Kinematics of Lateral Transfers: A Pilot Study

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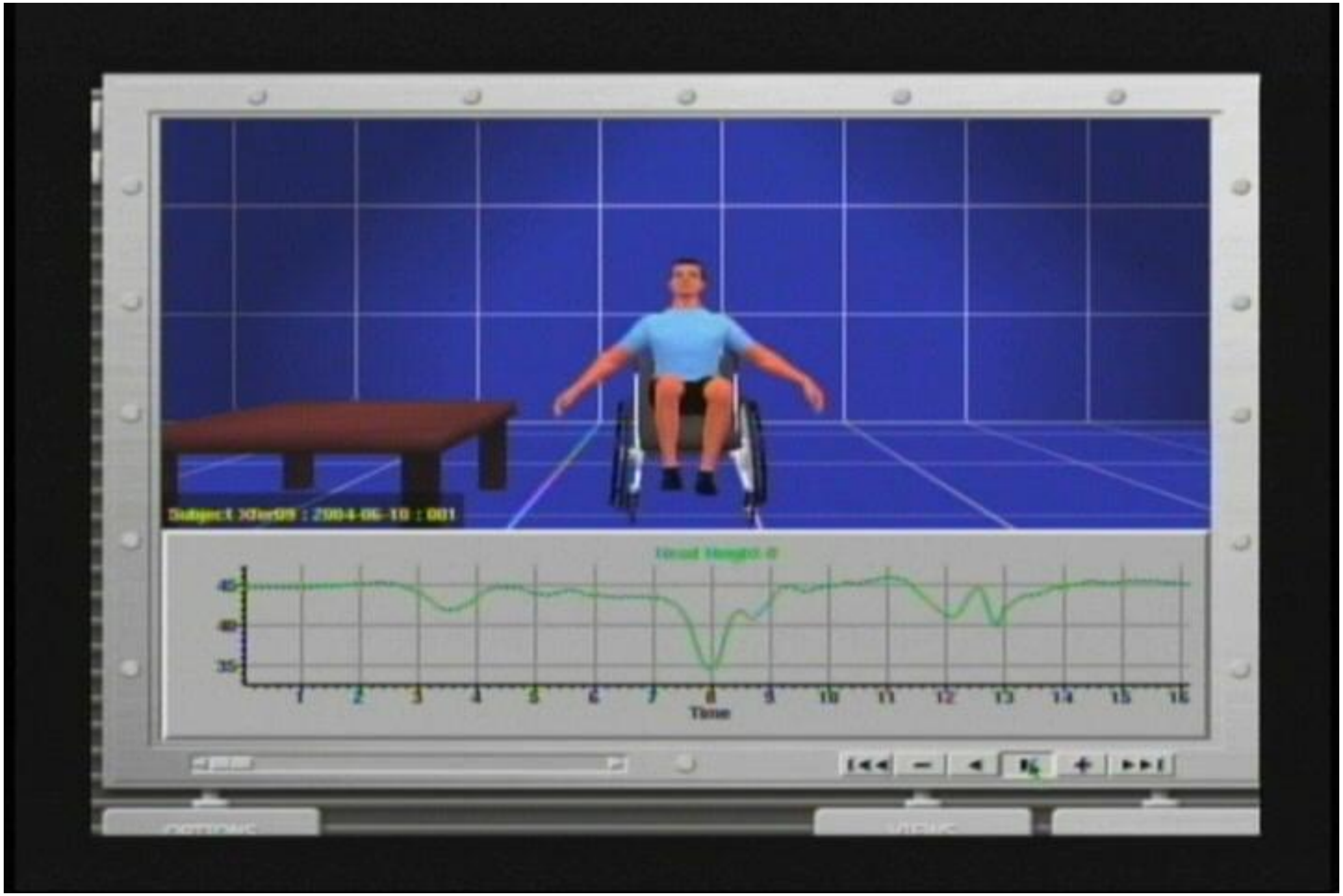
What is a lateral transfer?



