BIOMECHANICAL JOINT DEMANDS AND FUNCTIONAL OUTCOMES DURING MANUAL WHEELCHAIR USE IN PEDIATRIC PATIENTS WITH SPINAL CORD INJURY

by

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ABSTRACT

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The University of Wisconsin-Milwaukee, 2014
Under the Supervision of Brooke A. Slavens, PhD

The biomechanical demands of the upper extremities (UEs) during pediatric manual wheelchair (MWC) use have not been fully explored. Children who use MWCs for mobility engage in a range of functional activities that may place large biomechanical demands on the UEs leading to a high risk on overuse injuries. This study aims to analyze the kinematics and kinetics of pediatric manual wheelchair use during propulsion, starting, stopping and weight relief tasks. Fourteen pediatric patients with spinal cord injury were recruited and data were collected using a 14-camera Vicon MX motion analysis system (Oxford Metric Group, Oxford, UK) and a SmartWheel system (Out-Front, Mesa, AZ). Additionally, pain and health-related quality of life outcomes were analyzed to identify correlations with kinematic and kinetic data. The weight relief task was found to be the most demanding, resulting in superior forces on the glenohumeral (GH) joint that were more than nine times greater during weight relief, 21.19 % body weight (BW) than during propulsion, 2.43 %BW. Stop task GH joint forces were higher in the inferior direction (9.68 %BW) and lower in the posterior direction (0.14 %BW) when compared to propulsion (6.85 %BW and 1.99 %BW respectively). Start task biomechanics were the least demanding with minimal statistical differences found from the demands of propulsion. Outcomes of pain were reported on the visual analog scale (VAS) with only one subject reporting an average daily pain of 15 on a scale of 0 to 100. Mean physical health scores (PCS) and mental health scores (MCS) from the Short-Form 12 Health Questionnaire (SF-12) were 44.3 and 56.3 respectively, indicating lower than normal physical health and higher than normal mental health in this population (norm=50). Clinical intervention is recommended to decrease the biomechanical demands of functional mobility through appropriate training methods to reduce the risk of UE overuse injuries.

I would like to dedicate this project to my amazing and supportive family and friends. Without your help I and encouragement I would not be where I am today.

To my mentors, Dr. Brooke Slavens and Alyssa Schnorenberg. Your dedication has been inspirational. To my husband Jesse, your love and support has been more than I could have ever asked for. Thank you.

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I. Introduction

An estimated 3.6 million individuals in the United States aged 15 years and older use a manual wheelchair for mobility (Brault, 2012). The physical demands of MWC propulsion put users at a high risk of developing musculoskeletal injuries. This thesis aims to quantify the upper extremity (UE) joint kinematics and kinetics of wheelchair propulsion and functional activities involved in pediatric manual wheelchair (MCW) use. The results of this study may help in the development of training programs, mobility device selection, and transitional care for pediatric patients.

Children who have sustained a spinal cord injury (SCI) may use a MWC for functional, home and community mobility. Functional mobility may include moving over various terrains, starting from a stationary position and stopping their wheelchair within a reasonable distance (Case-Smith & O'Brien, 2010). These activities require varying levels of physical ability, particularly in the upper extremities (UEs).

Statement of the problem

MWC propulsion is a highly repetitive task and results in a high force demand on and large range of motion (ROM) of the upper extremities (Slavens, Graf, Krzak, Vogel, & Harris, 2011)(Schnorenberg et al., 2014). This may lead to an increased risk of developing musculoskeletal conditions such as degenerative arthritis, carpal tunnel syndrome and shoulder impingement (Mercer et al., 2006) (Morrow, Hurd, Kaufman, & An, 2010). Secondary conditions may cause pain and restrict movement, interfering with the individual's ability to maintain independence in activities of daily living (ADLs) including mobility. Preventive measures and proper training of wheelchair use may reduce the risks associated with MWC mobility, thereby allowing users to continue using their devices for as long as possible.

There are a large number of studies that have been published investigating the biomechanics of adults MWC users (Boninger et al., 2004; Boninger, Baldwin, Cooper, Koontz, & Chan, 2000; Hurd, Morrow, Kaufman, & An, 2009; Koontz et al., 2005; Morrow, Hurd, Kaufman, & An, 2010; Morrow, Kaufman, & An, 2011) however, there is a large gap in the literature regarding pediatric MWC users.

Purpose

The primary purpose of this study is to quantify the upper extremity joint demands (range of motion, forces, and moments) required of a pediatric MWC user during functional mobility. This includes four functional tasks: 1) propulsion, 2) starting from a static position, 3) stopping from a steady state propulsion and 4) weight relief. Data obtained from this thesis may be used to establish differences in joint dynamics between adults and children in addition to determining the need for pediatric training protocols. Quantifying joint dynamics may also contribute to clinical knowledge, allowing for those who work with this population to make more informed decisions for device selection and use. Additionally, subjects will complete two validated outcomes assessment tools to measure pain and health-related quality of life (HRQoL). The results of these surveys will be analyzed along with biomechanical metrics to identify correlations. Identifying correlations of biomechanics to pain and HRQoL may aid clinicians in treatment planning and could also be used to determine the need for additional training and in-depth testing related to device use and risk of overuse injuries.

