Rehabilitation Engineering Research Center on Technologies for Children with Orthopaedic Disabilities

Program Director: Gerald F. Harris, Ph.D., P.E
Co-Director: Li-Qun Zhang, Ph.D.
Expected Impact on Target Population

- Primarily children with cerebral palsy (CP), clubfoot (CF), osteogenesis imperfecta (OI), myelomeningocele (MM) and spinal cord injury (SCI)
- Children with other chronic conditions that affect manipulation and mobility may also be affected by the study findings
- Our aim is to have a national impact on care and treatment through improved technologies
  - Specific R (research) findings
  - D (development) contributions and commercialization
  - Evolution of improved assessment and evidence-based evaluation tools
R1: Nano- and Microstructural Tissue Characterization for Improved Care of Children with Osteogenesis Imperfecta and Severe Clubfoot Deformity (Focus Topic)

- Co-PI’s
  - Gerald Harris, Ph.D., P.E.
  - Jeffrey Toth, Ph.D.

- Patient populations
  - Osteogenesis Imperfecta (OI): 45
  - Clubfoot (CF): 12
R1 Hypotheses

1. Patient-specific FEMs can be used to predict bone fracture and deformation (strain) patterns in children with OI

2. Fiber orientation, distribution and mechanical behavior of MFMT (medial fibrotic mass tissue) in CF are predictive of longer-term maintenance of restoration

3. FEMs incorporating hard and soft tissue can be used to develop more optimized conservative treatment for the prevention of recurrence in pediatric CF
R2: Diffusion Tensor Imaging and Restoration of Upper and Lower Limb Function in Children with Cerebral Palsy

- **Co-PI’s**
  - Michelle J. Johnson, Ph.D.
  - Brian D. Schmit, Ph.D.

- **Patient population**
  - Cerebral Palsy (CP): 40

- **Overall goal**
  - Quantitatively assess brain white matter structure (DTI and fMRI) before and after combined intervention strategies of surgery plus novel robot therapies
R2 Hypotheses

1. The motor adaptations to hamstring lengthening and wrist tendon transfers depend on the underlying structure of the brain white matter tracts, (e.g. corticospinal tracts and thalamic radiations) as measured using DTI
2. fMRI measures of brain plasticity will reflect the extent of motor adaptation to hamstring lengthening and wrist tendon transfers
3. Robotic interventions will accelerate fMRI changes as well as subsequent recovery of motor function
R3: Home-Based Tele-Assisted Robotic Rehabilitation of Joint Impairments in Children with Cerebral Palsy

- Co-PI’s
  - Li-Qun Zhang, Ph.D.
  - Yupeng Ren, M.S.

- Patient population
  - Cerebral Palsy (CP): 48
R3 Hypotheses

1. **Combined** intelligent stretching and voluntary movement training **reduces** ankle impairment in children with CP in terms of selected biomechanical and functional measures.

2. **Home-based rehabilitation** in patients with CP will be **more effective** than lab-based rehabilitation in reducing ankle impairment with improved motor control in terms of the biomechanical and functional measures.
R4: Advanced Mobility Modeling to Improve Function and Longer Term Transitional Care of Children with Orthopedic Disabilities

- Co-PI’s
  - Brooke Slavens, Ph.D.
  - Gerald Harris, Ph.D., P.E.

- Patient population
  - Cerebral Palsy (CP): 12
  - Myelomenginocele (MM): 12
  - Spinal Cord Injury (SCI): 12
  - Osteogenesis Imperfecta (OI): 12
  - Pes Planovalgus: 20
R4 Hypotheses

1. **Proximal** upper extremity joint demands are significantly **greater than distal** joint demands during assisted mobility in children using walkers, crutches and wheelchairs.

2. **Lower extremity joint demands** (hip, knee, talocrural, and subtalar) in children with pes planovalgus are significantly **reduced following subtalar arthroereisis**.
D1: Elliptical System to Improve Off-Axis Neuromuscular Control in Children with Orthopaedic Disabilities

- Co-PI’s
  - Yupeng Ren, M.S.
  - Li-Qun Zhang, Ph.D.

- Patient population
  - Cerebral Palsy (CP): 18
  - Patello-femoral Pain Syndrome: 18

- Project goal
  - Develop novel off-axis rehabilitation system to train children with severe orthopaedic disabilities
D1 Specific Aims

1. To design the **pivoting and sliding elliptical rehabilitation system** with integrated motivating **biofeedback training games** for children with orthopedic disabilities
   a. System will follow children during running/walking activities in sagittal plane
   b. Optional assistance and off-axis pivoting-sliding (training) motions in the frontal and transverse planes
   c. Guide users to improve neuromuscular control about the off-axes
   d. Obtain quantitative measurements
   e. Developed off-axis virtual reality games will further motivate children for more active involvement in the training

2. To evaluate the off-axis training **system and resulting neuromuscular control changes** in terms of stability, strength, stiffness, proprioception, and reaction time in tibial rotation and mediolateral sliding
   a. Employ a “design-build-test-design” strategy
   b. Evaluation/quality control paradigm
   c. Clinical use and further commercialization
D2: 3D Pediatric Robotic Gait Training to Improve Locomotor Function in Children with CP

- PI
  - Ming Wu, Ph.D.

