Dynamic Characteristics of Upper Body for Applied Human Factor Design

Dr. Newman Lau
PolyU UoA 38

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Descriptor

This research provides substantial insight for human factor design, in particular upper body, of applying ergonomic principles into design by understanding the underlying motor control, movement mechanism and performance of human activities. The objective is to explore the dynamic characteristics from the joint movements captured into analyzing the data to trace the hints in human motor control that governs the whole body biomechanics of movement.

Together with the methods from design research as a whole, a scientific approach has been developed in analyzing the information from a cross-disciplinary manner based on various configuration designed to capture and evaluate human body movement. There are a few approaches of investigation, namely, static posture with internal body balance, static posture with external hint of balance, dynamic posture on activities, effects of wearable design features on activities. From the analysis results, individual human body characteristics on postural control, developmental process, performance evaluation can then be retrieved. The significance of these information is to allow a better understanding on the human factors that can be derived from applied design to wearable on user experience, especially for healthcare and performance indication.

The originality of the framework in this study serve as a cross-disciplinary foundation for the design and technical guidelines on how design features can be investigated and developed to capture user characteristics and issues for various potential applications. This study demonstrated the feasibility in a few scopes of design features investigation in provoking to activity performance strategies and product features to facilitate better movement and postures. It encourages further experiments to be carried out in the future to extend the scenarios of investigation, enhance the systematic approach and analysis, and inquire more design issues as aroused from user design research.

Biography

Dr. Newman Lau
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Dr. Newman Lau is the Associate Professor in the School of Design. He specializes in user experience design and applies the concepts to cross-disciplinary works. His current research focuses on human factor design through user behavior, motivation, and user-centric analysis. Design for healthcare and wellbeing is one of his major project themes. Capturing and analyzing human body movement is his core research topics. Various research projects include interpreting movement appears in various areas, for instance, ergonomics, sports, wearables in daily activities, etc. Based on his extensive network with the industry and society, collaboration with various stakeholders has been facilitated in various research publications, funded research projects and awards. That aligns entities ranging from design, engineering, healthcare, community, business, etc.

He has more than 40 research publications, in which about 10 of those are journal articles, including International Education Studies, International Journal of Visual Design, Leonardo, Journal of Biomechanics, Journal of Human Kinetics, Motor Control, Materials, Design Principles and Practices: An International Journal, etc., with the highest Impact Factor as 2.972 from InCites Journal Citation Reports.

What Constitutes the Body of Work

- A systematic approach of investigation from human activities in both dynamic and static body postures, to human factor and movement analysis, and finally to design features investigation in provoking to activity performance strategies and product features facilitating better movement and postures.
- Scenarios of 3 activities to illustrate the analysis and facilitate design features.
- Experiments with altogether 86 participants studied.
- Research publications in 3 journals.

Research Questions

The research sets out to:

1. Explore the human factor design by investigating the movement control through retrieving underlying mechanism and individual characteristics by non-invasive analysis on biomechanical and dynamic properties of body movement.
2. Derive a systematic approach from defining the activities to body movement, and later methods of analysis for body control findings.
3. Derive the meaning and implication on design from the body control mechanism, model and pattern extracted for interpretation.
4. Address the design features and performance strategies based on anthropometric factors, activities, wearable, for human user experience.

Research Questions

Keywords

1. Dynamic characteristics of body movement and activities
2. Anthropometric user factors
3. Design issues provoked from body control mechanism
4. Activity performance strategies
5. Product design features facilitating better postures

Research Methods & Materials

Milestone 1: Define the dynamic / static activities of investigation

- Task 1: Define the details on movement in phases of body posture
- Task 2: Define the visual cues implying the various balance control mechanisms

Milestone 2: Capture human factors and analyze movement and motor control

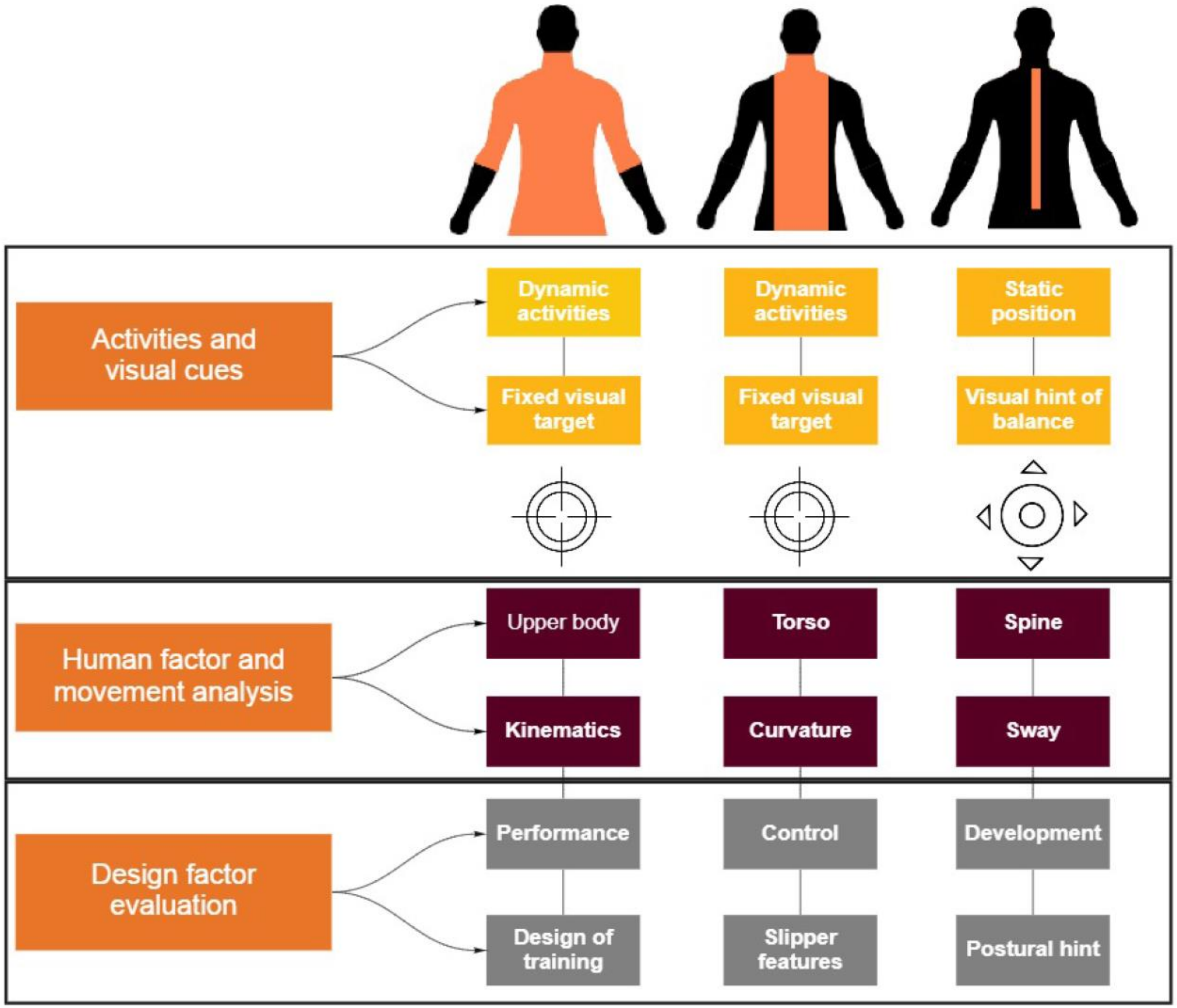
- Task 1: Define the human factors for analysis
- Task 2: Define the method to capture and analyze the movement in dynamic and static postures

