Journal of Visualized Experiments

The impact of motor task conditions on goal-directed arm reaching kinematics and trunk compensation in chronic stroke survivors

--Manuscript Draft--

Article Type:	Invited Methods Collection - Author Produced Video
Manuscript Number:	JoVE61940R5
Full Title:	The impact of motor task conditions on goal-directed arm reaching kinematics and trunk compensation in chronic stroke survivors
Corresponding Author:	Bokkyu Kim State University of New York Upstate Medical University Syracuse, NY UNITED STATES
Corresponding Author's Institution:	State University of New York Upstate Medical University
Corresponding Author E-Mail:	kimbo@upstate.edu
Order of Authors:	Jaimie Girnis
	Vanessa Sweet
	Tarek Agag
	Tobias Nobiling
	Bokkyu Kim
Additional Information:	
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TITLE:

The impact of motor task conditions on goal-directed arm reaching kinematics and trunk compensation in chronic stroke survivors

AUTHORS AND AFFILIATIONS:

Jaimie Girnis[1, 2], Tarek Agag[1], Tobias Nobiling[1, 3], Vanessa Sweet[1, 4], Bokkyu Kim[1]

[1]Department of Physical Therapy Education, SUNY Upstate Medical University, Syracuse, NY, USA
[2]College of Health and Rehabilitation Sciences: Sargent College Center for Neurorehabilitation, Boston University. Boston, MA, USA
[3]Department of Physical Medicine and Rehabilitation, University of Rochester Medical Center, Rochester, NY, USA
[4]Rehabilitation Today, Olean, NY, USA

E-mail Addresses of co-authors:

Jaimie Girnis	girnisj@bu.edu
Tarek Agag	agagt@upstate.edu
Tobias Nobiling	tobias_nobiling@urmc.rochester.edu
Vanessa Sweet	Vanessa.Sweet16@houghton.edu

Corresponding author:

Bokkyu Kim (kimbo@upstate.edu)

KEYWORDS:

Stroke Rehabilitation, compensatory movement strategies, task conditions, chronic stroke, kinematics, motion analysis, upper extremity, fine hand motor control

SUMMARY:

This protocol is intended to investigate the impact of task conditions on movement strategies in chronic stroke survivors. Further, this protocol can be used to examine if a restriction in elbow extension induced by neuromuscular electrical stimulation causes trunk compensation during goal-directed arm reaches in non-disabled adults.

ABSTRACT:

Trunk compensation is the most common movement strategy to substitute for upper extremity (UE) motor deficits in chronic stroke survivors. There is a lack of evidence examining how task conditions impact trunk compensation and goal-directed arm reaching kinematics. This protocol aims to investigate the impact of task conditions, including task difficulty and complexity, on goal-directed arm reaching kinematics. Two non-disabled young adults and two chronic stroke survivors with mild UE motor impairment were recruited for testing the protocol. Each participant performed goal-directed arm reaches with four different task conditions (2 task difficulties [large vs. small targets] X 2 task complexities [pointing vs. picking up]). The task goal was to reach and point at a target or pick up an object located 20 cm in front of the home position as quickly as possible with a stylus or a pair of chopsticks, respectively, in response to an auditory

cue. Participants performed ten reaches per task condition. A 3-dimensional motion capture camera system was used to record trunk and arm kinematics. Representative results showed that there was a significant increase in movement duration, movement jerkiness, and trunk compensation as a function of task complexity, but not task difficulty in all participants. Chronic stroke survivors showed significantly slower, jerkier, and more feedback-dependent arm reaches and significantly more compensatory trunk movements than non-disabled adults. Our representative results support that this protocol can be used to investigate the impact of task conditions on motor control strategies in chronic stroke survivors with mild UE motor impairment.

INTRODUCTION:

Trunk movement is the most common strategy to compensate for limited degrees of freedom in the elbow and shoulder in individuals with post-stroke upper extremity (UE) motor deficits[1,2]. Previous studies have shown that post-stroke individuals employ different movement strategies in different motor task environments[3–5]. Dynamic systems motor control theory explains that movements emerge from internal individual factors and external factors, such as task conditions and environment[6]. Further, Fitt's law explains the relationship between task difficulty and movement speed, with a tendency to perform more difficult tasks with slower speeds[7]. In terms of goal-directed arm reaching tasks, Gentilucci reported that people slow down their reaching movements when they reach and grasp a smaller object compared to a larger object[8]. However, the impact of task complexity on goal-directed arm reaching kinematics and compensatory movement strategies in chronic stroke survivors is not well understood. A previous study that examined pointing and grasping tasks in chronic stroke survivors demonstrated that differences in kinematic variables between two different tasks explained differences in UE motor impairment as measured by the Fugl-Meyer Upper Extremity Score[9]. However, this study did not directly compare how movement strategies are different in terms of kinematic variables between pointing and grasping tasks. A better understanding of the impact of task conditions on compensatory movement strategies in consideration of individual motor impairment level is crucial to design effective treatment sessions to minimize compensatory movements and maximize restitution of motor impairment. Therefore, it is imperative to investigate how task conditions, specifically task complexity, impact movement strategies in individuals with post-stroke motor impairment. This proposed study protocol will investigate the impact of task conditions on goal-directed arm reaching kinematics in non-disabled adults and stroke survivors. The aims of this protocol are two-fold: 1) to investigate whether the task complexity influences trunk compensation and goal-directed arm reaching kinematics in chronic stroke survivors; 2) to determine if this protocol can differentiate the kinematics of goal-directed arm reaches between non-disabled adults and chronic stroke survivors.