Hypothesis and aims. The following four hypotheses were formulated and addressed during this study.

H1: Range of motion in all UE joints will be larger during each functional task than during propulsion. ROM at the wrist, elbow and GH joints will be measured during MWC propulsion as well as during specific functional tasks: start, stop and weigh relief.

H2: Joint reaction forces and moments on the dominant-side UE joints will be higher during functional tasks when compared to propulsion. Peak forces and moments during each task will be calculated for wrist, elbow and GH joints in three dimensions for comparison.

H3: GH joint forces and moments will be higher than elbow or wrist forces for all tasks: propulsion, start, stop and weight relief.

H4: Subject-reported pain will show a positive correlation with joint biomechanics, while health-related quality of life outcomes will correlate inversely with joint biomechanics. Subjects will complete the visual analog scale (VAS) to quantify pain and the Short Form 12 Health Questionnaire (SF-12) to quantify outcomes of health-related quality of life.

Significance to occupational therapy. It is important for the clinician to consider the biomechanical risks of increased force demands, increased ROM and repetitive motion during manual propulsion as they may compromise long-term safety. It is especially important to identify risk factors early in order to delay or prevent secondary injuries and maintain independent mobility for as long as possible. A better understanding of joint dynamics, outcomes data, and their correlations to one another, may be used for developing treatment planning and choosing appropriate mobility devices and training programs for pediatric MWC users. Proper equipment and training may reduce the risks of long-term MWC use by reducing the ROM, force and moment demands on the UEs. Data gathered from this work may also help in determining the need for push activated power assist wheelchairs, powered wheelchairs and additional assistive technology for transitional care to increase function and independence and decrease risk of injury with not only children diagnosed with SCI, but all pediatric patients with orthopaedic impairments.

II. Literature Review

Spinal Cord Injury

Approximately 200,000 people in the United States are currently living with spinal cord injury (SCI) and an estimated 15 to 40 new cases per million people, or 12,000 to 20,000 new patients, sustain this type of injury each year ("Spinal Cord Injury (SCI): Fact Sheet," 2010). SCI often occurs as a result of an accidental injury or traumatic event and may result in physical limitations that can affect functional mobility. Studies have shown that trends in mechanisms of injury for pediatric patients with SCI differ from the adult population with children exhibiting better potential for neurological recovery (Parent, Mac-Thiong, Roy-Beaudry, Sosa, & Labelle, 2011). The two most common etiologies of SCI in the pediatric population are motor vehicle accidents and sports activities (Parent et al., 2011).

The potential for physical rehabilitation following a spinal cord injury is largely dependent on the level of injury. An injury at the C5 level and above will likely limit the person's ability to extend the elbow, making MWC use impractical (Pedretti, Pendleton, & Schultz-Krohn, 2013). Level C6 injuries and below may allow for flexion and extension at the elbow and GH joint as well as wrist extension, making independent MWC use possible (Pedretti et al., 2013).

The International Classification of Functioning (ICF) describes impairments associated with a particular condition, illness or disability by grouping them into the following domains: body functions, body structures, activity, participation, environmental factors and personal factors (Cieza et al., 2010). The ICF can be used as a mapping tool to describe these domains in the context of SCI as a population. Figure 1 shows the activities that are often affected by the physical limitations associated with SCI and illustrates how all other domains interact with each other, either directly or indirectly. Addressing an individual's mobility by reducing biomechanical demands can positively influence all domains.