Background

- Lateral transfers are very important to the independent function of a manual wheelchair user. It is believed that a better understanding of the kinematics would lead to improved clinical training and interventions.
- Current Research is limited
  - Multiple studies have addressed upper extremity kinematics during transfers, but do not address the overall strategy used to perform the transfers *(Finley et al, Perry et al, etc)*
  - Two studies of full body kinematics – but neither looked at the more frequently used lateral transfers.
    - long-sitting transfers (2 views, mostly quadriplegic) (Allison *et al)*
    - posterior transfers (Gagnon *et al)*

Research Goals

– Kinematic description of transfers
– Identify transfer strategies (and how they are influenced by injury level and demographics)
– Long Term:
  - Identify the safest and most efficient transfer strategies for different people
  - Inform clinicians for improved and personalized transfer training

Methods: Subjects

- Convenience sample of 19 male adults with IRB approval and subject consent
- Transfer independently or with minimum assistance
- No pressure sores or upper extremity orthopaedic conditions

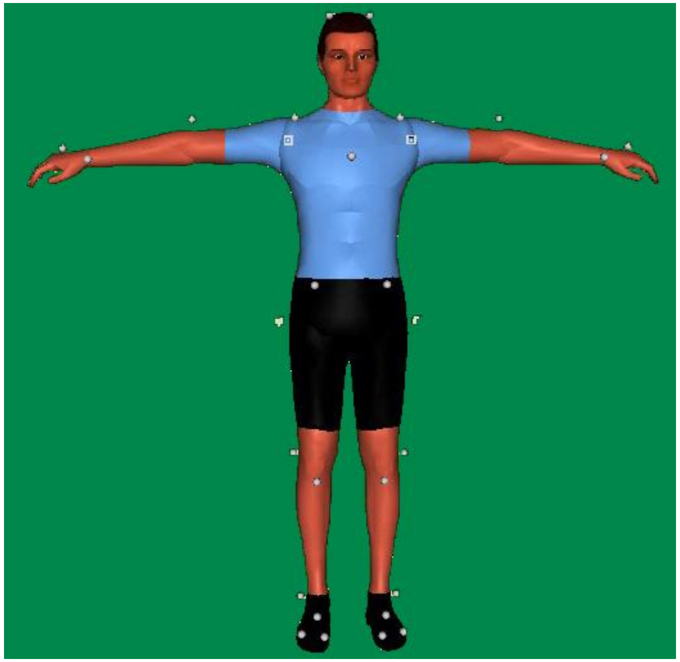
Methods: Protocol

- Subjects transferred towards their stronger side from their wheelchair to 20” therapy mat and back.
- Repeat for 3 trials
- All 3 motion captured and analyzed
- At least one transfer videotaped

Methods: Motion Capture

Instrumentation

- Proprietary Software by Motion Reality Inc. (Marietta, GA)
- 8 – 60Hz cameras
- 41 markers on the body; 8 markers on the wheelchair

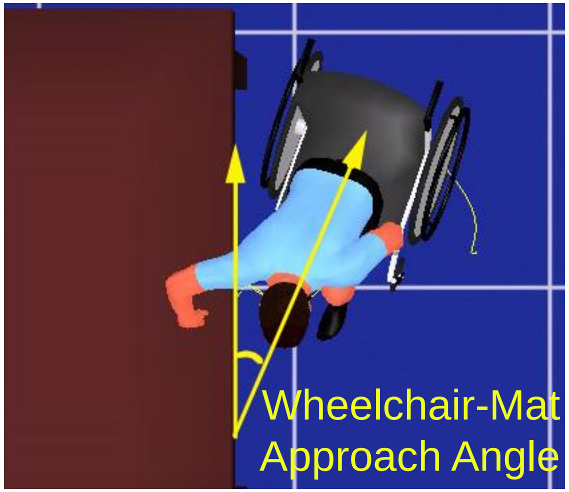


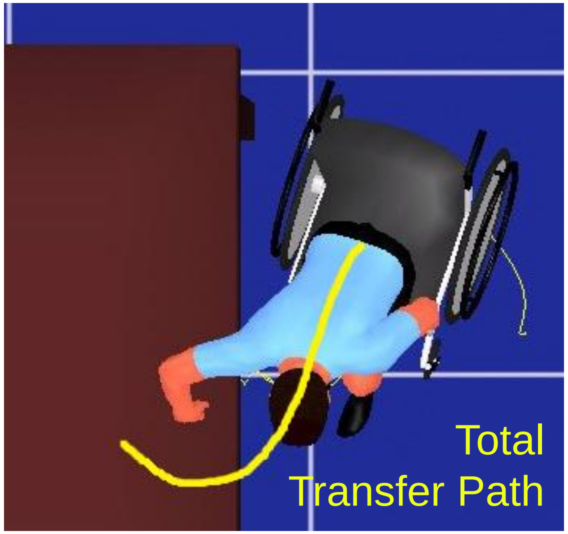
Capture

- Modified T-Pose, height, and weight to scale model
- Capture performs real-time best fit of visible markers to scaled model
- Tracks model body segments rather than joint centers