Milestone 3: Evaluate the implication of design factors from outside-in relating to motor control

- Task 1: Design from evaluation at performance level
- Task 2: Design from evaluation at body control level
- Task 3: Design from evaluation at motor control level

Research Methods & Materials

Under this research topic, the objective is to create a systematic approach in investigating the human activities, through the analysis of human factors and body movement, in order to address design issues. The aim is to understand the underlying motor control mechanism of body movement through a non-invasive approach. The movement control inside human body is a complicated knowledge domain, including, neurological, physiological matters that usually involve invasive examination. Our approach is an outside-in analysis of body movement to extract hints about the complication of human body motor control. Through the evaluation and understanding of the users, the design issues can be provoked to activity performance strategies and product features to facilitate better movement and postures.



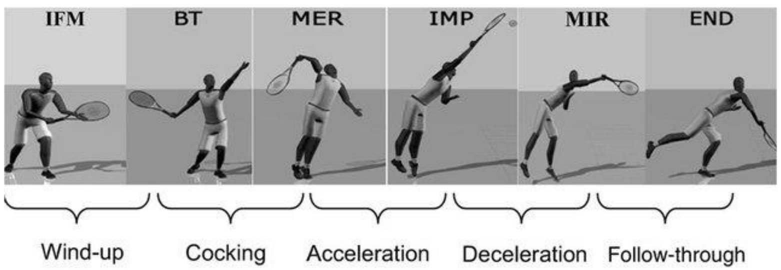
Research Methods & Materials

Milestone 1: Define the dynamic / static activities of investigation

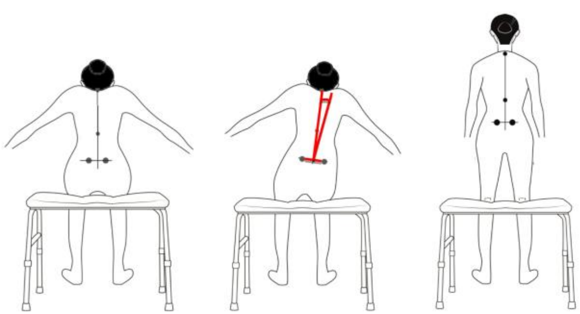
Task 1: Define the details on movement in phases of body posture

To breakdown the activity, either dynamic or static, into phases of body posture for analysis. The two major approaches we applied is based on time basis for dynamic activity, e.g. sit-to-stand task, tennis serving, and space basis for static activity, e.g., sitting upright.

<u>Time basis for dynamic activities</u>

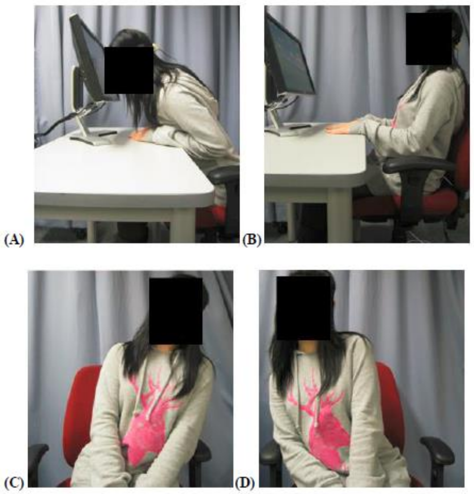


Subject movement of body posture during tennis serving (TS) activity



Subject movement of torso during sit-to-stand (STS) task

<u>Space basis for static activities</u>



Subject movement of spine along anterior-posterior and lateral planes during upright sitting

