

Research

Research is currently based in six centres in USA (2), UK(2), Denmark and Hong Kong. A short summary of the status at the individual centres is outlined below:

1. Hartford, Connecticut

Research Team:

PI's: Sandy Saavedra, MS, PT, PhD; Adam Goodworth, MS, PhD; Doctoral Student (visiting scholar from Brazil): Carolina Da Costa MS, PT Master's Student in Neuroscience: Kerian Duncan

Clinical Specialist: Danni Bellows PT, MHS DPT

Student research teams:

DOTS Team: Kaci Brandt, Kate Callahan, Alexis Hutchings, Mariah Ferrigan, Jessica Zalagens

SIT with CP Team: Jessica Bado, Kathleen Carroll, Alysha Kaminski, Kasey Mayer, Molly Spargo,

Scoliosis Team: Anthony Carrasquillo, Kelsey Dewitt, Jacob Lang, Brian Wally, Ryan Partridge,

Undergraduate research assistants: Sarah Oeyeniyen, Kelly Blochlinger

Study 1.1 Title: '*Sensory Contributions to Typical and Atypical Development of Trunk Control.*'

Goal: to identify sensory reliance and sensory reweighting for postural control in typical infants longitudinally, from 1-8 months of age and children with moderate-to-severe cerebral palsy (GMFCS 3-5).

Status: We receive funding from the National Institute of Health to complete this project. (June 2014-May 2017). Dr Yen-Hsun Wu, joined us as a postdoctoral research fellow, September 16, 2014 and will work with us through September 15, 2016. We refined the protocols and built a visual surround to allow manipulation of visual data in addition to platform perturbations. We have completed longitudinal testing for 3 TD infants and have 2 infants currently in data collection. We have completed testing for

1 child (GMFCS III) before, during and after a 6-month series of Targeted Training. Four children (GMFCS IV-V) who are involved in Targeted Training are currently in longitudinal data collection.

Study 1.2 Title: *'Normalization of the Segmental Assessment of Trunk Control (SATCo) in Typical Infants.'*

Goal: to determine normalised standards for typical development of segmented trunk control.

Status: We received a Seed grant to cover the costs of collecting these data. We have collected data from 119 typically developing (TD) infants, 72 from Connecticut and 47 from Brazil. We are seeking more infants in the 1-4 month range to complete the study. We hope to finish the data collection for this project by May 2016.

Study 1.3 Title: *'Parental sensitivity and responsiveness to their infant's segmental level of trunk control.'*

Goal: to determine if parents automatically adjust their support as infants gain segmental control of the trunk.

Status: Data collection for this study is now completed. We have data from 61 infants and parents. Mariah Ferrigan, will be the first author on this publication and we hope to submit it early in 2016.

Study 1.4 Title *'Effectiveness of segmental training on trunk control in children with moderate-to-severe motor impairment: a case series'*

Goal: To examine outcome measures in a case series of Targeted Training for 11 children with neuromotor deficits.

Status: Blinded scoring has been completed for GMFM. SATCo blinded scoring is nearly completed and SAROMM scoring is underway. Sandy Saavedra, Danni Bellows and Molly Spargo will continue work on this manuscript next year.

Study 1.5 Title: *'Non-linear analysis of the segmental contributions to trunk control in children with moderate to severe cerebral palsy'*

Goal: to calculate approximate entropy, correlation dimension and lyapunov exponent, and conduct a surrogate analysis of postural sway data as measured by head or trunk movement and examine stability with different levels of trunk support.

Carol Da Costa completed her analysis, her manuscript has been submitted to Physical Therapy Journal and is currently under revision.

Study 1.6 Title: '*Segmental sensorimotor control of trunk posture in adolescent idiopathic scoliosis.*'

Goal: to use engineering-based systems identification to characterize sensorimotor integration for trunk control in adolescents with and without scoliosis. This pilot study will be the first attempt at quantifying sensory contributions, active and passive stiffness, reflexes and neural time delays in the trunk posture system in adolescents with idiopathic scoliosis. Our second goal is to determine if abnormalities in sensorimotor integration are specific to certain regions of spinal curvature.

Status: This small exploratory study was funded by the Scoliosis Research Society. Adam Goodworth will lead a DPT student team focused on this project during 2014-2015. Data collection has been completed and an abstract for conference presentation is being prepared.