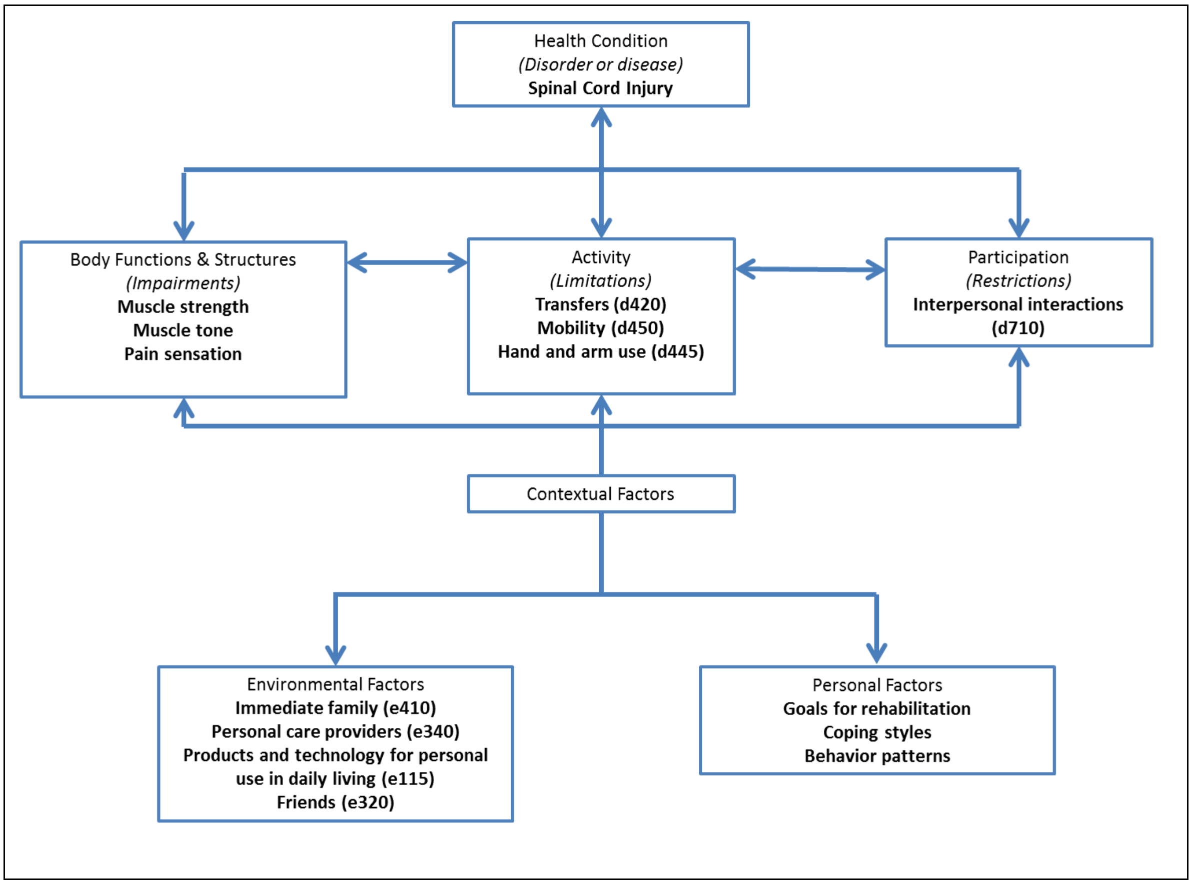


Figure 1: International Classification of Functioning (ICF) codes are given for each impairment description as they relate to the diagnosis of SCI (Hyung Seok Nam, 2012).

Pain

The visual analog scale (VAS) has been described as simple, quick and easy to use in assessing pain (Wewers & Lowe, 1990). While pain is difficult to quantify, as it is a multi-dimensional, subjective construct, assessment tools such as the VAS, numeric rating scale (NRS) (Farrar, Young Jr., LaMoreaux, Werth, & Poole, 2001) and faces scale (Bieri, Reeve, Champion, Addicoat, & Ziegler, 1990) all aim to quantify pain intensity. The VAS consists of a line diagram 100 mm in length while the NRS uses a scale of 0-10 or 0-100, with 0 being no pain at all and 10 or 100 being the worst pain one can imagine. The faces scale is similar to the NRS, but uses a series of faces to represent each number of pain intensity on the scale. The faces start out smiling and progress to crying at the highest level of pain.

The VAS is considered valid for children aged 8-17 (Bailey, Gravel, & Daoust, 2012). It is used clinically at Shriners Hospitals for Children - Chicago, making it easily accessible for this study.

Health-Related Quality of Life (HRQoL)

The Short Form 12 Health Questionnaire (SF-12) has been used clinically at Shriners Hospitals for Children - Chicago to assess HRQoL. It consists of 12 questions aimed at quantifying physical and mental health. While this tool was not originally developed for children, the questions, which can be seen in Appendix A, are certainly applicable to people of all ages. Other measures, such as the Pediatric Evaluation and Disability Inventory (PEDI), the Pediatric Outcomes Data Collection Instrument (PODCI), and the Child Health Questionnaire (CHQ), assess HRQoL. While these measures were developed specifically for the pediatric population, they are administered to parent or caregivers, raising questions of the true reliability of results (McCarthy et al., 2002). A study by White-Koning et al. (2007) concluded that parent proxy reports of both HRQoL and pain were not reliable and should only be used when no child self-report is available. In instances where self-report is not possible, assessments should be given to multiple parents, teachers or caregivers to obtain complementary information on the child's quality of life, making them impractical for the purposes of this study (McCarthy et al., 2002).