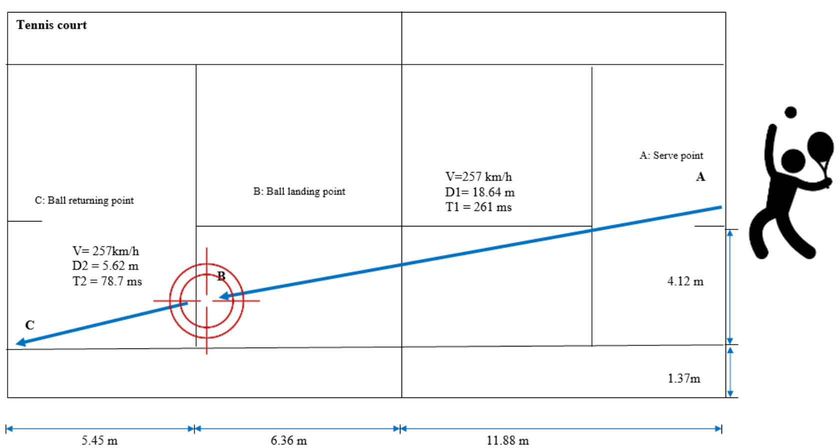
Research Methods & Materials

Milestone 1: Define the dynamic / static activities of investigation

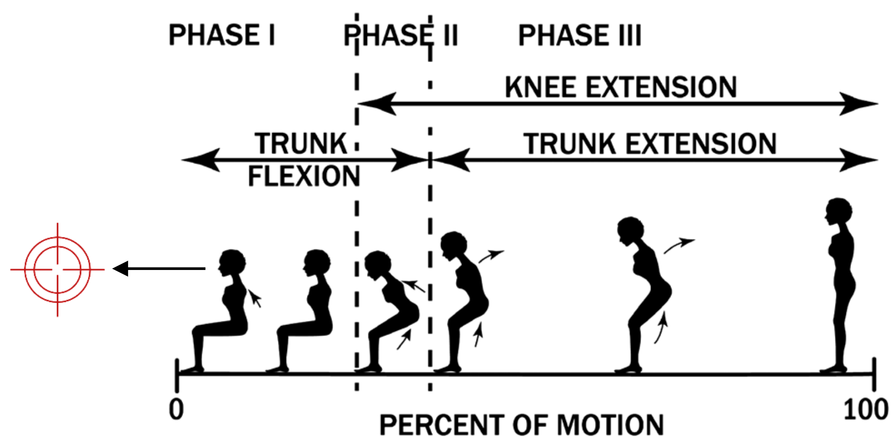
Task 2: Define the visual cues implying the various balance control mechanisms

Motor control is determined by sensory inputs, which involves the somatosensory, visual, and vestibular system. The sensory inputs serve as the stimuli to initiate movements and also provide feedback to modulate movements. The visual system plays a crucial role to provide necessary information for the correctness in proprioception, which maintains the quality of balance and control about joints and muscles of movement. Here is to define two types of visual cues for subjects to engage though the visual system. The first one is a fixed visual target as a stationary reference point of action. The other one is also a fixed target but includes a hint of body posture information in real-time as a reference for maintaining the body balance.

Fixed point visual target as stationary reference point



Fixed point visual target during TS



Fixed point visual hint of balance during STS

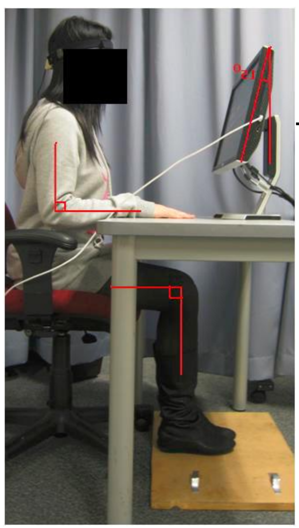
Research Methods & Materials

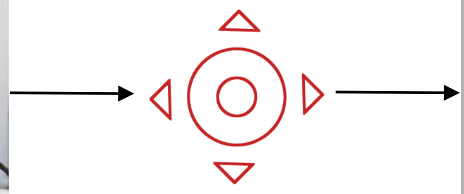
Milestone 1: Define the dynamic / static activities of investigation

Task 2: Define the visual cues implying the various balance control mechanisms

The other one is also a fixed target but includes a hint of body posture information in real-time as a reference for maintaining the body balance.

Fixed visual target with hint of body posture information in real-time





Visual hint of balance from spinal curvature in real-time, monitored using accelerometers to measure the angle of inclination at specific spinal region

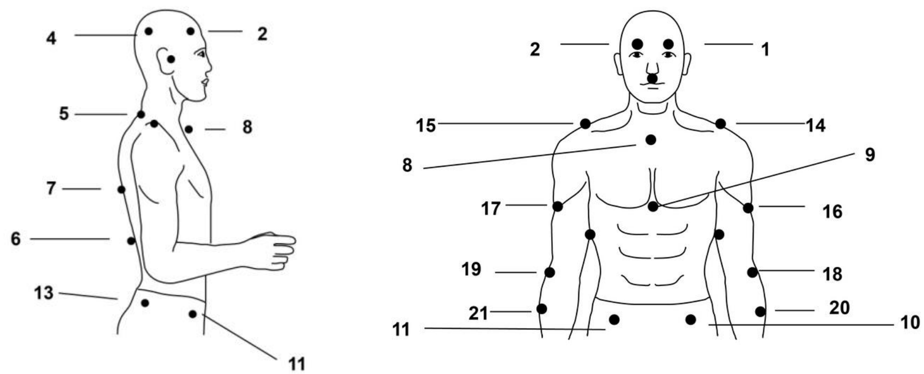
Research Methods & Materials

Milestone 2: Capture human factors and analyze movement and motor control

Task 1: Define the human factors for analysis

To define the characteristics of subject groups, including criteria of inclusion and exclusion. Recruit subjects and collect anthropometric information for correlation analysis, aiming to customizing design features based on subject variability. Then to define the body parameters as another factor to capture the body posture and movement for later analysis.