Analysis: Kinematic Variables

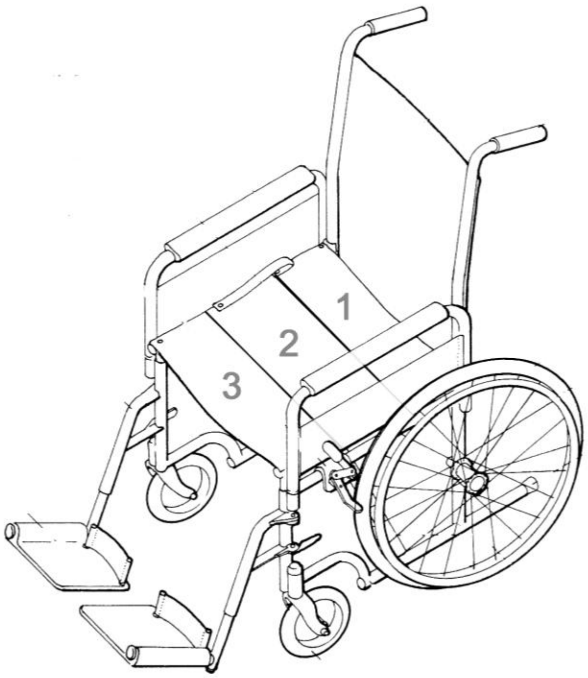
- Trunk Flexion
- Trunk Rotation
- Elbow Flexion
- Wheelchair-Mat Approach Angle
- Total Transfer Path
- % Transfer Path at Max Buttocks Elevation





Methods

- Distance from back of wheelchair at final liftoff
- Hand position on wheelchair:
  - To Mat
    - Arm Rest
    - Seat Rail
    - Wheel
    - Cushion
    - Back Rest
  - To Chair
    - Arm Rest
    - Cushion
    - Seat Rail



Analysis: Statistics

- Paired t-tests: to compare kinematic variables for transfers to and from wheelchair
- General Linear Model: predict kinematic variables based on the subject demographics and starting positions

Results: Subjects

14 subjects analyzed: (3 sliding boards and 2 cervical injuries were excluded)	
Age	32 years (18-50)
Body Mass Index (BMI)	23 (20-32)
Arm Length (inches)	28” (21”-42”)
Time Since Injury	12 years (3 months – 46 years)
Injuries	10 complete injuries (T3-T12) (most T9-T10) 3 incomplete thoracic injuries (T4, T6, T8) 1 incomplete post-polio

Results: Subjects

- Only **time since injury** and **age** were highly correlated (0.88)
- *Time since injury vs. BMI (-0.51)*
- *Injury Level vs. BMI (0.53)*

Average Kinematics

Kinematic Variables	Transfer from Wheelchair to Mat	Transfer from Mat to Wheelchair	p-value
	Average (Range)	*Average (Range)*	
Max Trunk Flexion (deg)	54 (31-73)	55 (37-73)	p>0.1
Max Trunk Rotation (deg)	23 (11-38)	23 (11-37)	p>0.1
Max Elbow Flexion - Leading Arm (deg)	89 (62-122)	82 (53-116)	p=0.009
Max Elbow Flexion - Trailing Arm (deg)	92 (47-130)	84 (57-113)	p=0.037
Wheelchair-Mat Approach Angle (deg)	22 (1-42)	24 (2-45)	p=0.061
Percent Path at Maximum Buttocks Elevation	0.54 (0.3-0.7)	0.48 (0.2-0.7)	p=0.01
Total Transfer Path (inches)	31.2 (20.3-40.8)	31.6 (14.5-40.6)	p>0.1

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Average Kinematics: Elbow Flexion

Max Elbow Flexion Greater from Wheelchair to Mat than Mat to Wheelchair

Leading arm: 89º vs. 82º

Trailing arm: 92º vs. 84º

Transfer to Mat

Transfer to Wheelchair

Average Kinematics:
Percent Path at Maximum Buttocks Elevation

Transfer to **mat** (Max at 54% path) in blue.

Transfer to **chair** (Max at 48% path) in red.

34 year old, T9

18 year old, T4

View of two men w/ similar BMI at maximum buttocks elevation.