Biomechanical Analysis

A search of current literature has shown that while there are many studies that consider the biomechanics of MWC use, few are focused on pediatric participants (Koontz et al., 2005) (Petuskey, Bagley, Abdala, James, & Rab, 2007) (Rice, Gagnon, Gallagher, & Boninger, 2010)(Schnorenberg et al., 2014). A study by Jensen (1989) confirmed changes in force and moment curves due to differences in proportionality and a redistribution of mass that occurs with age (Jensen, 1989). Children are not physically proportionate to young adults or adults and we cannot assume that scaling the data will give an accurate picture of the true demands of propulsion. It is therefore important that current research focuses on the pediatric population to provide further insight into the unique biomechanics of young MWC users.

Additional studies have considered the efficacy of training programs in adult MWC use to reduce the forces and repetitive motion involved with propulsion. Many of these studies fail to adequately quantify the demands of propulsion as they consider only kinematics or kinetics and many do not address additional functional tasks. Training programs used in these studies are tailored to the needs of each participant and as a result are not well-defined, making them difficult to reproduce (Petuskey et al., 2007) (Rice et al., 2010).

A study done by Rice et al. (2010) quantified joint dynamics in adult MWC propulsion; however, the focus was on propulsion patterns, reaction forces at the hand rim, and ranges of motion (Rice et al., 2010). One study found that participant performance initially improved after training and showed a reduction in the forces at the hand rim used to propel a MWC; however, the changes were not sustained over time. This same study also found that a reduction in forces was correlated with an increase in cadence (strokes per minute), leaving room for an improvement in training methods (Rice et al, 2010). This study does not specify joint forces at the wrist, elbow or GH joint or address functional tasks such as start, stop or weight relief, suggesting that additional work is needed to explore the biomechanics of these everyday activities.

A study by Petuskey, et al. (2007) investigated upper extremity (UE) kinematics during functional activities with children. They were able to quantify the demands on the UE during everyday activities such as grooming, reaching up to a shelf, waving or throwing a ball. The participants were healthy with no musculoskeletal pathologies. The methods used provided range of motion (ROM) data, however, joint force was not measured leaving questions regarding the actual demands of each activity.

A study of adults diagnosed with SCI, multiple sclerosis or with an amputation by Koontz et al. (Koontz, Cooper, Boninger, Yang, Imp ink, & Van der Woude 2005) used a SmartWheel to quantify the three dimensional hand rim forces needed to travel across grass, travel across interlocking pavers, and perform a ramp ascent. They found that the three dimensional forces at the hand rim were typically higher during ramp assent, over interlocking pavers and over grass when compared to tile, wood and smooth level concrete. While these findings confirm that certain terrains require the MWC user to apply more force in propulsion, Koontz et al. did not report specific joint forces or kinematics. Another limitation of this study was that the participants were all over the age of 18. As previously discussed, Jensen (1989) has shown that there are differences in the biomechanics of children when compared to adults, therefore we cannot assume that findings from adult studies can be accurately generalized to the pediatric population (Jensen, 1989).

The mobility devices that have been developed as a result of studies done with adults cannot simply be scaled down to fit a pediatric client. Accurate joint biomechanics and outcomes data from pediatric patients is needed for treatment planning and the development of products to the fit the unique needs of children with disabilities.

III. Manuscript

Introduction

The 2010 United States Census reported an estimated 3.6 million individuals aged 15 years and older who use a manual wheelchair for mobility (Brault, 2012). These individuals are at a high risk of developing musculoskeletal injuries secondary to the physical demands of MWC propulsion (Bayley, Cochran, & Sledge, 1987; Curtis et al., 1999; Lin, Boninger, Worobey, Farrokhi, & Koontz, 2014; Wylie & Chakera, 1988).

Children who have sustained a spinal cord injury (SCI) may use a MWC for functional, home and community mobility. Functional mobility may include moving over various terrains, starting from a stationary position and stopping their wheelchair within a reasonable distance (Case-Smith & O'Brien, 2010). These activities may require varying levels of physical ability, particularly in the upper extremities (UEs).

The primary purpose of this study is to quantify upper extremity kinematics and kinetics of pediatric MWC use during functional mobility. This includes four functional tasks: 1) propulsion, 2) starting from a static position, 3) stopping from a steady state propulsion and 4) weight relief. We hypothesize that three dimensional ranges of motion, forces and moments in the wrist, elbow and glenohumeral (GH) joints would be larger during each functional task than during propulsion. Additionally, GH joint forces and moments will be higher than elbow or wrist forces and moments for each task.

Subjects will also complete two validated outcomes assessment tools to measure pain and health-related quality of life (HRQoL). We hypothesize that joint biomechanics will correlate positively with subject-reported pain while correlating negatively with HRQoL outcomes. Identifying these potential correlations may aid clinicians in treatment planning and could also be used to determine the need for additional training and in-depth testing related to device use and risk of overuse injuries.

Methods

Approval for this study was obtained from the Institutional Review Board (IRB) in accordance with the policies in place at the University of Wisconsin in Milwaukee, Marquette University and Shriners Hospital for Children-Chicago. Informed consent was obtained from each subject and their legal guardian (as appropriate) prior to data collection. Please see Appendices B and C for consent and assent forms.