Subject group and upper body data factors defined for TS



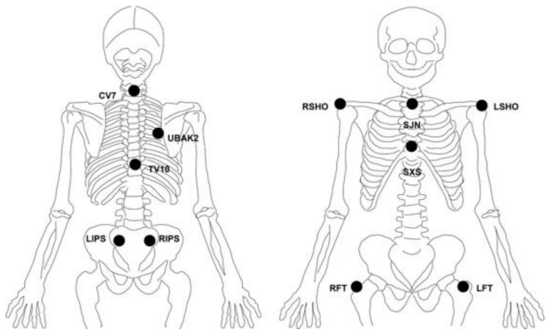
	Mean	SD	Min	Max
Age (years)	20.5	3.8	13.0	25.0
Body Height (cm)	174.8	7.1	170.0	184.5
Body Mass Index (BMI) (kg/m^2)	22.2	2.8	16.5	27.5
Years of Tennis Training	8.3	5.7	2.0	19.0
Training Hours per Month	36.9	39.9	10.0	150.0

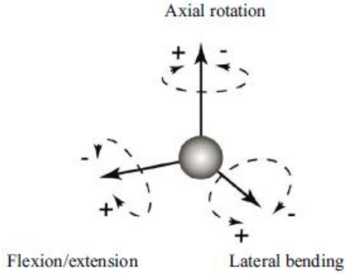
Research Methods & Materials

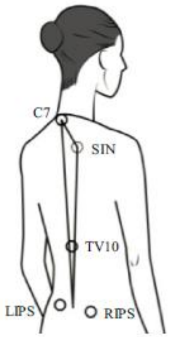
Milestone 2: Capture human factors and analyze movement and motor control

Task 1: Define the human factors for analysis

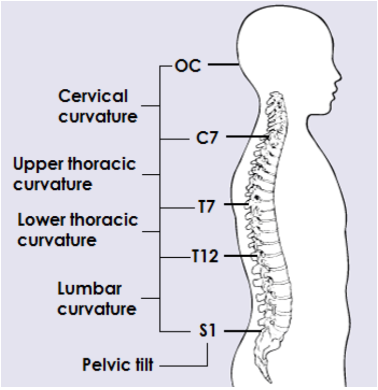
Subject group and upper body data factors defined for STS







N = 10	Mean	SD	Min	Max
Age (years)	62.85	2.81	60	67
Weight (kg)	56.2	5.9	51	71
Height (cm)	155.1	5.0	148	166
Body Mass Index (kg/m^2)	23.40	2.67	20.41	28.62
Left foot size (cm)	229.1	9.9	214.1	244.1
Right foot size (cm)	228.5	8.7	212.0	241.4



Subject groups and spinal curvature data factors defined

Group	Characteristics			
	Gender	Age	Height (cm)	Weight (kg)
A (n = 16)	male	11 years 6 months (6 months)	151.9 (7.1)	44.7 (7.4)
B (n = 16)	male	15 years 1 months (6 months)	167.9 (5.2)	57.7 (6.2)
C (n = 16)	female	11 years 2 months (5 months)	144.1 (6.3)	37.8 (8.7)
D (n = 16)	female	15 years 2 months (7 months)	158.5 (5.9)	52.0 (5.6)

Research Methods & Materials

Milestone 2: Capture human factors and analyze movement and motor control

Task 2: Define the method to capture and analyze the movement in dynamic and static postures

Based on the previous body movement landmarks defined, system devices are setup capture the movement of each marker points. The movements are then separated into phases based on the activity.

Body data factors captured and separated into phases of movement for analysis during TS

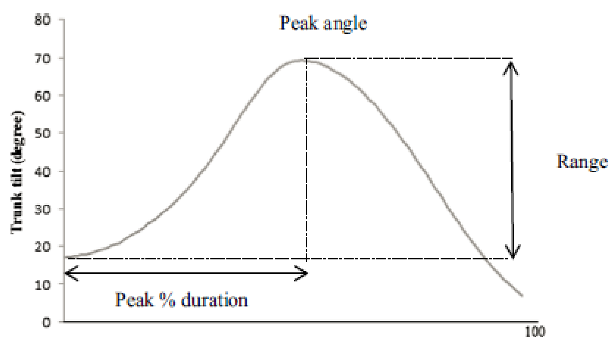
Phases of the Serve	
Phase I	Back Swing Phase (Preparation Phase) From maximum shoulder internal rotation (MSJR) to maximum front knee joint flexion (MKF)
Phase II	Lead Leg Drive Phase From maximum front knee joint flexion (MKF) to maximum shoulder external rotation (MSER)
Phase III	Forward Swing Phase From maximum shoulder external rotation (MSER) to racket-ball impact (IMP)
Phase IV	Follow-through Phase From after racket-ball impact (IMP) to subsequent foot contact with the ground

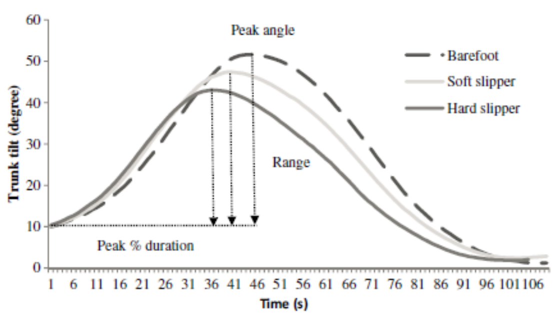
Research Methods & Materials

Milestone 2: Capture human factors and analyze movement and motor control

Task 2: Define the method to capture and analyze the movement in dynamic and static postures

Body data factors captured and separated into phases of movement for analysis during STS