Study 1.7 Title: '*Relation of segmental trunk control to visual/vestibular interactions for posture across typical and atypical development.*'

Goal: This study will examine the trajectory of Vestibular Ocular Reflex (VOR) and inhibition of VOR along with responses to angular and translational movements in TD infants and children with moderate to severe CP. We will examine the relation between postural responses to movement and inhibition of VOR and the child's segmental level of control (SATCo)I.

Status: We have collected data from 10 TD infants (1-8 months of age) and from 1 child with CP. Preliminary data analysis confirmed that we have testable hypotheses. We have refined the protocol based on our initial participants and will now proceed to full data collection.

Additional Publications related to segmental trunk control.

Saavedra S, Woolacott MH. (2015) Segmental contributions to trunk control in children with moderate-to-severe cerebral palsy. *Arch Phys Med Rehab* 96(6):1088-1097.

2. Eugene, Oregon

Principal investigators: Dr. Marjorie Woollacott, Dr. Andrew Gordon, Dr. Sandra Saavedra.
Collaborators: Jaya Rachwani PPT, PhD. Victor Santamaria, PPT. PhD.

Study 2.1 Rachwani J, Santamaria V, Saavedra SL, Wood S, Porter F, Woollacott MH (2013). Segmental Trunk Control Acquisition and Reaching in Typically Developing Infants. *Exp Brain Res*, 228 (1), 131-139.

The aim of this recently published paper was to study how the thoracic and pelvic

supports impacted the arm and head - trunk kinematics during a reach-to-grasp task in an immature central nervous system. This was a cross sectional study developed in a sample of infants aged from 4 to 6 months.

Study 2.2 Healthy young adults and trunk support during a reach-to-grasp task.

In this ongoing project, we are studying the biomechanics of trunk, head and arm during a reaching task. Also, arm and bilateral electromyographic patterns of trunk muscles are being analyzed in order to thoroughly understand how the central nervous system of healthy individuals would deal with the imposed trunk constraints during reaching.

Data have been collected, analyzed and are being written up for publication. This manuscript has been submitted and is now in revision for Journal of Motor Control.

Study 2.3 Longitudinal study during development of motor control of arm, trunk and head in infants.

The principal purpose of this ongoing project is to analyze the influence of pelvic and thoracic levels of support during the neuromaturation of arm and head-trunk control in a sample of infants from 3 to 8 months of age. The main components being analyzed are kinematics of posture and reaching together with the EMG muscle patterns of arm and back during the development of head control, sitting and motor control of the arm in infants.

This manuscript was published in January 2015.

Rachawani J, Santamaria V, Saavedra SL, Woollacott MH, (2015) The development of trunk control and its relations to reaching in infancy: a longitudinal study. *Frontiers in human neuroscience*, 9

Study 2.4 Trunk support and motor control of arm, trunk and head in children diagnosed with Cerebral Palsy.

The principal purpose of this ongoing cross-sectional study is to analyze how three different levels of support, pelvic, thoracic and axillae, would impact head-trunk-arm kinematics during a reach. Additionally, the muscle patterns of activation at these three different levels of support are being studied for understanding of the activation of neuromuscular patterns in moderate to severely involved children with CP unable to maintain a sitting position or sit by themselves.

These data have been collected, analyzed and manuscripts have been submitted for publication

Study 2.5 This project is working to create a modified version of the Segmental Assessment of Trunk Control (SATCo), a clinical tool for measuring a child's level of spinal control. During the course of our research we observed possible areas for refinement of the SATCo. We are currently doing research to modify the SATCo, to increase its validity,

sensitivity and specificity in the assessment of spinal control in individuals with moderate to severe cerebral palsy, by, for example, adding reaching movements as part of the assessment of pro-active postural control and expanding the assessment scale.

This project is being carried out by Victor Santamaria in collaboration with Andrew Gordon. The data are currently being collected and analyzed.

Study 2.6 Eye tracking system and trunk support

In this novel project done on moderate to severe CP, we are exploring the interaction between the visuomotor ability, posture and arm movements during a reach-to-grasp task at different levels of support. Additionally, we are analyzing the ocular and head control while the subject follows specific targets in space at different levels of support.

This project did not yield helpful results and has been tabled for now.

Marjorie will be retiring in February and will no longer be conducting research at University of Oregon.