PROTOCOL:

The Institutional Review Board (IRB) of SUNY Upstate Medical University approved this protocol.

1. Participant screening

1.1. Perform all research methods with IRB approval by the Declaration of Helsinki.

1.2. Recruit non-disabled adults who do not have any neurological or musculoskeletal issues that prevent upper extremity motor task performance.

1.3. Recruit chronic stroke survivors whose stroke onset is at least six months before study participation and who have mild-to-moderate upper extremity motor impairment, indicated by Fugl-Meyer Assessment of upper extremity score of 19 to 60 out of 66, and can extend hemiparetic wrist and fingers at least 10 degrees voluntarily.

1.4. Schedule potential participants to attend a data collection session.

1.5. Obtain written informed consent from all research participants before initiating any experimental procedures.

1.6. Screen all participants for study participation eligibility using questionnaires regarding their demographics, previous arm injury history, hand dominance, and confidence in specific fine hand motor skill tasks.

2. Upper Extremity Motor Outcome Measures

2.1. Perform the Perdue Pegboard Test with the standard procedure[10].

2.2. Perform the Fugl-Meyer Assessment of Upper Extremity Motor (FMA-UE) using the standard procedure[11,12].

3. Psychosocial and cognitive-behavioral assessments

3.1.1. Have participants complete the following questionnaires using the online survey platform: Edinburg Handedness Inventory; a questionnaire for previous experience on the use of chopsticks.; and a self-efficacy questionnaire for the use of chopsticks.

4. Preparation of Goal-directed Arm Reaching Tasks

4.1. Prepare the motion capture camera system for kinematic recording.

4.1.1. Calibrate the motion capture camera using the motion capture workstation software.

4.1.2. Set the origin of the world coordinate using the motion capture workstation software.

4.1.3. Place all marker triads on a table in the field of view of motion capture cameras and check if all marker triads are within the field of view.

4.2. Prepare the motion capture data acquisition software to build the skeletal model.

4.2.1. Import the marker sets from the motion capture workstation software to the motion capture data acquisition software.

4.2.2. Activate virtual sensors (i.e., marker triads).

4.2.3. Set world axes.

4.2.4. Assign virtual sensors to body segments of the skeleton model.

4.3. Set up goal-directed arm reaching task conditions.

4.3.1. Place a table at the center of the motion capture cameras field of view.

4.3.2. Put the laminated goal-directed arm reaching template paper at the designated area on the table.

4.3.3. Prepare a pair of chopsticks on the table.

4.3.4. Prepare to play the auditory cue audio file.

4.3.5. Prepare the task instruction scripts.

4.3.6. Test the motion capture system to ensure it is working appropriately.

4.4. Set up the participant.

4.4.1. Attach the reflective marker triads to the skin of the participant’s arms, hands, and trunk. Use the following description for the marker triad locations:
A marker triad for the trunk: between medial borders of the scapulae
A marker triad for each upper arm: in the middle of the lateral surface of the upper arm
A marker triad for each forearm: in the middle of the dorsal surface of the forearm
A marker triad for each hand: in the middle of the dorsal surface of the 3rd metacarpal bone

4.4.2. Prepare a chopstick with a marker triad.

4.4.3. Place a marker triad on a table located center of the field of view of motion capture cameras.

4.4.4. Digitize the participant’s body segments using an upper extremity joints and trunk skeleton model that includes following landmarks using the motion capture data acquisition software:
Upper trunk: a spot between C7 and T1 vertebrae
Lower trunk: a spot between T12 and L1 vertebrae

Shoulder (glenohumeral joint), two spots equidistance from center of the head of humerus
Elbow: two spots on the medial and lateral elbow that are equidistant from the joint center
Wrist: two spots on the medial and lateral wrist that are equidistant from the joint center
Hand: the tip of the third phalanx of each hand

4.4.5. Digitize the tip of the chopstick with a marker triad using the motion capture data acquisition software.

4.4.6. Digitize the home position and target position using the marker triad located on the table using the motion capture data acquisition software.

5. Performance of Goal-directed Arm Reaching Tasks

5.1. Position the participant in a sitting position.

5.2. Ask the participant to reach forward without trunk movement, then locate the table to position the target at approximately 80% of the participant's maximum arm reaching distance.

5.3. Instruct the participant to maintain the upright trunk posture at the beginning of each task performance. There will be no restriction to the trunk movements during the task performance.

5.4. Instruct the participant how to use chopsticks using a Youtube video (https://youtu.be/2Bns2m5Bg4M) to standardize the way to use the chopsticks.

5.5. Perform the task condition 1 – Reaching and Pointing to a large target.

5.5.1. Instruct the participant to hold a chopstick with the dominant hand (non-disabled adults) or the paretic hand (stroke participants). The participant will place the tip of a chopstick touching at the center of the home position. Instruct the participant to maintain the upright trunk posture at the beginning.

5.5.2. Fixate the task condition template paper at the designated area on the table. The template paper includes two squares with a cross at the center of each square: one for the home position and the other one for the target area. For this task, the target square size is 1 x 1 cm^2. The target position is located 20 in front of the home position.