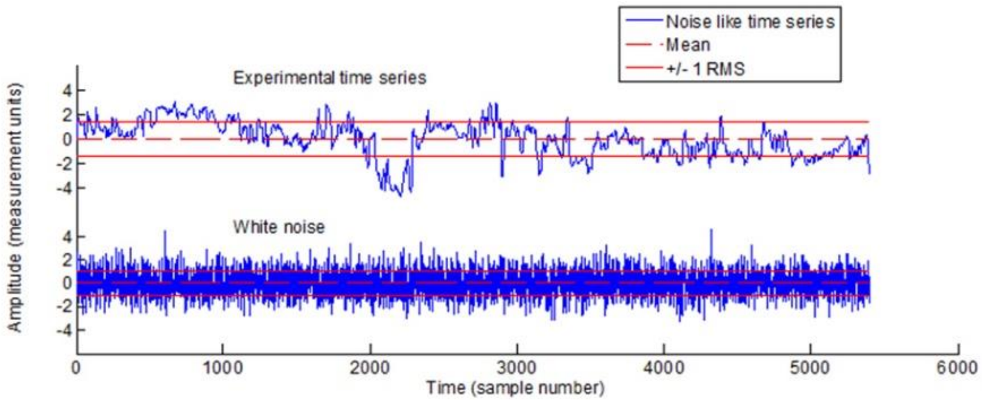


	Barefoot	Soft Slippers	Hard Slippers
Time duration (s)	109 (11.4)	110 (14.3)	111 (13.7)
Trunk displacement			
Mediolateral angle (°)	2.4 (4.0)	2.4 (6.0)	1.6 (5.1)
Trunk tilt			
Peak angle (°)*	53.2 (5.6)	48.5 (4.3)	47.9 (4.6)$^{+}$
Peak % duration	47.7 (5.3)	43.2 (4.4)	43.5 (5.0)
Range (°)*	44.2 (3.9)	39.0 (4.0)	39.3 (4.5)$^{+}$
Percentage of motion			
Phase I*	47.0 (7.9)	42.6 (7.5)$^{\#}$	42.3 (5.2)$^{+}$
Phase II	5.1 (2.7)	6.6 (4.6)	6.4 (4.5)
Phase III	52.3 (5.3)	56.8 (4.4)	56.5 (5.0)

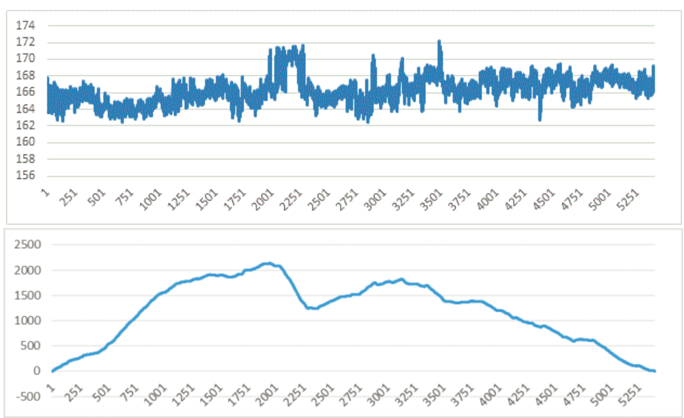
Research Methods & Materials

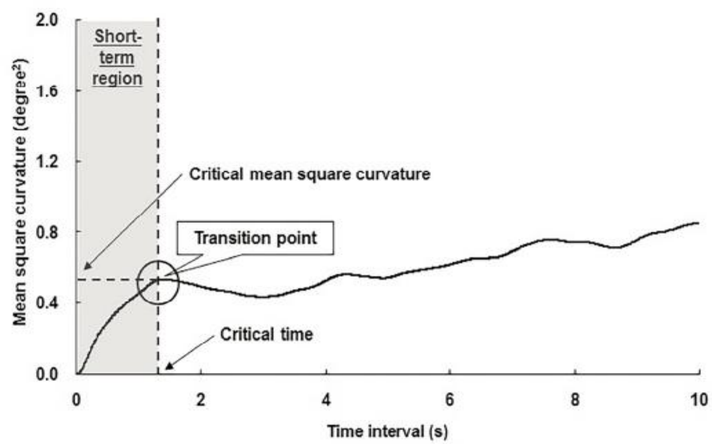
Milestone 2: Capture human factors and analyze movement and motor control

Task 2: Define the method to capture and analyze the movement in dynamic and static postures



Body data factors captured, and movement along spinal curvature are transformed using multifractal analysis to diffusion plot separated into short-term and long-term phases of control