3. Copenhagen, Denmark

Research Team:

PI's: Derek Curtis MS, PT, PhD, Dr. Sandy Saavedra, MS, PT, PhD; Dr. Marjorie Woollacott PhD

Master's Students in Health Science: Lisbeth Hansen BSc PT and Katrine Erharden BSc PT

BSc students in Physical Therapy: Silje Vindheim Jørgensen and Isa-Nora Carlsen (SALLCo study) and Lina Kristine Sollie, Elisabeth Lothe Eltvik og Marie Gry Richardy (SATCo translation)

Study 3.1 'Repeatability of the SATCo test in children with Cerebral Palsy'

This was Lisbeth Hansen and Katrine Erharden's Masters project. The SATCo test repeatability was tested on 32 children with CP intra- and interday and intra and inter-tester. The study investigated the degree of agreement between video scoring and 'live' tester scoring. The protocol required participants to be SATCo-tested twice on the same day by 2 testers and twice again later in the same week. SATCo was scored by the tester and video scored by experts (at The Movement Centre). The test-retest included 6 children from all of the 5 GMFCS categories.

Status: This project has been finalized and has been submitted for publication.

Study 3.2 'The effect of trunk control on gait in children with Cerebral Palsy'

This study will be looking at the effect of trunk control on gait kinematics and kinetics in children with CP GMFCS I and II. Ethical approval has been obtained and data collection has been started. Inclusion continues.

Study 3.3 'SALLCo test - Development of test score sheet and instructions' Physical therapy students Silje Vindheim Jørgensen and Isa-Nora Carlsen have completed this study. The SALLCo test has been developed and used by Dr. Butler and The Movement Centre for a number of years but has not been formally described and published. The scoring sheet and manual have been written in close cooperation with Dr Butler and The Movement Centre and performed and video recorded for 7 children with motor control issues in the lower extremities. The test videos were scored independently from the test manual by 3 scorers to determine the repeatability. The study is currently on hold awaiting inclusion of further participants.

Study 3.4 'Danish translation of the SATCo test'

Lina Kristine Sollie, Elisabeth Lothe Eltvik og Marie Gry Richardy have translated the SATCo test to Danish. The back translation has been approved by Dr. Butler and the translation is now available on the Movement Centre website. The test is now available on the Movement Centre and the Danish Association of Physiotherapists website.

Study 3.5 'Effect of Targeted Training on gross motor function in children with CP' An RCT including 28 children with CP GMFCSIII-V. Intervention is TT, 5 times a week for 6 months and control is treatment as usual.

Status: This study is submitted for publication.

Study 3.6 'Normative values for posture and sway for typically developing children in unsupported sitting'.

A study of 20 children documenting repeatability and normal values for sway in an unsupported seated position using a 3D trunk model with levels corresponding to the SATCo levels.

This study is now published:

Curtis DJ, Hansen L, Luun M, Løberg R, Woollacott M, Saavedra S, Sonne-Holm S, Berggreen S, Bencke J. Measuring postural sway in sitting: a new segmental approach. J Mot Behav. 2015;47(5):427-35

Study 3.7 'The Central role of trunk control in gross motor function and activity in children with severe cerebral palsy'

GMFM, PEDI and SATCo data from 92 referrals to the Movement Centre in the UK have been analysed to determine the relationship between trunk control, gross motor function and functional mobility in children with CP.

This study is now published:

Curtis DJ, Butler P, Saavedra S, Bencke J, Kallemose T, Sonne-Holm S, Woollacott M. The central role of trunk control in the gross motor function of children with cerebral palsy: a retrospective cross-sectional study. Dev Med Child Neurol. 2015 Apr;57(4):351-7.

4. The Movement Centre / Manchester Metropolitan University, UK

Research Team:

PIs: Ian Loram PhD, Penny Butler PhD, FCSP, John Darby PhD, Paul Holmes PhD, Richard Major FIPEM, CEng.

Doctoral Student: Maria Sanchez PT, MSc.

Clinical Specialists: Pauline Holbrook BA (Hons), Grad Dip Phys, MACP, Sarah Bew BSc (Hons), MCSP

Physiotherapy Assistant: Lynne Ford

Study 4.1

Quantification of posture in a clinical setting: development of a clinical tool for full trunk and trunk segment analysis

Aims: 1) to generate a numerical definition of postural alignment in sitting based on segmental angles; 2) to develop a clinical video-based method for defining and measuring alignment and deviations from alignment [Note: it is intended that this should be a marker-free or minimal-marker system to enable use with children with the greatest severity of movement dysfunction]; 3) to develop a clinical video-based method for defining the presence of open or closed kinetic chains during assessment of postural alignment; 4) to validate these clinical methods using a gold standard motion analysis system

Study 4.1.1 The quantification of postural alignment in a clinical setting

Status: Data has been collected from 12 healthy young adults using a 3D motion capture system (Vicon) and simultaneously with two video cameras (lateral and frontal to the participant). This has been processed and analysed to generate a numerical model of alignment in sitting focussing on the sagittal plane and tracking trunk and head movements. The video-based tool has been validated against the 3D motion capture system. A paper is in preparation for submission for publication.