Results: Linear Model

5 variables can be predicted for transfers to and from the mat (separately) with R^2>50%

- Buttocks elevation
- Torso rotation
- Torso flexion
- Wheelchair/mat angle
- Total path

Results: Linear Model

	Max Trunk Flexion	Max Trunk Rotation	Max Trailing Elbow Flexion	Total transfer path
Level of Injury	–		–	–
Arm Length		+	+	
BMI		–		–
Time Post Injury	–	–		–
Age		+		
Distance from back of chair	–		–	–
hand position	*	*		
R-squared	82%	68%	85%	69%

+ positive influence; – negative influence

* contributes to the model, but because it is a discrete variable, the influence cannot be described as positive or negative

Results: Linear Model

	Max Trunk Flexion	Max Trunk Rotation	Max Trailing Elbow Flexion	Total transfer path
Level of Injury	–		–	–
Arm Length		+	+	
BMI		–		–
Time Post Injury	–	–		–
Age		+		
Distance from back of chair	–		–	–
hand position	*	*		
R-squared	82%	68%	85%	69%

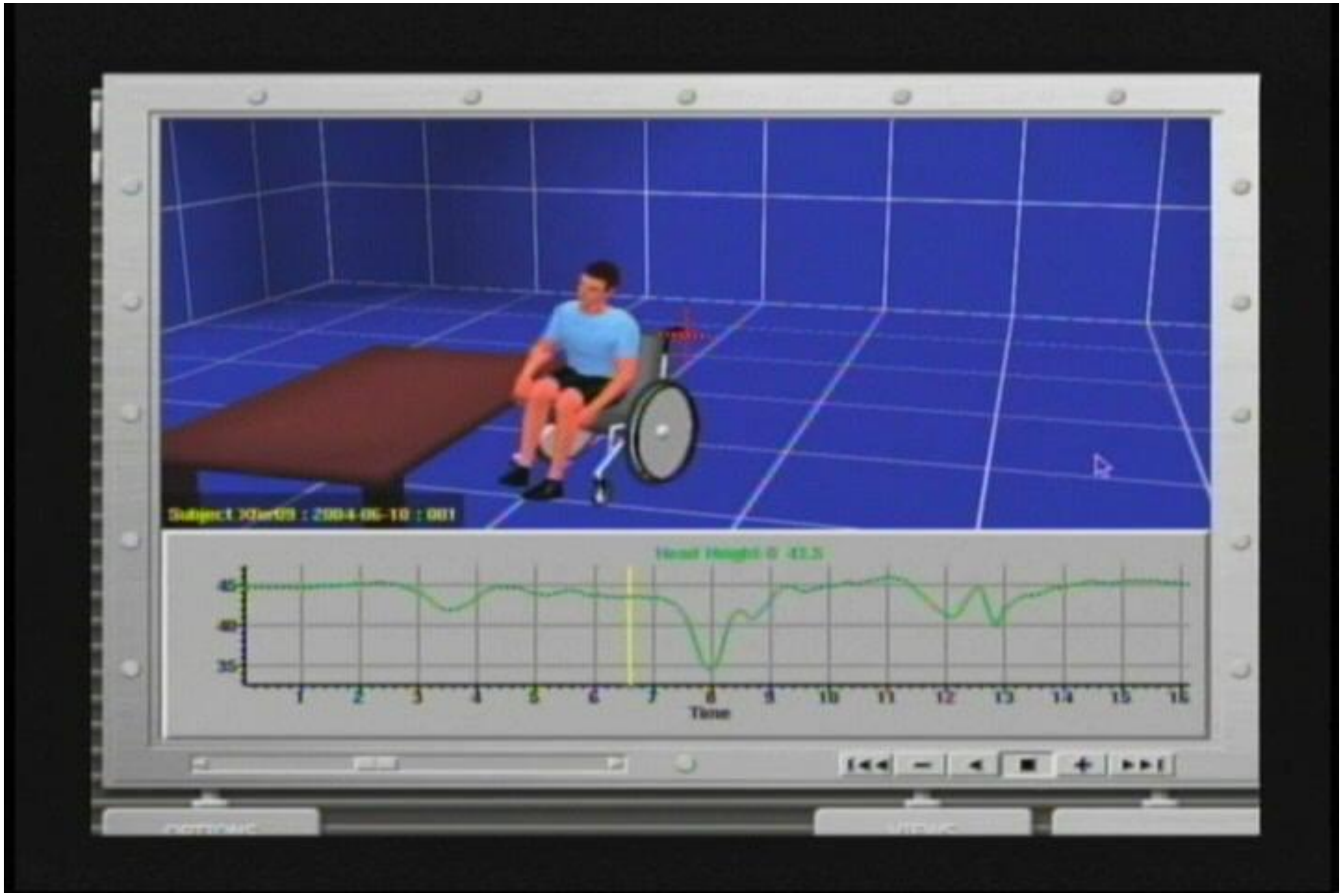
As **level of injury** increases (severity increases, function decreases) – There is less motion in terms of trunk and elbow flexion, and the total transfer path is shortened.