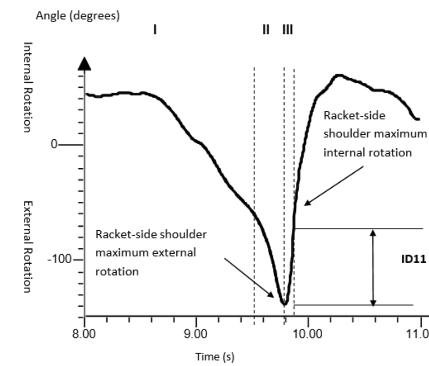


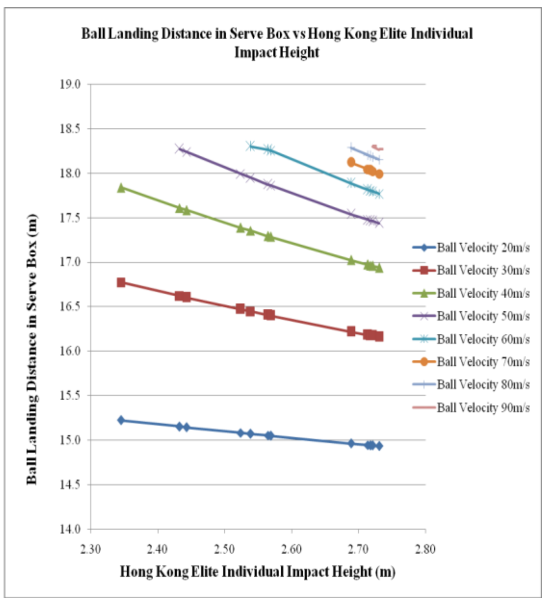
Research Methods & Materials

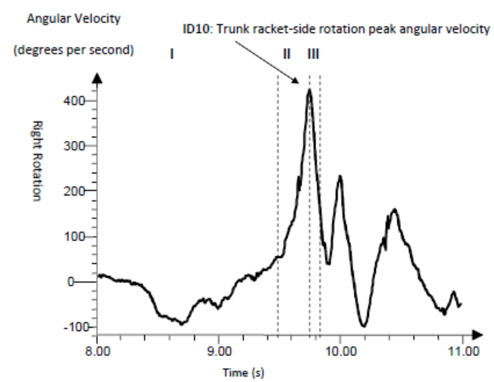
Milestone 3: Evaluate the implication of design factors from outside-in relating to motor control

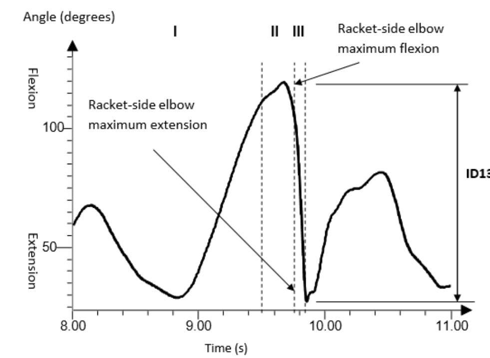
Task 1: Design from evaluation at performance level

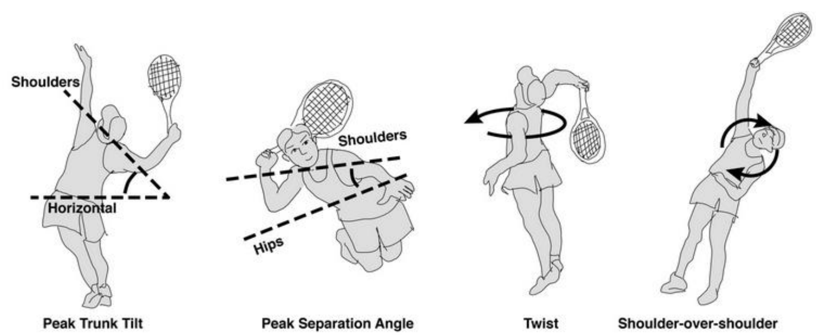
Based on the performance of ball landing speed and distance, the design of training set can be customized based on various body kinematics, e.g., trunk peak rotation during phase II, shoulder range of motion during phase III, elbow range of motion during phase II and III.











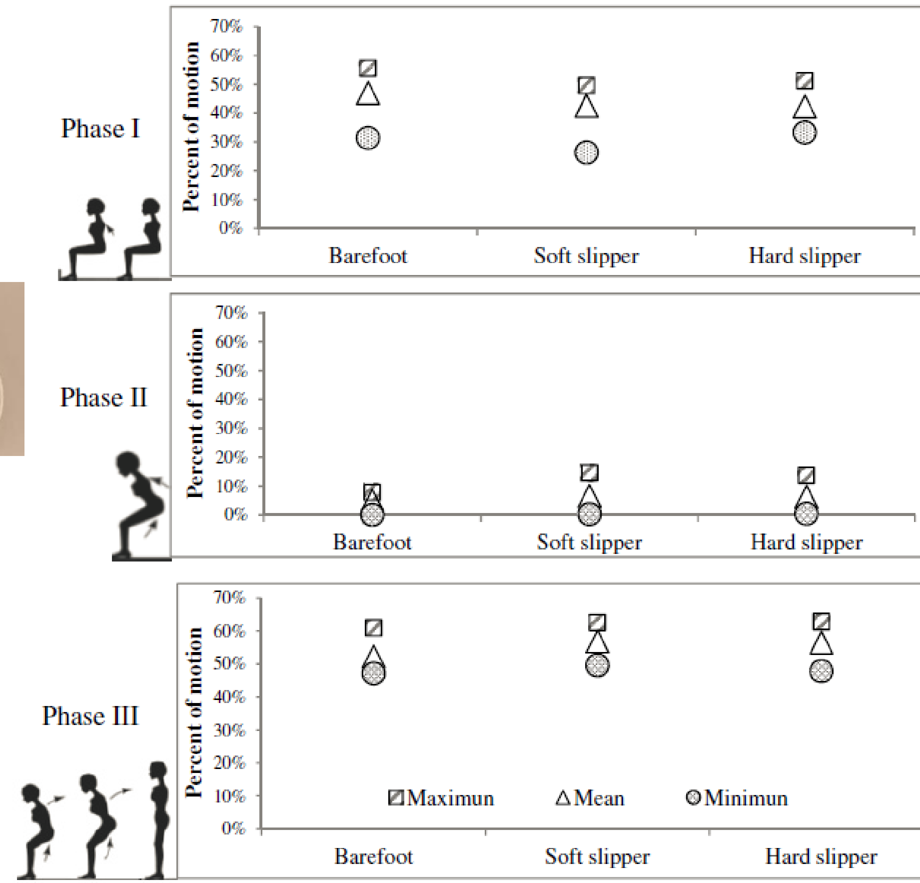
Research Methods & Materials

Milestone 3: Evaluate the implication of design factors from outside-in relating to motor control

Task 2: Design from evaluation at body control level

Based on the movement control of senior women captured and separated into phases by performing the sit-to-stand (STS) task, the quality of control implied can be summarized to various design features of slippers. After correlating the details of design features to the evaluation of body control, the findings therefore provide a better understanding of slipper features and designs associated to senior women.