5.5.3. Describe the task instructions.

5.5.3.1. State the following: "The goal of this task is to reach and tap the target area with the chopstick's tip as quickly and accurately as possible. You will hold a chopstick with your right (or left) [indicate the performing hand]. Place the chopstick's tip on the home position [indicate the home position]. When you hear a 'GO' signal, reach and tap the target [indicate the target] with the chopstick's tip as quickly as possible. Try to tap the center of the target as much as you can. You will have three seconds to tap the target. I will give you a 'STOP' signal 3 seconds after the 'GO' signal. If you did not tap the target within 3 seconds, bring the chopstick's tip to the home position and wait for the next trial. You will perform ten trials with a 10-second break between trials. Do you have any questions? [Address any questions that the participant has, then proceed to familiarization trial] You will have three trials as a practice. [After the practice trials, proceed to the actual trials] Now, we will perform actual trials. Try to reach and tap as quickly as you can."

5.5.4. Play the auditory cue signal audio file with a computer to familiarize the participant with the cue.

5.5.5. Perform three familiarization trials.

5.5.6. Instruct the participant to be ready for the task performance. Ensure the participant fully understands the task performance procedure.

5.5.7. Start motion capture recording with the motion capture data acquisition software.

5.5.8. Play the auditory cue audio file with a computer.

5.5.9. Perform 10 trials.

5.5.10. Stop motion capture recording.

5.5.11. Take a 2-minute break.

5.6. Perform the task condition 2 – Reaching and Pointing to a small target.

5.6.1. Instruct the participant to hold a chopstick with the dominant hand (non-disabled adults) or the paretic hand (stroke participants). The participant will place the tip of a chopstick touching at the center of the home position. Ask the participant to maintain the upright trunk posture at the beginning.

5.6.2. Fixate the task condition template paper at the designated area on the table. For this task, the target square size is 0.3 X 0.3 cm^2. The target position is located 20 in front of the home position.

5.6.3. Describe the task instruction.

5.6.3.1. State the following: "The goal of this task is the same as the previous task: reach and tap with the chopstick's tip the target as quickly and accurately as you can. We will use a smaller target [indicate the target]. The instruction is the same as the previous task. When you hear a 'GO' signal, reach and tap the target [indicate the target] with the chopstick's tip as quickly as possible. Try to tap the center of the target as much as you can. Do you have any questions?

[Address any questions that the participant has, then proceed to familiarization trial] You will have three trials as a practice. [After the familiarization trials, proceed to the actual trials] Now, we will perform actual trials. Try to reach and tap as quickly as you can."

5.6.4. Play the auditory cue signal audio file with a computer to familiarize the participant with the cue.

5.6.5. Perform three familiarization trials.

5.6.6. Instruct participant to be ready for the task performance. Ensure the participant fully understands the task performance procedure.

5.6.7. Start motion capture recording with the motion capture data acquisition software.

5.6.8. Play the auditory cue audio file with a computer.

5.6.9. Perform 10 trials.

5.6.10. Stop motion capture recording.

5.6.11. Take a 2-minute break.

5.7. Perform the task condition 3 – Reaching and Picking up a large target object.

5.7.1. Instruct the participant to hold a pair of chopsticks with the dominant hand (non-disabled adults) or the paretic hand (stroke participants). The participant will place the tips of chopsticks touching at the center of the home position. Ask the participant to maintain upright trunk posture at the beginning.

5.7.2. Fixate the task condition template paper at the designated area on the table. For this task, the target object is a plastic cube 1 cm on edge. The target object is located 20 in front of the home position.

5.7.3. Place the target object on the target area.

5.7.4. Describe the task instructions.

5.7.4.1. State the following: "The goal of this task is to reach and pick up a plastic cube [indicate the cube] with a pair of chopsticks as quickly as possible, about an inch in height without dropping. You will hold a pair of chopsticks with your right (or left) [indicate the performing hand]. Place the chopsticks' tips on the home position [indicate the home position]. When you hear a 'GO' signal, reach and pick up the cube [indicate the target] with the chopsticks as quickly as you can, about an inch in height. You will have three seconds to pick up the target. I will give you a 'STOP' signal 3 seconds after the 'GO' signal. If you did not pick up the target within 3 seconds, bring the chopsticks' tips to the home position and wait for the next trial. You will perform ten trials with a 10-second break between trials. Do you have any questions? [Address any questions that the participant has, then proceed to familiarization trial] You will have three trials as a practice. [After the familiarization trials, proceed to the actual trials] Now, we will perform actual trials. Try to reach and pick up as quickly as you can."

5.7.5. Play the auditory cue signal audio file with a computer to familiarize the participant with the cue.

5.7.6. Perform three familiarization trials.

5.7.7. Instruct participant to be ready for the task performance. Ensure the participant fully understands the task performance procedure.

5.7.8. Start motion capture recording with the motion capture data acquisition software.

5.7.9. Play the auditory cue audio file with a computer.

5.7.10. Perform 10 trials.

5.7.11. Stop motion capture recording.

5.7.12. Take a 2-minute break.

5.8. Perform the task condition 4 – Reaching and Picking up a small target object.

5.8.1. Instruct the participant to hold a pair of chopsticks with the dominant hand (non-disabled adults) or the paretic hand (stroke participants). The participant will place the tips of chopsticks touching at the center of the home position. Ask the participant to maintain upright trunk posture at the beginning.

5.8.2. Fixate the task condition template paper at the designated area on the table. For this task, the target object is a plastic cube 0.3 cm on edge. The target object is located 20 in front of the home position.