Sample. Fourteen (14) pediatric manual wheelchair users, 9 male and 5 female, aged 6-20 years (mean age 13.7 years) participated in the study (Table 1). All subjects were diagnosed with a spinal cord injury (SCI) at least one year prior to participation. Subjects were recruited at Shriners Hospitals for Children - Chicago where data collection occurred in the Motion Analysis Laboratory. Subjects with other neurological conditions or those who had undergone orthopaedic surgery during the past year were excluded as these may further limit their mobility or ability to participate. Subjects with upper extremity joint contractures or who have received botulinum toxin type-A in the past 6 to 12 months were also excluded. The use of the SmartWheel (Out Front, Mesa, AZ) for this study required that each subject's wheelchair have a quick release axle in order to temporarily install the Smart Wheel for use during data collection.

Table 1

Subject Demographics

Subject #	Age (years)	Limb dominance	Gender	Height (cm)	Weight (kg)
1	11.1	Right	Male	177.8	24.4
2	17.3	Right	Male	169.9	63.8
3	16.8	Right	Male	183.1	63.8
4	11.8	Right	Male	128.9	58.5
5	20.9	Left	Female	167.6	51.1
6	19.5	Left	Male	193.0	93.0
7	7.2	Left	Male	121.9	26.5
8	6.5	Right	Male	119.4	28.5
9	10.2	Right	Female	121.9	24.0
10	16.6	Right	Male	133.1	31.6
11	18.9	Right	Male	178.3	76.0
12	14.5	Right	Female	139.7	42.5
13	13.0	Right	Female	153.4	44.0
14	7.8	Right	Female	118.1	22.6
Mean ± standard deviation	13.7 ± 4.8	---	---	150.4 ± 27.2	46.5 ± 22.1

Data Collection. Prior to biomechanical analysis, the VAS and SF-12 were administered. Pain outcomes were collected using the visual analog scale (VAS) (Figure 2). Subjects were asked to indicate their average daily pain level by marking it on the scale with a pen, or pointing, to indicate their rating. Results were recorded as the corresponding number from 0-100.

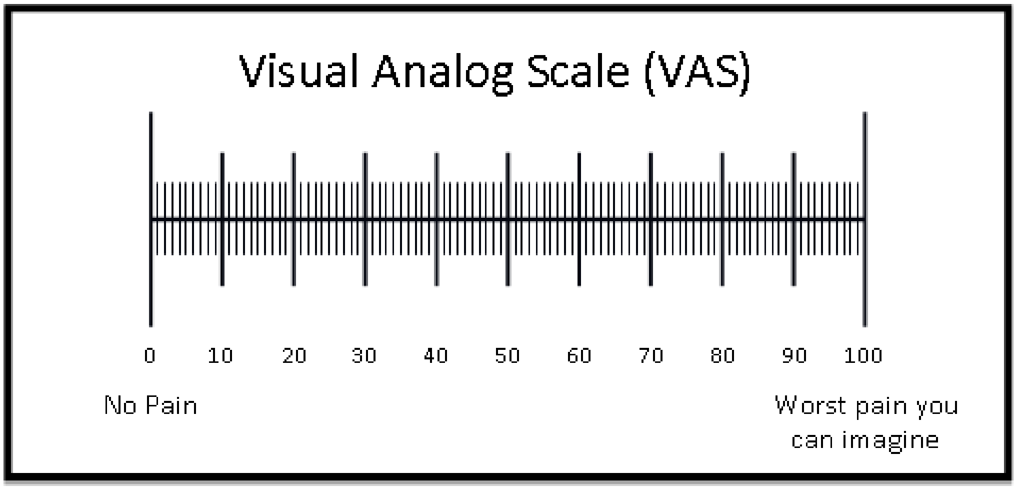


Figure 2: Visual analog scale (VAS) for pain (Wewers & Lowe, 1990). Subjects were asked to mark their average daily pain with 0 being no pain at all and 100 being the worst pain you can imagine.

Health-related quality of life (HRQoL) was assessed using the Short-Form 12 Health Questionnaire (SF-12) v2 (Optum, Eden Prairie, MN). Subjects were asked to respond to each of the 12 questions using the form provided. The 12 items on the questionnaire encompass the following domains in determining overall scores: general health, physical functioning, role functioning (physical), role functioning (emotional), bodily pain, vitality, mental health and social functioning (Utah Department of Health, 2001).

Subject’s anthropometric measurements were recorded prior to data collection to determine upper extremity segment length and circumference as well as subject height and weight. Protocol and data collection forms can be found in Appendix E: Protocols and Checklists.

A previously published custom pediatric model and marker set proposed by Schnorenberg et al. (2014) was used to acquire motion analysis data (Figure 3). This model used strategic marker placement and incorporated equations for segmental parameters proposed by Jensen (1989) to allow for a more accurate calculation of kinematic and kinetic data (Schnorenberg et al., 2014). Reflective markers were applied to each subject and to their manual wheelchair for reference.