	Soft Slipper	Hard Slipper
Shoe size range (mm)	220–245	220–245
Weight range (g)	58.01–60.64	186.99–215.34
Strap girth (mm)	212–218	217–233
Thickness under heel (mm)	21.1	18.8
Hardness (Shore A) ASTM D 2240	20	32
Coefficient of friction	0.69	0.78
Compression (kPa) ISO 3386-1	1607	13713
Force reduction (%) ASTM D 2632	70.1	54.2
Bending stiffness (N mm)	55.02	22.23

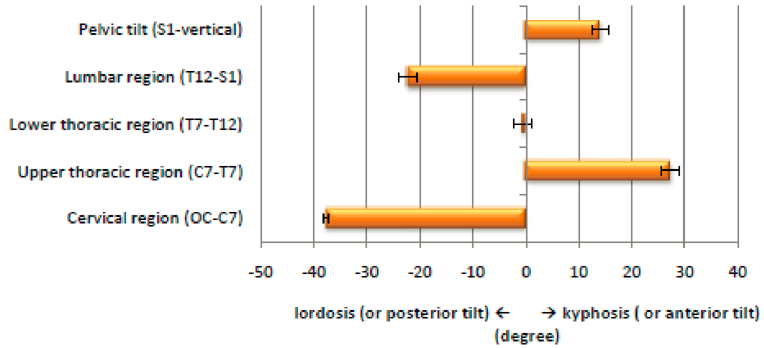


Research Methods & Materials

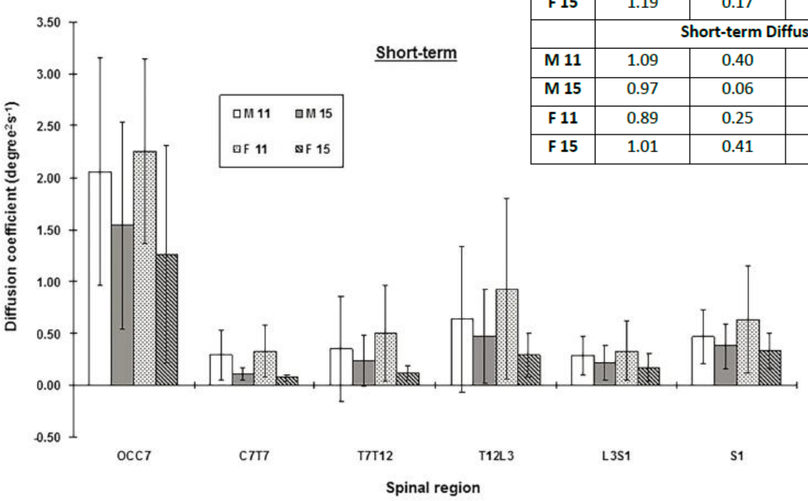
Milestone 3: Evaluate the implication of design factors from outside-in relating to motor control

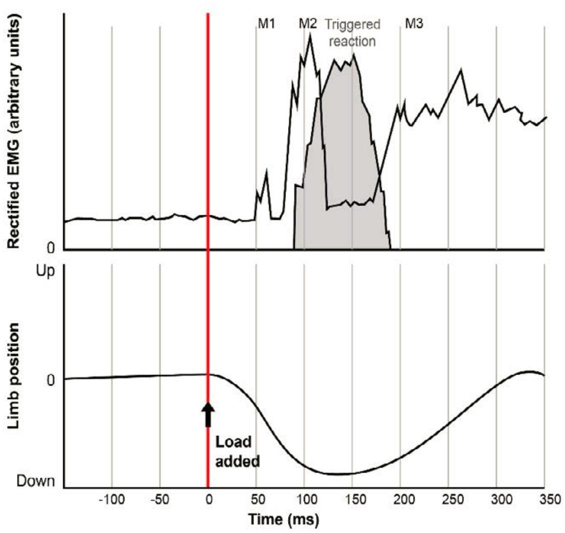
Task 3: Design from evaluation at motor control level

The spinal curvatures of different spinal regions in 64 children aged 11 or 15 years old during upright sitting were captured and compared for the effects of age and gender. The findings reveal that the spinal motor control in children is significantly affected by age and 11 years old children was underdeveloped when compared. In order to correct poor posture for children, the design of visual hint as postural sensor at T7 for subjects to keep upright sitting position was recommended.



	OC & C7	C7 & T7	T7 & T12	T12 & L1	L1 & L3	S1
	Short-term Diffusion Coefficients (Mean)					
M 11	2.06	0.34	0.35	0.63	0.29	0.47
M 15	1.64	0.11	0.24	0.51	0.22	0.39
F 11	2.26	0.33	0.50	0.93	0.33	0.63
F 15	1.19	0.17	0.14	0.35	0.27	0.34
	Short-term Diffusion Coefficients (Standard Deviation)					
M 11	1.09	0.40	0.50	0.70	0.18	0.26
M 15	0.97	0.06	0.25	0.52	0.17	0.23
F 11	0.89	0.25	0.46	0.87	0.29	0.51
F 15	1.01	0.41	0.15	0.32	0.49	0.16





Research Conclusions

A systematic approach has been explored in investigating the human activities, through the analysis of human factors and body movement, in order to address design issues. The research method investigated the scope of activities in both dynamic and static body postures. The research findings provide individual human factor characteristics on the basis of the non-invasive body movement data captured and computed. From laboratory experimental environment with specific capturing procedures, upper body movement from kinematics, curvatures, and sway are analyzed, resulting in hints extracted about the complication of human body motor control from the outside-in approach.