5.8.3. Place the target object on the target area.

5.8.4. Describe the task instructions.

5.8.4.1. State the following: "The goal of this task is the same as the previous task: reach and pick up a plastic cube with a pair of chopsticks as quickly as you can. We will use a smaller plastic cube [indicate the target]. The instruction is the same as the previous task. When you hear a 'GO' signal, reach and pick up the cube [indicate the target] with chopsticks as quickly as possible. Do you have any questions? [Address any questions that the participant has, then proceed to familiarization trial] You will have three trials as a practice. [After the familiarization trials, proceed to the actual trials] Now, we will perform actual trials. Try to reach and tap as quickly as you can."

5.8.5. Play the auditory cue signal audio file with a computer to familiarize the participant with the cue.

5.8.6. Perform three familiarization trials.

5.8.7. Ask participant to be ready for the task performance. Make sure the participant fully understands the task performance procedure.

5.8.8. Start motion capture recording with the motion capture data acquisition software.

5.8.9. Play the auditory cue audio file with a computer.

5.8.10. Perform the actual 10 trials.

5.8.11. Stop motion capture recording.

5.8.12. Take a 2-minute break.

5.9. Perform the Intrinsic motivation inventory (IMI) for the use of chopsticks using online survey platform.

6. Kinematic data analysis

6.1. Export the data of the following landmarks from the motion capture data acquisition software. Export position data in the x-, y-, and z-axes as a text file for each task condition.

Tip of a chopstick
Home position on the table
Target position on the table
Hands
Elbow joints
Shoulder joints (glenohumeral joints)
Trunk (at C7)

6.2. Preprocess the kinematic data.

6.2.1. Use custom programming script to process the kinematic data.

6.2.2. Filter and smooth the raw position data using a 3rd order Butterworth low pass filter with a 3 Hz cutoff.

6.2.3. Calculate the resultant of x-, y-, and z-direction position of the performing hand.

6.3. Determine movement onset and offset of each goal-directed arm reach.

6.3.1. To determine the reaching movement onset and offset, use the tangential velocity (the first derivative of the position data) from the resultant of the 3-dimensional position of the performing hand.

6.3.2. Define movement onset as the first frame of the reach, where the tangential velocity is above 0.01 m/s.

6.3.3. Define movement offset as the last frame of the reach, where the tangential velocity is above 0.01 m/s.

6.3.4. Inspect the individual reaching movement onset and offset visually to ensure the onset and offset are correctly labeled.

6.4. Determine the peak velocity. The peak velocity is defined as the maximum tangential velocity amplitude of the trial that exceeds the amplitude of 0.2 m/s, and the time interval between 2 peaks must be at least 2 seconds[13].

6.5. Calculate kinematic variables of reaching movements.

6.5.1. Calculate movement duration (MD). Calculate the time difference between movement onset and offset[13].

6.5.2. Calculate peak velocity (PV). Calculate the highest velocity during each of the reaches.

6.5.3. Calculate absolute and relative time to peak velocity (TTPV and TTPV % of movement duration)[13].

6.5.3.1. Calculate the time difference between movement onset and peak velocity (absolute TTPV).

6.5.3.2. Calculate the percentage of TTPV relative to movement duration (relative TTPV).

6.5.4. Calculate log dimensionless jerk.

6.5.4.1. Calculate the third derivative from the resultant of the 3-dimensional position of the performing hand, then calculate the log dimensionless jerk of each arm reaching movement.

6.5.5. Calculate trunk displacement during goal-directed arm reaching movement[9,14].

6.5.5.1. Calculate the trunk displacement.

6.5.5.1.1. Calculate the distance difference of the trunk landmark between movement onset and offset. Use the following equation.

$$\sqrt{(Trunk_{X_k} - Trunk_{X_1})^2 + (Trunk_{Y_k} - Trunk_{Y_1})^2 + (Trunk_{Z_k} - Trunk_{Z_1})^2}$$

Where X, Y, and Z are the trunk landmark positions in x-, y-, and z-axis, respectively; 1 is the time frame at the reaching movement onset; k is the time frame at the reaching movement offset.

6.5.5.2. Calculate shoulder trajectory length.

6.5.5.2.1. Calculate the shoulder landmark's travel distance between arm reaching movement onset and offset. The shoulder landmark is a virtual landmark digitized from the motion capture data acquisition software using the upper extremity skeleton model. Use the following equation for the shoulder trajectory length calculation.

$$\sum_{t=1}^{k}\sqrt{(Shoulder_{X_{t+1}} - Shoulder_{X_t})^2 + (Shoulder_{Y_{t+1}} - Shoulder_{Y_t})^2 + (Shoulder_{Z_{t+1}} - Shoulder_{Z_t})^2}$$

Where X, Y,and Z are the positions of the shoulder landmark in x-, y-, and z-axis, respectively; t is the time frame; t=1 is the time frame at the reaching movement onset; t=k is the time frame at the reaching movement offset

REPRESENTATIVE RESULTS:

These results are preliminary data from two non-disabled young adults and two chronic stroke survivors with mild motor impairment (Fugl-Meyer Scores of these two participants were above 60 out of 66). Non-disabled participants were right-handed and performed the tasks with their right hand. Stroke participants were also right-handed before the stroke and both had right hemiparesis. They also performed the task with their right hand. These kinematic variables between populations and between target conditions were compared using the Wilcoxon signed-rank test.

Shoulder trajectory length is a more sensitive measure of trunk compensation during goal-directed arm reaches (**Figure 1**). The trunk displacement and shoulder trajectory length were compared to determine which variable would be more appropriate to represent trunk compensation during goal-directed arm reaches. There was no significant difference in trunk displacement between non-disabled adults and chronic stroke survivors in all four task conditions. However, there was a significantly greater shoulder trajectory length for chronic stroke survivors than non-disabled adults for reaching and picking up tasks.