Kinematic and kinetic data were collected using a 14-camera Vicon MX motion analysis system (Oxford Metric Group, Oxford, UK) and a SmartWheel system (Out-Front, Mesa, AZ), respectively, during propulsion and functional mobility. The SmartWheel is installed on the subjects' dominant side and senses three-dimensional force and torque and wirelessly sends the data to laptop. Each system was calibrated before data collection began and a static baseline trial was conducted. Biomechanical data was collected using SmartWheel at 240 Hz and the Vicon motion analysis system at 120 Hz. Data collection between the two systems was synchronized at the beginning of each trial.

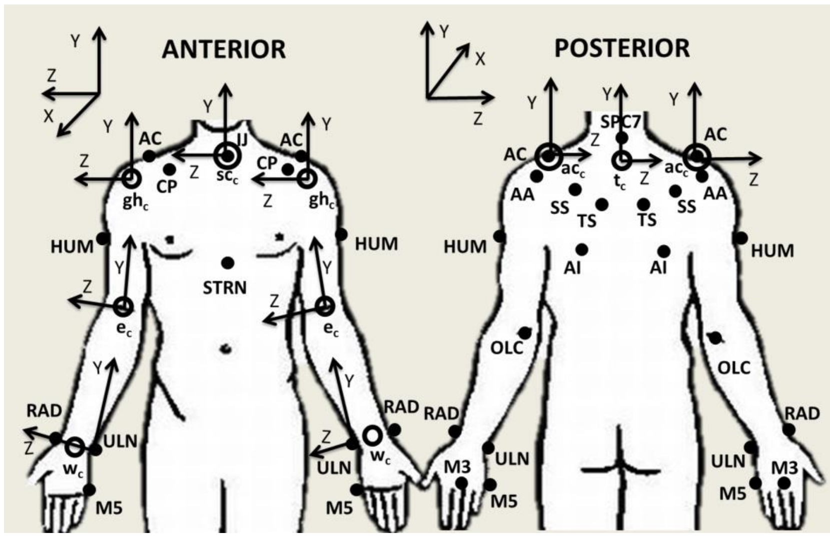


Figure 3: Upper extremity marker set used in biomechanical analysis (Schnorenberg et al., 2014).Figure used with the permission of Elsevier Limited, 2014.

Subjects propelled their wheelchair along a 15 meter walkway to simulate the demands of propulsion in the home and community. A self-selected speed and self-selected propulsion pattern was used over a hard, level tile floor. Subjects were allowed to acclimate to each activity for a self-selected period of time before multiple trials were conducted giving them sufficient time to adjust to a new task.

Propulsion. Propulsion trials were conducted first. Subjects were asked to propel their MWC across the room while staying on a colored walkway in the center of the capture volume. Subjects were allowed to rest between trials as needed.

Start task. Subjects began this task in the center of the capture volume in a static position. They were asked to begin to propel themselves to the end of the capture volume at the far side of the room. Three trials were collected for this task.

Stop task. The stop task began with the subject outside of the capture volume. They were then asked to propel themselves into the room and to stop when they reached the center of the room. Three trials stopping trials were collected for each subject.

Weight relief. Subjects also completed two weight relief push-ups for approximately two seconds each while seated in their wheelchair with their hands on the hand rim. Many subjects demonstrated difficulty with fully extending their elbows to complete this maneuver and were unable to hold the pose for a full two seconds. These subjects were instructed to complete the task to the best of their ability.

Data analysis. Data was analyzed and reported using MATLAB (Math Works, Natick, Massachusetts), Microsoft Excel (Microsoft, Redmond, WA) and R 3.1.0 (University of Auckland). The UE inverse dynamics model developed by Schnorenberg et al. (2014) was used to calculate joint angles, forces and moments. All data was normalized to percent stroke cycle and kinetic data were down sampled to allow for processing and analysis.

Forces for all tasks were normalized to percent body weight (%BW) and moments were normalized to percent body weight times height (%BWxH). Direction of internal joint forces are defined in Figure 5. Number of trials analyzed for each task varied due to limitations encountered during data collection.

Propulsion. Complete stroke cycles from within each propulsion trial were identified according to the manual wheelchair stroke cycle determination proposed by

Kwarciak et al. (2009) with the cycle beginning and ending with hand contact with the hand rim (Kwarciak et al., 2009). Hand rim contact was objectively identified using kinetic data from the SmartWheel and a force threshold. Ten stroke cycles per subject were analyzed and mean ROM, mean peak forces and mean peak moments were identified for the wrist, elbow and GH joints in all three planes of movement. Propulsion patterns found to be used during steady state propulsion were identified according to Boninger et al. (2004) and are reported in Figure 4.