The research outputs generated from this study has demonstrated the feasibility in a few scopes of design features investigation in provoking to activity performance strategies and product features to facilitate better movement and postures. The framework serve as a cross-disciplinary foundation for the design and technical guidelines on how the design features can be investigated and developed to capture user characteristics and issues for various potential applications. Further experiments can be carried out in the future to extend the scenarios of investigation, enhance the systematic approach and analysis, and inquire more design issues as aroused from user design research.

Dissemination and Distribution of Outcomes

- The research has been published in 3 international, double-blind peer-reviewed journals.
- Among the journals, the highest Google Scholar h5-index is 29, with InCites JCR IF (SSCI) as 1.795.
- There are a total of 19 citations world-wide on the journal publications.
- The research has facilitated the collaboration between 3 universities, and 5 departments.

Dissemination and Distribution of Outcomes

Journal publications

Year	Research Publication
2014	**Journal of Human Kinetics, Section I – Kinesiology (Google Scholar h5-index: 31, InCites JCR IF (SCIE): 1.174)** Wong, F.K.H., Keung, J.H.K., Lau, N.M.L., Ng, D.K.S., Chung, J.W.Y., & Chow, D.H.K. (2014). Effects of body mass index and full body kinematics on tennis serve speed. Journal of Human Kinetics 40, 21-28. DOI:10.2478/hukin-2014-0003.
2016	**Motor Control (Google Scholar h5-index: 12, InCites JCR IF (SCIE): 0.957)** Chow, D.H.K., & Lau, N.M.L. (2016). Dynamic characteristic analysis of spinal motor control between 11 and 15 year-old children. Motor Control 20(3), 285-298. DOI:10.1123/mc.2014-0079.
2017	**Journal of Aging and Physical Activity (Google Scholar h5-index: 29, InCites JCR IF (SSCI): 1.795)** Lo, W.T., Yick, K.L., Lau, N.M.L., Tse, L.T., Ng, S.P., & Yip, J. (2017) Effects of slipper features and properties on walking and sit-to-stand tasks in older women. Journal of Aging and Physical Activity 25(4), 587-595. DOI: 10.1123/japa.2016-0298

Dissemination and Distribution of Outcomes

Journal of Human Kinetics, Section I – Kinesiology

Abstract: The design of an effective training package to improve serve speed is important for competitive tennis players. The purpose of this study was to propose possible training strategies for improving the quality of tennis serves by the investigation of the correlation between performance and body factors, in particular, the body kinematics. After the analysis of 12 male elite Hong Kong players, significantly correlation between serve performance and kinematic parameters. This serves as important information as basis when designing the training guidelines for coaches and players.

The Journal of Human Kinetics is a respected interdisciplinary periodical offering the latest research in the science of human movement studies. This comprehensive professional journal features articles encompassing topic areas as motor learning and motor development, exercise physiology and biochemistry, sports medicine, sport nutrition, biomechanics, sports training, as well as measurement and evaluation in sport and physical education, especially taking into account sport's competitive and elite aspects.

Journal Impact Factor from InCites Journal Citation Reports (JCR)
Impact Factor 2018: 1.414
5-year Impact Factor: 1.858

CiteScore 2018: 1.60

SCImago Journal Rank (SJR) 2018: 0.644
Scource Normalized Impact per Paper (SNIP) 2018: 0.941

Google h5-index: 31
Google h5-median: 42

Link to the journal

Link to the publication entry

Dissemination and Distribution of Outcomes

Motor Control

Abstract: The objective of this study is to explore the hint of development through the human factor evaluation of designing the measures of connection between vision and spinal control. The experiment adopted guided vision control for participants to reposition the spinal curvature through visual feedback. Through the analysis, the results showed evidence of better motor control of 15-year-old children than 11-year-old children with smaller repositioning error and less curvature variability as well as shorter response time and smaller curvature deformation. This implies another applicability of evaluation on human factor based on different subject profiles.

Motor Control (MC), a peer-reviewed international journal, provides a multidisciplinary examination of human movement across the lifespan. To keep abreast of current developments in the field of motor control, it offers timely coverage of important topics from varied disciplines as biomechanics, kinesiology, neurophysiology, neuroscience, psychology, physical medicine, and rehabilitation. This international journal publishes many types of research papers, from clinical experimental to modeling and theoretical studies.

Journal Impact Factor from InCites Journal Citation Reports (JCR)
Impact Factor 2018: 1.302
5-year Impact Factor: 1.063

CiteScore 2018: 0.95

SCImago Journal Rank (SJR) 2018: 0.386
Scource Normalized Impact per Paper (SNIP) 2018: 0.564

Google h5-index: 12
Google h5-median: 15

Link to the journal

Link to the publication entry

Dissemination and Distribution of Outcomes

Journal of Aging and Physical Activity

Abstract: This study evaluated the range of movement and changes in trunk displacement during sit-to-stand when 10 healthy older women wore two types of slippers and were barefoot. During the sit-stand transition when slippers are worn, there is a significant reduction in the peak trunk tilt angle and range, as well as the duration of the weight shift when motion is initiated. The findings therefore provide a better understanding of slipper features and designs associated to older women.

The Journal of Aging and Physical Activity (JAPA) is a multidisciplinary journal that publishes peer-reviewed original research reports, scholarly reviews, and professional-application articles on the relationship between physical activity and the aging process. The journal encourages the submission of articles that can contribute to an understanding of (a) the impact of physical activity on physiological, psychological, and social aspects of older adults and (b) the effect of advancing age or the aging process on physical activity among older adults.

Journal Impact Factor from InCites Journal Citation Reports (JCR)
Impact Factor 2018: 1.795
5-year Impact Factor: 2.144

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