Chronic stroke survivors had different kinematic characteristics of goal-directed arm reaches than non-disabled young adults across different task conditions (**Figure 2**). Chronic stroke survivors showed significantly slower (**Figure 2A & B**), more feedback-dependent (**Figure 2C**), and jerkier (**Figure 2D**) goal-directed arm reaches across four different task conditions compared to non-disabled adults. Further, chronic stroke survivors demonstrated significantly more trunk compensation than non-disabled adults during goal-directed arm reaches (**Figure 2E**).

Task complexity impacted kinematic variables of goal-directed arm reaching movement (Figure 2 & 3). Both non-disabled adults and chronic stroke survivors demonstrated slower, feedback-dependent, and jerkier goal-directed arm reaches for the more complex task requiring greater hand dexterity than the simple pointing task (**Figure 2**). There was no difference in shoulder trajectory length between two populations for the pointing tasks, while stroke survivors showed significantly greater shoulder trajectory length than non-disabled young adults for the picking up tasks (**Figure 2**). Further, motor performance had more variability across trials for the more complex task compared to the simper task (**Figure 3**).

FIGURE AND TABLE LEGENDS:

Figure 1. Comparison of two different kinematic measures of trunk compensation during goal-directed arm reaches. Green violin plots indicate the Shoulder Trajectory Length, and red violin plots show the Trunk Displacement.

Figure 2. Comparison of goal-directed arm reaching kinematics in different task conditions between non-disabled adults and chronic stroke survivors. (**A**) Movement duration. Red boxplots are data of chronic stroke participants, and blue boxplots are data of non-disabled adults. (**B**) Peak velocity amplitude. (**C**) Relative time to peak velocity. This variable is the time to peak velocity as a percentage of movement duration. (**D**) Log dimensionless jerk. This variable indicates the movement's smoothness. A higher negative value in this variable means a jerkier movement. (**E**) Shoulder trajectory length. This variable indicates the amount of trunk compensation during goal-directed arm reaches in all x-, y-, and z-directions.

Figure 3. Visualization of goal-directed arm reaching kinematics. (**A**) Goal-directed arm reaching performance of reach and point task with a large target. (**B**) Goal-directed arm reaching performance of reach and pick up task with a large object. Positions of shoulder, elbow, hand and tip of a chopstick landmarks are visualized with colored dots for all ten arm reaching trials for the task condition. Positions of those landmarks, arm, and hand at the movement onset and offset are highlighted in purple and orange, respectively.

DISCUSSION:

Preliminary results support that this protocol may be appropriate to investigate the impact of task complexity on trunk compensation and goal-directed arm reaching kinematics in both non-disabled adults and chronic stroke survivors.

These representative results also support that this protocol may be appropriate to determine the kinematic differences in goal-directed arm reaches between non-disabled adults and chronic stroke survivors. These findings are consistent with previous studies that characterized goal-directed arm reaches of chronic stroke survivors as slower, jerkier, and more feedback-based movements compared to non-disabled controls[9,13,14].

In this preliminary study, a fine hand motor task using a pair of chopsticks was employed. Picking up a small object using a pair of chopsticks requires a high level of hand dexterity[15,16]. This task has been used in previous studies to investigate brain function during the performance of fine hand motor tasks[15–17]. Further, the object pick-up task using a pair of chopsticks can also be used as an intervention for improving fine hand motor skills in neurologic populations[18–20]. These preliminary results support that post-stroke individuals with mild upper extremity motor impairment can perform the object pick-up task using a pair of chopsticks.

These representative results support the use of this protocol to investigate the impact of task complexity on movement strategies in both non-disabled adults and post-stroke individuals. A hypothesis that chronic stroke survivors will utilize more trunk compensation for a more complex motor task has been tested with two non-disabled adults and two chronic stroke survivors. Preliminary data analysis examined the reaching portion (transportation of the hand) of the motor task performance. These results support that people employ different goal-directed arm reaching movement strategies for different tasks. Specifically, both non-disabled individuals and chronic stroke survivors plan the movement differently when they have different task goals. For the reaching and pointing task, the end goal is to tap the target with the tip of a chopstick. On the other hand, the object pick-up task end goal is to manipulate the chopsticks to pick up the object accurately. Thus, the object pick-up task requires a more accurate endpoint of the chopstick tip. Increased demands for the endpoint position accuracy result in the participant moving more slowly to control the endpoint effector more precisely. Thus, it is theorized that participants relied more on feedback-based control of the goal-directed arm reaches for the object pick-up task compared to the pointing task. Further, using more trunk compensation for the object pick-up task than the pointing task could be a motor control strategy to improve the endpoint effector control accuracy by reducing degrees of freedom of the upper extremity.[1] Employing compensatory trunk movements reduces the necessity to control more complex degrees of freedom of the shoulder and elbow joints. In other words, increased trunk compensation during the performance of more complex motor tasks would increase the probability of the accomplishment of the task goal.