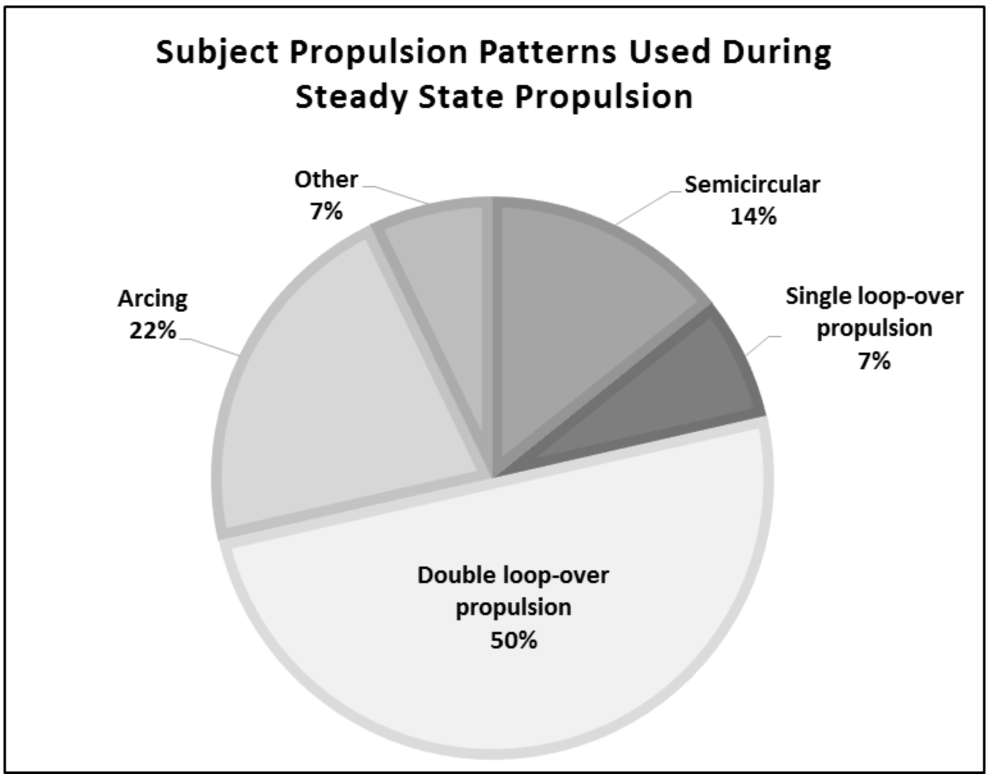


Figure 4: Self-selected propulsion patterns exhibited by each subject were identified according to Boninger et al. (2004).

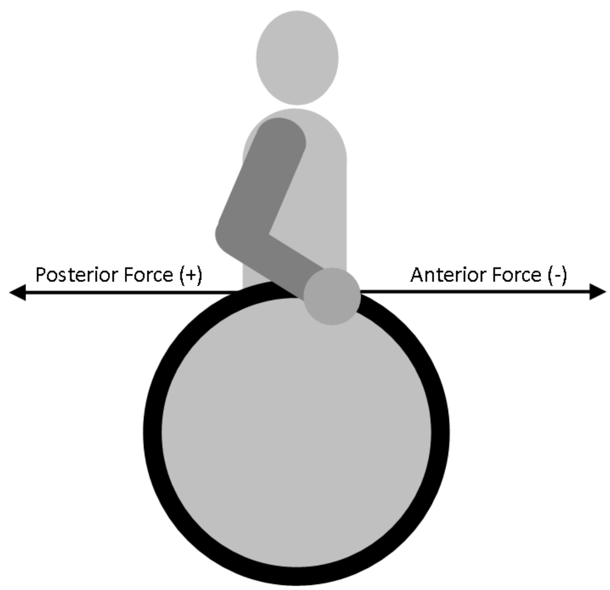
Start task. Stroke cycles during the start tasks were also identified according to Kwarciak et al. (2009). The initial stroke was analyzed for each subject for three trials and mean ROM, mean peak forces and mean peak moments for the wrist, elbow and GH joints in all three planes of movement were recorded.

Stop task. The stop task was defined as the last stroke cycle to occur as the subject came to a stop. The stopping stroke cycle was identified as the point at which the subject's hand came into contact with the SmartWheel hand rim to the point when the braking moment fell below or very close to zero. Three stopping stroke cycles were analyzed for each subject. Mean ROM, mean peak forces and mean peak moments were calculated at the wrist, elbow and GH joints in all three planes of motion.

Weight relief task. The beginning and ending of the weight relief tasks were visually identified due to limitations in the data collection process. Ranges of motion and mean three dimensional peak forces and moments were identified at the wrist, elbow and GH joints for two trials per subject. Data collected for subjects who were unable to complete the task for a full two seconds were analyzed in the same way and are considered to be acceptable as peak forces and moments were found to be within the lifting portion of the task.

