sensors

MDPI

Article

Joint Function and Movement Variability During Daily Living Activities Performed Throughout the Home Setting: A Digital Twin Modeling Study

Zhou Fang [1], Mohammad Yavari [1], Yiqun Chen [2], Davood Shojaei [2], Peter Vee Sin Lee [1], Abbas Rajabifard [2] and David Ackland [1,*]

[1] Department of Biomedical Engineering, University of Melbourne, Melbourne, VIC 3010, Australia; mohammad.yavari@student.unimelb.edu.au (M.Y.); pvlee@unimelb.edu.au (P.V.S.L.)
[2] Department of Infrastructure Engineering, University of Melbourne, Melbourne, VIC 3010, Australia
* Correspondence: dackland@unimelb.edu.au

Highlights

What are the main findings?

- A digital twin was developed to support real-time mobility and joint motion measurement and monitoring in the home setting.
- Activities of daily living, and the way they are executed, vary throughout the home setting, even for the same task.

What are the implications of the main findings?

- The findings have implications for home interior design and layout to improve mobility and reduce the risk of falls.
- The framework presented may be useful for real-time monitoring of movement in the home setting, as well as telemedicine and telerehabilitation.

Table S1. Predefined activity sequences for operator-instructed data collection.

Location	Task	Location	Task
			Walking
			Walking while playing with a phone
	Walking		Stand-to-sit on bed
	Walking while working with a phone		Sit-to-lie
	Reaching (opening the fridge)		Lying
Kitchen	Reaching to a cup	Bedroom to kitchen	Lying while playing with a phone
	Reaching (closing the fridge)		Sit-to-lie
	Food chopping		Lie-to-sit
	Stand-to-sit on chair		Sitting
	Eating and drinking		Sit-to-stand
	Sit-to-stand		Walking
	Standing		Reaching (opening the fridge)
	Reaching to a cup		Reaching to a cup

	Reaching (opening the fridge)		Reaching (closing the fridge)
	Reaching (returning the cup)		Food chopping
			Eating and drinking
			Standing
Bedroom	Walking	Living room to bedroom	Walking
	Walking while playing with a phone		Walking while playing with a phone
	Pulling the blind		Stand-to-sit
	Walking		Sitting on sofa
	Standing		Sit-to-stand
	Stand-to-sit on bed		Picking up an item
	Sit-to-lie on bed		Pulling the blind
	Lying		Stand-to-sit
	Lying while playing with a phone		Sit-to-lie on bed
	Lie-to-sit		Lying while playing with phone
	Sitting		Lying
	Sit-to-stand		
Bathroom	Door opening	Bedroom to bath-room	Walking
	Walking		Walking while playing with a phone
	Walking while playing with a phone		Stand-to-sit on bed
	Standing		Sit-to-lie
	Tooth brushing		Lying
	Hair combing		Lie-to-sit
	Sitting		Sit-to-stand
	Door closing		Pulling the blind
			Walking to the bathroom
			Door opening
			Tooth Brushing
			Hair Combing
			Walking
			Door closing
Study	Walking	Study to kitchen	Walking
	Walking while playing with a phone		Walking while playing with a phone
	Walking		Stand-to-sit
	Picking up an item		Sitting
	Reaching to an item on the shelf		Working at the desk
	Stand-to-sit		Sit-to-stand
	Sitting		Walking to the kitchen
	Working at the desk		Reaching (opening the fridge)
	Sit-to-stand		Reaching to a cup
	Standing		Reaching (closing the fridge)
			Food chopping
			Stand-to-sit
			Eating and drinking
			Sit-to-stand

Living room	Walking	Study to living room	Walking
	Walking while playing with a phone		Walking while playing with a phone
	Picking up an item		Reaching to an item on the shelf
	Standing		Stand-to-sit
	Stand-to-sit		Sitting
	Sitting on sofa		Working at the desk
	Sit-to-stand		Sit-to-stand
	Opening balcony door		Reaching to an item on the shelf
	Closing balcony door		Picking up an item
			Stand-to-sit on the sofa
			Sitting

Table S2. Mean and standard deviation of the averaged maximum shoulder plane of elevation and shoulder elevation measured using the video camera data during operator-instructed and self-directed upper limb activities of daily living. Differences between operator-instructed and self-directed data were calculated using paired t-tests, and the resulting p-values given. Acronyms included: OI, operator instructed; and SD, self-directed.

Task	Max shoulder plane of elevation (degrees)			Max shoulder elevation (degrees)		
	OI	SD	P-value	OI	SD	P-value
Door opening	83.2 ± 12.4	83.4 ± 10.6	0.828	76.6 ± 24.9	79.5 ± 17.7	0.645
Reaching	95.8 ± 16.0	91.1 ± 11.3	0.226	77.2 ± 16.9	70.6 ± 23.2	0.366

Table S3. Mean and standard deviation of the averaged maximum hip flexion, maximum knee flexion, maximum ankle dorsiflexion, and ankle plantar flexion measured using the video camera data during operator-instructed tasks and self-directed lower limb activities of daily living. Differences between measured and predicted data were calculated using paired t-tests, and the resulting p-values given. Acronyms included: OI, operator instructed; and SD, self-directed.

Task	Max hip flexion (degrees)			Max knee flexion (degrees)			Max ankle dorsiflexion (degrees)			Max ankle plantarflexion (degrees)		
	OI	SD	P-value	OI	SD	P-value	OI	SD	P-value	OI	SD	P-value
Sit-to-stand	74.3 ± 7.5	77.0 ± 4.4	0.144	90.7 ± 11.6	93.7 ± 13.5	0.133	16.2 ± 9.0	19.8 ± 10.8	0.060	0.4 ± 7.2	-1.7 ± 8.8	0.642
Walking	29.2 ± 3.8	28.3 ± 4.0	0.310	59.8 ± 4.0	61.1 ± 6.3	0.744	17.6 ± 2.7	16.7 ± 6.8	0.596	21.9 ± 4.3	22.6 ± 5.2	0.720