These preliminary results support that the shoulder trajectory length is a more sensitive measure of trunk compensation during goal-directed arm reaches in chronic stroke survivors. Although trunk displacement is the most common kinematic variable in the current literature, it has a significant limitation in representing trunk compensation during goal-directed arm reaches[9,14]. While the trunk displacement captures trunk flexion, trunk compensation during arm reaches can be accomplished by a combination of trunk flexion, rotation, and lateral flexion. These preliminary results showed more contrast in the shoulder trajectory length between non-disabled adults and chronic stroke survivors compared to the trunk displacement measure. Thus, this protocol proposes the shoulder trajectory length, which is the shoulder landmark's (lateral end of the clavicle) travel distance between arm reaching movement onset and offset, be reported to characterize compensatory trunk movement during goal-directed arm reaching performance. Future studies with larger sample size should be conducted to determine the properties of this novel trunk compensation measure.

Although our representative results support this protocol's utility, researchers should be cautious about using this protocol to investigate the relationship between task conditions and arm reaching movement kinematics in chronic stroke survivors. The object pick-up task using chopsticks would not be appropriate for chronic stroke survivors with moderate-to-severe upper extremity motor impairment as individuals with greater severity of hand fine motor impairment may have too much difficulty performing this task. Specifically, the smaller object used in this study was a plastic cube 3-mm on edge. Picking up this small object may be too difficult to perform for those who have severe hand motor impairment, even with their fingers. Alternatively, we suggest using a tweezer instead of chopsticks to perform the object pick-up task if this protocol were to be used for a research study with post-stroke individuals with more severe hand motor impairment. The object pick-up task using a tweezer has been used in previous studies.[18,19] The tweezer motor task requires similar level of hand dexterity for the chopstick motor task, but easier than the chopstick task, and it would be more feasible for post-stroke individuals with severe upper extremity motor impairment.[18]

The increased trunk compensation in the object pick-up task using chopsticks may be influenced by the novelty of the task to the participants, given that a motor control strategy for a new task is freezing some degrees of freedom and all of the participants in this preliminary study had no or little experience in the use of chopsticks[21]. The use of trunk movements is associated with reduced degrees of freedom in the shoulder and elbow joints. Thus, compensatory trunk movement during the object pick-up task may be utilized to reduce the degrees of freedom and make the reaching movement more controllable to accomplish the task goal. Therefore, increased trunk compensation in the object pick-up task compared to the pointing task may be related to the task's novelty to the participants.

Representative results are from a small number of participants. Thus, larger-scale clinical studies should be conducted to demonstrate this protocol's efficacy and utility to investigate the relationship between motor task conditions and movement strategies in chronic stroke survivors.

ACKNOWLEDGMENTS:
The authors wish to appreciate Christopher Neville, Girolamo Mammolito, and F. Jerome Pabulayan for their vital contributions to developing this protocol and data collection.

DISCLOSURES:
No disclosure.