Results: Linear Model

	Max Trunk Flexion	**Max Trunk Rotation**	**Max Trailing Elbow Flexion**	**Total transfer path**
Level of Injury	–		–	–
Arm Length		+	+	
BMI		–		–
Time Post Injury	–	–		–
Age		+		
Distance from back of chair	–		–	–
hand position	*	*		
R-squared	82%	68%	85%	69%

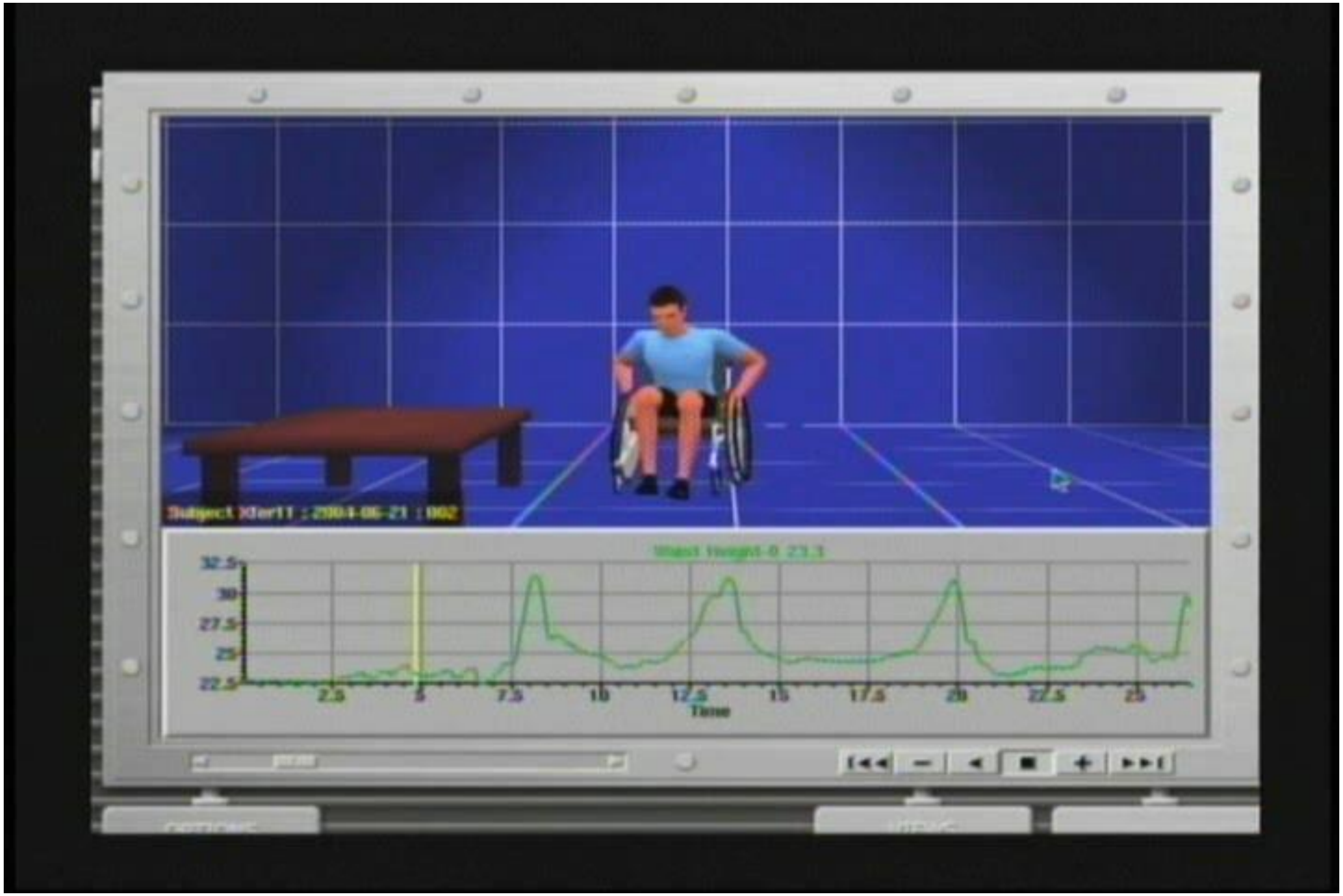
As **time since injury** increases – There is less trunk motion (flexion and rotation), and the total transfer path is shortened.