Study 4.1.2 Validation of the video-based method of quantification of posture in children with cerebral palsy

Status: Data has been collected from eleven children with cerebral palsy during a routine clinical review at The Movement Centre. The Segmental Assessment of Trunk Control (SATCo) (from the head to the lowest segmental level the child was able to tolerate without risks) was recorded using both lateral view video and 3D motion capture system. Data is being processed and results will be used to define the methods for study 4.1.4.

Study 4.1.3 Validation of a method to identify and quantify the presence and duration of open kinetic chains during assessment of trunk alignment / control

Status: The frontal videos recorded during study 4.1.1 were used to track the hand and elbow movements (left and right). Additional markers were used to reconstruct the upper limbs in Vicon. Trunk markers and landmarks were used in both systems to identify the trunk area (video) and volume (3D). The combination of hand and elbow tracking with trunk area/volume enabled definition of the limits of closed/open kinetic chains. Both the video and the 3D system have demonstrated identification of open or closed kinetic chains. This will now be validated against an expert's rating.

Study 4.1.4 To quantify trunk posture of children with Cerebral Palsy participating in a course of Targeted Training therapy

Status: Data collection has commenced and will continue during the first semester of 2016.

Study 4.2 Gestural interfaces for the home-based inducement and monitoring of head control in children participating in Targeted Training (TT) therapy

Principles and Aims: 1) To monitor head control at TMC and in the child's home during TT therapy or during everyday activities using Kinect; 2) To thus provide data that can be usefully reviewed by the treating neuro-physiotherapist to identify instances of specific head pose in children with greatest severity of movement disability; 3) To induce head control through gesture-based human-computer interactions; 4) To provide extra data on the efficacy of Targeted Training

Study 4.2.1 An evaluation of 3D head pose estimation using the Microsoft Kinect

Status: Eight participants performed a series of pre-defined head movements which were simultaneously recorded using: i) Kinect v2's HDFT and ii) a marker-based Vicon motion capture system. The head movements included movements designed to test the limits of the Kinect's performance. Kinect v2 sensor was found to give state of the art head pose estimation accuracy in real time and without the need for calibration. A paper has been submitted for publication.

Study 4.2.2 Exemplar-based analysis of head posture data: a tool for physiotherapists

Status: A post-processing tool has been built to interactively search the output of Kinect recordings based on a physiotherapist's real-time head rotation. The tool enables identification of all instances of certain key head poses and movements as defined by the

physiotherapist. Physiotherapists in TMC are now using this tool to review the entire dataset of recordings made in Study 4.2.1 thus providing data on the value and potential of this system.

5. The Movement Centre / Liverpool John Moores University, UK

Research Team:

PIs: Penny Butler PhD FCSP

Other Investigators: Gabor Barton MD PhD, Pauline Holbrook BA (Hons), Grad Dip Phys, MACP, Malcolm Hawken BA (Eng) PhD, Andrzej Przybyla BEng PhD

Study 5.1 TouchGame – development of a clinical tool for evaluating the efficacy of physiotherapy to promote trunk control in neurodisability

Status: This project is to develop a prototype of a novel interactive clinical tool 'TouchGame' to quantify active trunk control in children with severe neurodisability. The TouchGame assesses trunk control by focusing on the fundamental movements of reaching towards and touching a surface. This mirrors the functional tests currently available of full trunk control but also has potential for segmental analysis of trunk control. An array of monitors will display bright coloured objects which respond to touching with motion and sound. Proof of concept has been demonstrated and funding is now being sought for prototype development with children attending The Movement Centre providing feedback during this phase. Once the prototype is operational, further funding will be sought for a 2-3 year project to evaluate the TouchGame in children with neurodisability and to explore wider dissemination including, potentially, use in adult neurophysiotherapy e.g. following a stroke.