- Patient population
  - Cerebral Palsy (CP): 30

- Project goal
  - Develop 3D robotic gait training system
  - Apply controlled forces in sagittal and frontal planes & allow natural 3D stepping motion
D2 Specific Aims

1. Development of 3D robotic gait training system that applies **controlled forces** to both **sagittal and frontal planes** during treadmill training
   a. Develop **3D cable driven** robotic gait training system that applies synchronized forces to both the pelvis and legs during treadmill training
   b. Develop **child-friendly biofeedback** system to improve active involvement of children with CP during training sessions

2. **Improve locomotor function** in children with CP through 3D robotic BWSTT
   a. **Test improvements** of locomotor function in children with CP through 3D robotic gait training that applies controlled forces to both pelvis and legs
   b. **Compare training** effect of the 3D robotic BWSTT vs. BWSTT alone
D3: Biplanar Fluoroscopic System for Dynamic, *in vivo* Foot and Ankle Motion Analysis

- **PI**
  - Taly Gilat Schmidt, Ph.D.

- **Patient population**
  - Other: 5 (children aged 10 – 18 yrs.)

- **Project goal**
  - Develop a biplane x-ray fluoroscopy system for analyzing *in vivo* motion of the bare or shod foot
D3 Specific Aim

- To develop a prototype biplane fluoroscopy system and manual feature extraction method for in vivo studies of subtalar hindfoot kinematics.
D4: 3D Fluoroscopy and Pressure Validated Orthotics in the Application of Pediatric Flatfoot

- **Co-PI’s**
  - X.C. Liu, Ph.D.
  - R. Rizza, Ph.D.

- **Patient population**
  - Pes Planovalgus: 3

- **Project goal**
  - Develop new orthotic based on 3D foot geometry below the malleolus, dynamic plantar and lateral-medial pressure during walking and validated by 3D calcaneous-talus orientation measured using 3D fluoroscopy
D4 Specific Aims

1. Develop a **trio-pressure measurement** technique for plantar and lateral calcaneus and medial talar head

2. Validate computer aided design and FE model for new design of orthosis using a **3D fluoroscopy kinematic model and kinetic data**

3. Establish effective **procedure to manufacture** dynamic orthosis for children with flexible flatfoot using a **Rapid Prototyping System (RPS)**

Trio-pressure measurements for flatfoot:
a medial shift of plantar pressure distribution at the midfoot and forefoot
8 Training Activities

1. Advanced Rehabilitation Research Training Fellowships (ARRTs)
2. Graduate Assistantships (RAs)
3. Online Training Course
4. Senior Design Projects
5. ATAD (Assistive Technology & Accessible Design) Certificate, University of Wisconsin-Milwaukee
6. RERC Teaching Modules
7. Summer Internships
8. Training Events – State-of-the-Science Conference
## Training Populations

<table>
<thead>
<tr>
<th>Training Activity</th>
<th>Target Population</th>
<th>Number of Trainees</th>
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<tbody>
<tr>
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<td>Res</td>
<td>Prac</td>
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<tr>
<td>T1: ARRT Fellowships</td>
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<tr>
<td>T2: Research Assistantships</td>
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<tr>
<td>T3: Online Training Course</td>
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<td>T4: Senior Design:</td>
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<td>T5: ATAD Certificate</td>
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<tr>
<td>T6: RERC Teaching Module (c = curricula)</td>
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<td>T7: Summer Internships</td>
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<td>T8: State-of-the-Science Conference &amp; Workshops</td>
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8 Dissemination Activities

1. *Publications, Accomplishments, Studies and Devices/Prototypes*
2. *Information Response and Referral/Technical Assistance*
3. *Primary RERC Website*
4. *Resources Component of the Website*
5. *Conference Presentations*
6. *Link to NCDDR/NARIC/SEDL/KT4TT*
7. *Accessibility*
8. *Technology Transfer*
   - Plan revisions & updates, Impact assessment
## Dissemination

<table>
<thead>
<tr>
<th>Dissemination Activity</th>
<th>Target Population</th>
<th>Timeline &amp; Quantity</th>
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<tbody>
<tr>
<td>DA1: Publications, Accomplishments, Studies and Devices (d=development; p=published)</td>
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<td>DA2: Information, Referral &amp; Technical Assistance</td>
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<td>DA3: Website - RERC Primary Site</td>
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<td>DA4: Website - Resources</td>
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<td>DA5: Conferences</td>
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<td>TT1: Technology Transfer - Revise Plan</td>
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<td>TT2: Technology Transfer - Early</td>
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<td>TT3: Technology Transfer - Impact</td>
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RERC: Overall **Impact** on Children with Orthopaedic Disabilities
THANK YOU.

Program Director: Gerald F. Harris, Ph.D., P.E
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