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Figure 1

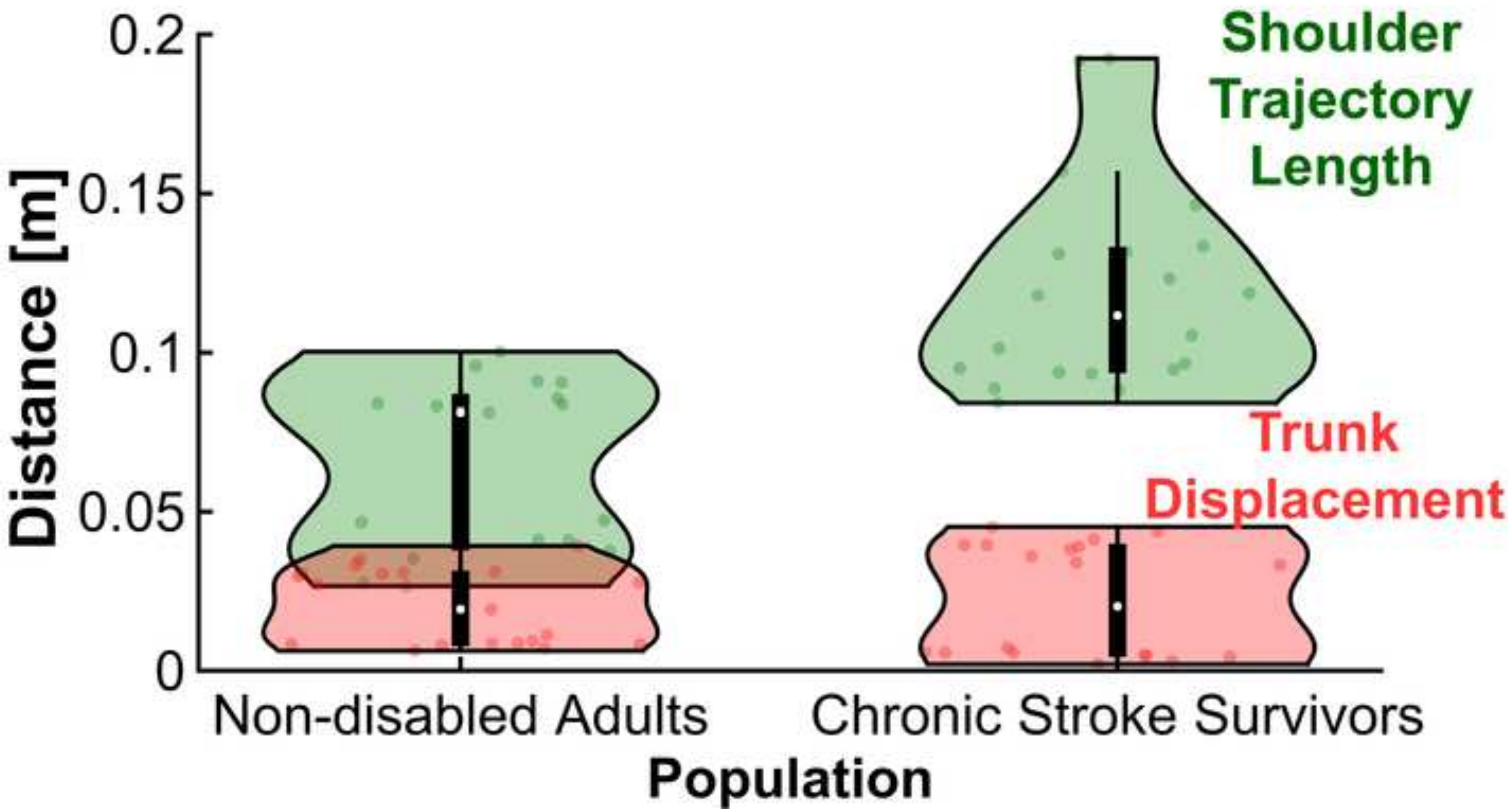

Shoulder Trajectory Length
Trunk Displacement
Distance [m]
0.2
0.15
0.1
0.05
0
Non-disabled Adults
Chronic Stroke Survivors
Population

Figure 2

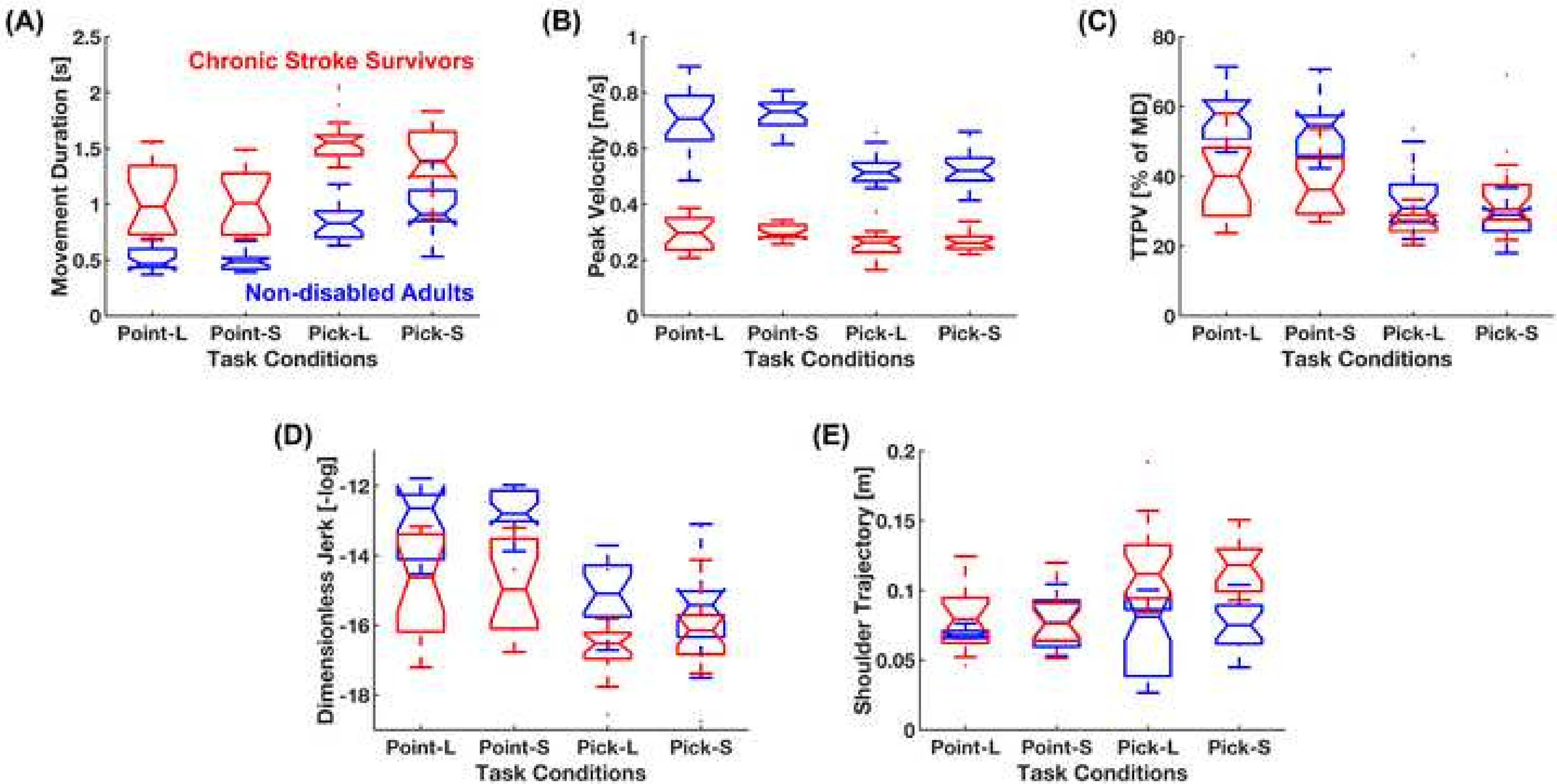
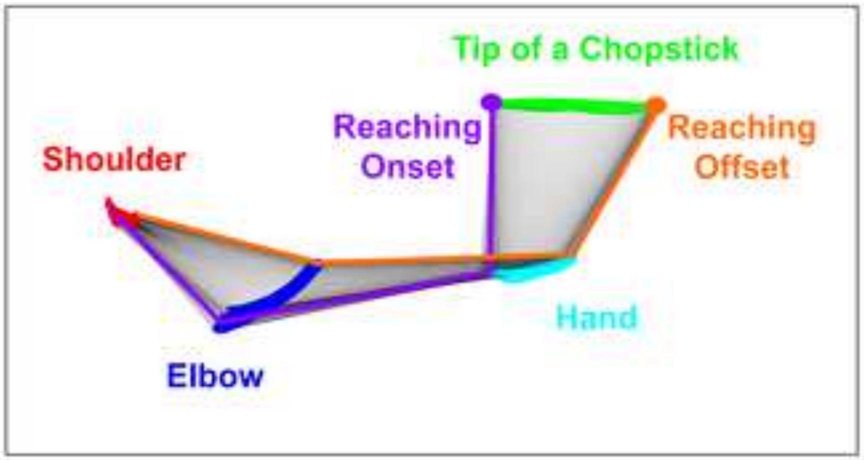