6. Department of Rehabilitation Sciences, Hong Kong Polytechnic University, Hong Kong

Research Team:

PI: Tamis Pin PhD, MSc, PT

Collaborators: Penny Butler PhD, FCSP, Dr Hon-Ming Cheung, M.B., B.S, FHKAM (Paediatrics), FHKC (Paediatrics); Mrs Sandra Lee, PDPT

Study 1: 'Psychometric study on Segmental Assessment of Trunk Control in preterm infants from 4 to 12 months corrected age'

Tamis is currently looking at the psychometric properties of the SATCo on preterm and full-term infants in a pilot longitudinal study from 4 to 12 months of (corrected) age. In this study, Tamis will collaborate with the Associate Consultant (Dr Cheung) and Senior Physiotherapist (Mrs Lee) in the preterm follow-up clinic in one of the teaching hospitals, Prince of Wales Hospital, in Hong Kong. Penny Butler will also be involved in the reliability side of this study. Tamis has completed the 20 full-term infants in the control group. The initial plan was to recruit 20 preterm infants but with the recent injection of extra fund from

the Department, the number of preterm infants has increased to 30. Both reliability and validity of the SATCo on young infants will be examined in this study. Tamis is about to analyse the reliability data.

Study 2: Pilot normative study on development of trunk control in typically developing infants

PI: Tamis Pin PhD, MSc, PT

Collaborators: Penny Butler PhD, FCSP, Mrs Sandra Lee, PDPT; Dr Hon-Ming Cheung, M.B., B.S, FHKAM (Paediatrics), FHKC (Paediatrics)

The objectives of the present study are to systematically investigate and document the development of trunk control in 20 typically developing full-term infants from 4 to 12 months of age. The recruited infants will be assessed using the SATCo every fortnightly. Tamis has nearly completed data collection on the first 10 infants and will start to examine the preliminary results.

Study 3: Effectiveness of interactive computer play on trunk control and gross motor function in children with cerebral palsy: a randomized cross-over trial

PI: Tamis Pin PhD, MSc, PT, Penny Butler PhD, FCSP

The overall objective of the study is to investigate the effect of a 6-week training programme using an interactive computer play training tool on the segmental trunk control, sitting and/or standing balance and gross motor function in children with cerebral palsy of GMFCS levels II to IV. This study has been submitted for research fund application to one of the largest research grants in Hong Kong and is waiting for the result.

Clinical services and development

1. Targeted Training in Oswestry, UK

The Movement Centre continues to provide Targeted Training on a routine clinical basis for children with problems of movement control around 50 children receiving services at any one time.

Outcome measures are:

- Range of joint movement (limbs and trunk) - SATCo
- Functional goals (specific and timed)
- PEDI (at start and end of a (9) month course of TT)
- GMFM (at start and end of a (9) month course of TT)
- Edinburgh Visual Gait Score (for children able to walk independently) (at start and end of a (9) month course of TT)
- Chailey Levels of Ability (at start and end of a (9) month course of TT)
- AbilHand-Kids assessment of manual ability (at start and end of a (9) month course of TT)
- Quality of Life (at start and end of a (9) month course of TT)

These outcome measures are reported on our website (see below).

2. Targeted Training in Hartford, CT, USA

There are currently 3 children in the Hartford area who are in the training program and 1 child who is in the process of being set up for Targeted Training beginning January 2016. Danni Bellows and Sandy Saavedra will be supervising the training. We will aim to produce case studies for publication and promotion of TT in the USA. We will have our current CP research group begin drafting the first 4 case studies during spring semester 2017. Training will end for the current children in May 2016.

Device measurements have been completed for the new child.

Outcome measures are:

- GMFM 66 (gross motor function measure)
- SAROMM (spinal alignment and range of motion measure)
- SATCo
- HAT (hypertonicity assessment tool)
- BAS (Barry Albright Dystonia Scale if the HAT indicates dystonia)
- Visual/vestibular screening test
- Anthropometrics
- Functional goals or Goal Attainment scale

3. Targeted Training in Copenhagen, Denmark

There is currently one child in a course of TT in Copenhagen with three children successfully completing a course of treatment. The aim of this clinical work is to produce case studies for publication and promotion of TT in Denmark. Outcome measures are:

- Range of joint movement (limbs and trunk) - SATCo.
- Functional goals (specific and timed)
- PEDI (at start and end of a (9) month course of TT)
- GMFM (at start and end of a (9) month course of TT)

We are using TT equipment loaned from The Movement Centre in Oswestry.

For further information on the studies and clinical work outlined above, contact:

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