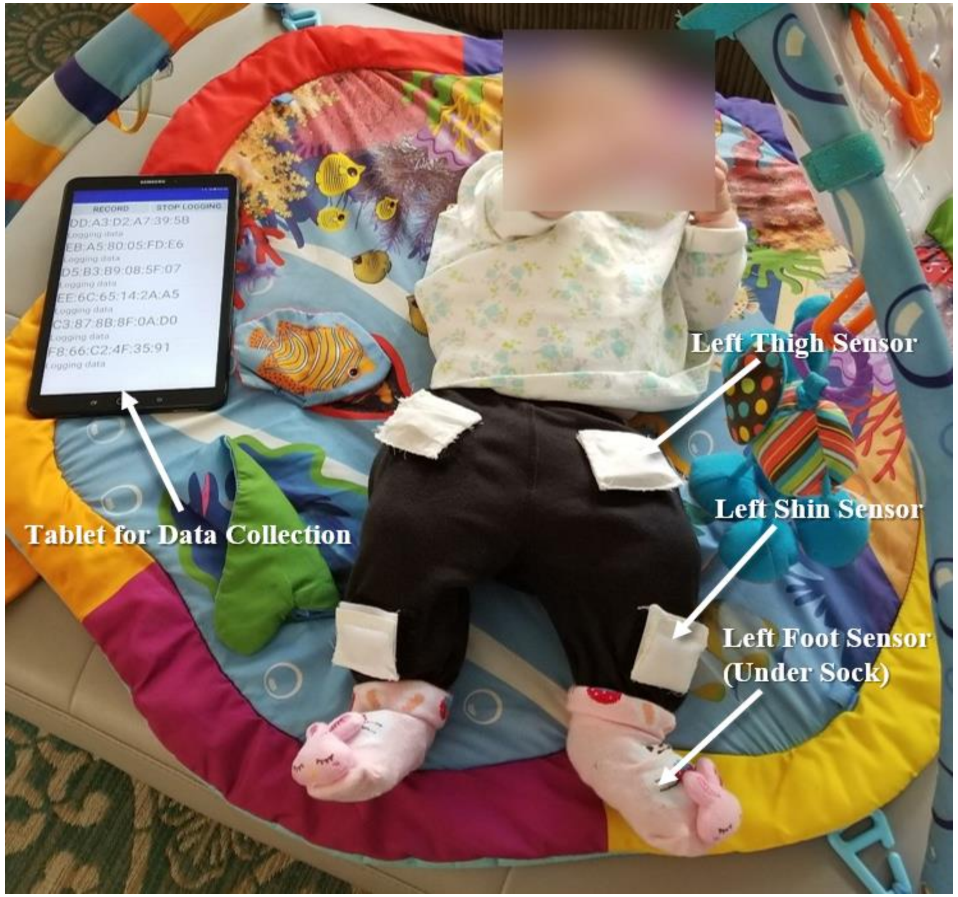
- Prototype system for collecting infant kinematic kicking data.
- Embedded sensor suit coupled with custom app.
- IMUs attached to the lower limb segments: foot, shin, and thigh.
- Custom app connects to and monitors each sensor.




Example of sensor placement for infant's left leg.

# Baby SmartyPants

- Gathers kicking data for each limb segment while infant is lying supine.
- **Data from term infants used determine normative values of kinematic features at various ages.**
- Features of an infant’s data can be compared to normative values to detect motor delays.




Example of sensor placement for infant’s left leg.

# Features Identified in Prior Work

| Metric | Variables | Equation |
| --- | --- | --- |
| **Frequency of Activity** | $n_{Act}$: number of active samples<br>$N$: total number of samples | $FA_i = {n_{Act}}/{N}$ |
| | | |
| | | |
| | | |