(A)
Movement Duration [s]
Chronic Stroke Survivors
Non-disabled Adults
0
0.5
1
1.5
2
2.5
Point-L
Point-S
Pick-L
Pick-S
Task Conditions
(B)
Peak Velocity [m/s]
0
0.2
0.4
0.6
0.8
1
Point-L
Point-S
Pick-L
Pick-S
Task Conditions
(C)
TTPV [% of MD]
0
20
40
60
80
Point-L
Point-S
Pick-L
Pick-S
Task Conditions
(D)
Dimensionless Jerk [-log]
-12
-14
-16
-18
Point-L
Point-S
Pick-L
Pick-S
Task Conditions
(E)
Shoulder Trajectory [m]
0
0.05
0.1
0.15
0.2
Point-L
Point-S
Pick-L
Pick-S
Task Conditions

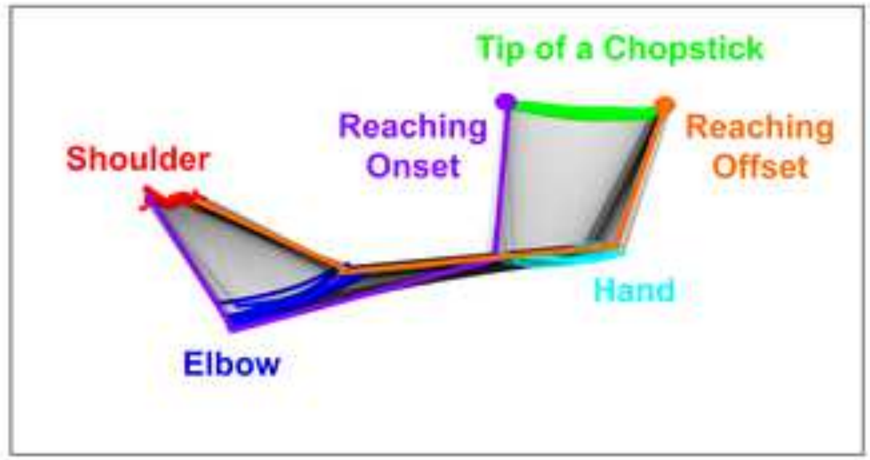
Figure 3

Click here to access/download;Figure;figure3.tif

(A) Reach and Point Task



(B) Reach and Pick Up Task



Name of Material/Equipment	Company	Catalog Number	Comments/Description
A pair of chopsticks	NA	NA	20 cm length, one chopstick had the passive motion capture markers (custom made)
Auditory cues for motor tasks	NA	NA	Custom made audio file are played on a smart phone
Matlab R2018b software	Mathworks		
MotionMonitor v 8.52 Software	Innovative Sports Training, Inc., Chicago, IL		
Perdue Pegboard Test			
Plastic cubes (0.3 cm on edge)	NA	NA	Custom made plastic cubes with 0.3 cm on edge. These were made using 3D printer
Plastic cubes (1cm on edge)	NA	NA	Custom made plastic cubes with 1 cm on edge. These were made using 3D printer
Template print	NA	NA	Custom made templates of the motor tasks, including home position, outlines of target positions.
Vicon 512 Motion-analysis System and Work station v5.2 software	OMG plc, Oxford, UK		

TO: Nam Nguyen, PhD

Manager of Review

JoVE

From: Bokkyu Kim

Assistant Professor

SUNY Upstate Medical University

SUBJECT: Revision of “The impact of motor task conditions on goal-directed arm reaching kinematics and trunk compensation in chronic stroke survivors.” Authors, Girnis J, Aga T, Sweet V, Nobiling T, and Kim B.

DATE: March 24, 2021

Dear Dr. Nguyen:

We are pleased to submit our fiftth revision of the protocol manuscript: *“*The impact of motor task conditions on goal-directed arm reaching kinematics and trunk compensation in chronic stroke survivors*”* by Girnis J, Agag T, Sweet V, Nobiling T, and Kim B for consideration in *Journal of Visualized Experiments (JoVE)*.

We have made changes in the video based on the editor’s comments. There is no change in the written manuscript for this revision. Please let us know if there is any revision needed for the written manuscript.

All correspondence in connection with this submission should be directed to the corresponding author: Bokkyu Kim.

Thank you, in advance, for your consideration of our submission.

Sincerely,

Bokkyu Kim
Assistant Professor of Physical Therapy Education
College of Health Professions
SUNY Upstate Medical University