Transfer to Mat (T9, 34yo)

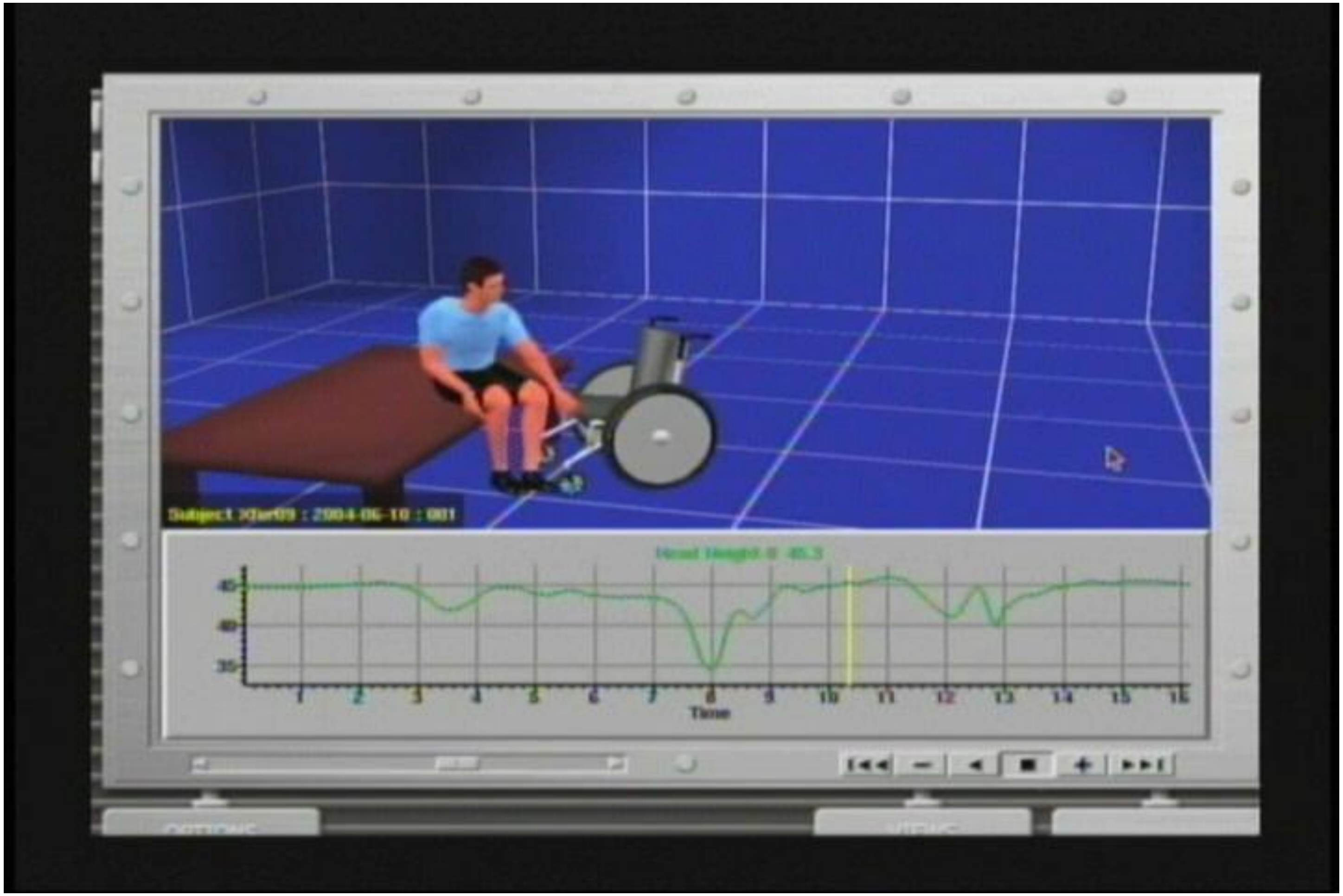


Another Transfer to Mat

(T6, 44yo, very similar BMI and arm length to previous transfer)



Transfer to Wheelchair



Conclusions and Future Work

- Varied strategies
- Pattern recognition and co-variance analysis to identify strategies
- Cluster analysis

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Questions???