# Features Identified in Prior Work

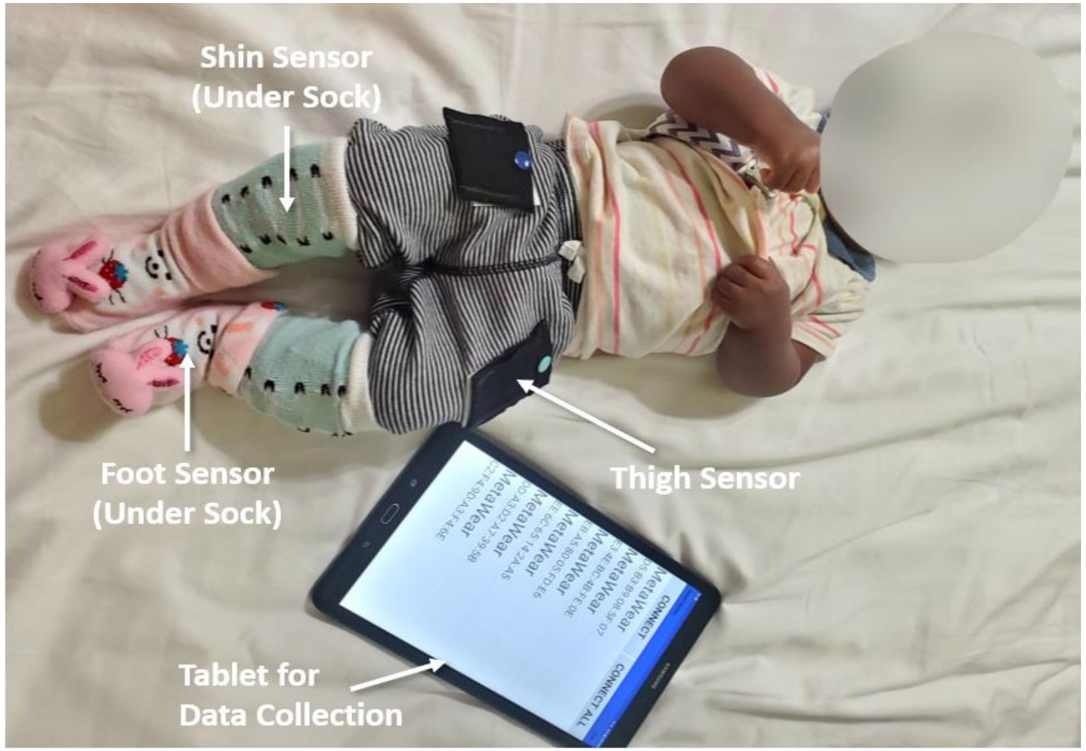
| Metric | Variables | Equation |
|---|---|---|
| **Frequency of Activity** | $n_{Act}$: number of active samples<br>$N$: total number of samples | $FA_i = {}^{n_{Act}}/_{N}$ |
| **Avg. Duration of Activity** | $K$: total number of movements in a one-minute segment<br>$(t_{start})_k$ : start time of the k[th] movement<br>$(t_{end})_k$ : end time of the k[th] movement | $AvgKDur_i = \frac{1}{K}\sum_{k=1}^{K}(t_{end})_k - (t_{start})_k$ |
| **Avg. Duration of Rest** | $R$: total number of rests in a one-minute segment<br>$(t_{start})_r$ : start time of the r[th] period of rest<br>$(t_{end})_r$ : end time of the r[th] period of rest | $AvgRDur_i = \frac{1}{R}\sum_{r=1}^{R}(t_{end})_r - (t_{start})_r$ |
| | | |

# Features Identified in Prior Work

| Metric | Variables | Equation |
|---|---|---|
| **Frequency of Activity** | $n_{Act}$: number of active samples<br>$N$: total number of samples | $FA_i = {n_{Act}}/{N}$ |
| **Avg. Duration of Activity** | $K$: total number of movements in a one-minute segment<br>$(t_{start})_k$ : start time of the k<sup>th</sup> movement<br>$(t_{end})_k$ : end time of the k<sup>th</sup> movement | $AvgKDur_i = \frac{1}{K}\sum_{k=1}^{K}(t_{end})_k - (t_{start})_k$ |
| **Avg. Duration of Rest** | $R$: total number of rests in a one-minute segment<br>$(t_{start})_r$ : start time of the r<sup>th</sup> period of rest<br>$(t_{end})_r$ : end time of the r<sup>th</sup> period of rest | $AvgRDur_i = \frac{1}{R}\sum_{r=1}^{R}(t_{end})_r - (t_{start})_r$ |
| **Peak Acceleration** | $GAct_i(s)$: vector identifying activity for data segment i<br>$GAct_i(s) \neq 0$ for an active sample<br>$\boldsymbol{a}_s$ : 3D vector of acceleration for sample s | $PeakAccel_i = \max(\lvert\boldsymbol{a}_s\rvert, \forall\, s = 1 \ldots N \mid GAct_i(s) \neq 0)$ |

# System Deployment

- Parents were instructed on setup and data collection procedures (15 to 30 minutes).
- Setup and data collection performed by the parents of the infant over 3 sessions.
- Kinematic features were calculated and compared to normative data.




Set up of the Baby SmartyPants system deployed to the home of a preterm, at-risk African American infant. Photo was taken during the third data collection session (38 weeks).

# Results

| Metric | At 26 Weeks | At 35 Weeks | At 41 Weeks |
|---|---|---|---|
| **Frequency of Activity** | 25-30 weeks | 35-40 weeks | *20-25 weeks |
| **Avg. Duration of Activity** | *5-10 weeks | *10-15 weeks | 40+ weeks |
| **Avg. Duration of Rest** | *5-10 weeks | 40+ weeks | 35-40 weeks |
| **Peak Acceleration** | *5-10 weeks | *10-15 weeks | 40+ weeks |

Estimated developmental maturity for each metric

# Conclusions

- Infant displayed decreased durations of continuous activity and peak accelerations at younger ages.
- Duration of rest improved more quickly than duration of activity.
- By 41 weeks, the infant had caught up on most metrics.
- **Pattern for frequency of activity may differ for preterm infants compared to term counterparts.**

# Future Work

- Deploy system to additional homes.
- Analyze features for more preterm infants.
  - Confirm how these features may differ for preterm infants.
  - Implement additional features.
- **Develop comprehensive model to estimate developmental age.**

# Thanks!