A one-way Analysis of Variance (ANOVA) with linear mixed model (LMM) analysis was performed using R 3.1.0 (University of Auckland) to compare biomechanical outcomes at the wrist, elbow and GH joints during propulsion, start, stop and weight relief tasks (Portney & Watkins, 2008). A Pearson correlation to compare three dimensional forces and moments to HRQoL was also performed using R 3.1.0 (University of Auckland) (Portney & Watkins, 2008).

Health-related quality of life. Results were analyzed using the scoring algorithm and interpretation guide provided by the developers of the tool. The SF-12 reports a physical composite score (PCS) and a mental health composite score (MCS) on a scale of 0-100, with the average score for healthy individuals being 50 (Utah Department of Health, 2001).



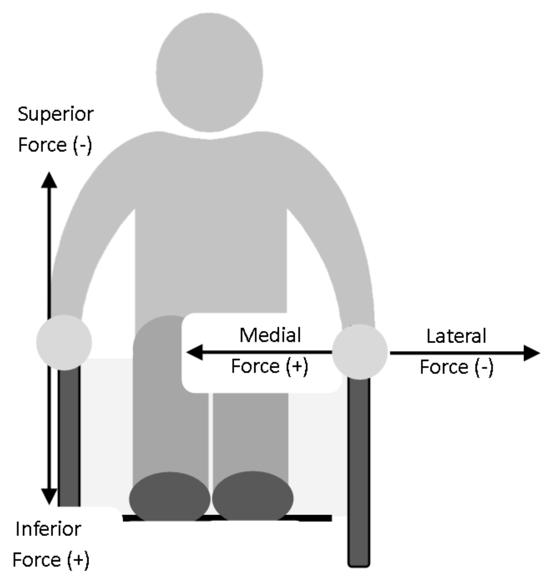


Figure 5: Direction of internal forces for wrist, elbow and GH joints are shown in relation to an individual using a manual wheelchair. Internal joint force is described as the force acting on the joint while external joint force is the interaction of the joint with the environment external to the body.

Results

Overall peak ranges of motion were found at the elbow in pronation and supination during the weight relief task (76.71 deg ± 38.04) and at the GH joint in flexion and extension during propulsion (48.43 deg ± 13.51). The largest forces of 26.26 %BW ± 14.13 and 24.50 ± 14.20 were found at the wrist and elbow respectively in the superior direction during the weight relief task. Peak moments also occurred during weight relief in extension at the wrist (3.19 %BWxH ± 1.62) and elbow (3.30 %BWxH ± 2.13)

Hypothesis one. Ranges of motion were expected to be greater during start, stop and weight relief tasks when compared to propulsion. Only dominant limb kinematics are reported here for consistency as there are no data for non-dominant kinetics due to the use of one SmartWheel. No significant difference in ROM from propulsion to the start task was found. ROM during the stop task was found to be significantly less than during propulsion in all joints and all planes of motion ($p < 0.01$). When comparing propulsion to weight relief, higher ranges of motion were found at the elbow in all planes of motion and at the wrist and GH joints in internal/external rotation. Lower ranges of motion during weight relief were found at the wrist in ulnar/radial deviation and flexion/extension and at the GH joint in pronation/supination and flexion/extension (Table 2).

Table 2

Mean Peak Ranges of Motion in Dominant Limb across Functional Activities

		Mean ROM (degrees)			
Joint	Direction of Movement	Propulsion	Start	Stop	Weight Relief
Wrist	Ulnar/Radial Deviation	29.80 ± 11.38	33.36 ± 10.39	11.18 ± 12.37**	20.56 ± 7.81**
	Internal/External Rotation	9.94 ± 4.73	9.47 ± 3.58	2.15 ± 2.48**	11.82 ± 4.66
	Flexion/Extension	40.73 ± 18.18	43.91 ± 17.18	17.76 ± 18.89**	25.80 ± 12.43**
Elbow	Medial/Lateral	Movement anatomically constrained			
	Pronation/Supination	40.02 ± 16.16	41.34 ± 14.65	21.97 ± 14.59**	76.71 ± 38.04**
	Flexion/Extension	25.53 ± 7.53	27.50 ± 7.28	12.32 ± 9.03**	30.6 ± 9.51*
GH	Adduction/Abduction	23.66 ± 11.43	21.21 ± 8.23	7.96 ± 6.05**	14.67 ± 5.23**
	Internal/External Rotation	37.17 ± 19.96	33.48 ± 15.29	14.75 ± 11.23**	73.56 ± 37.16**
	Flexion/Extension	48.43 ± 13.51	44.49 ± 13.46	15.97 ± 13.02**	32.80 ± 8.00**

Mean ranges of motion (ROM) ± standard deviation in the wrist, elbow and glenohumeral (GH) joints across all subjects during propulsion with comparison to each functional task: start, stop and weight relief.

* = p < 0.05 , ** = p < 0.01

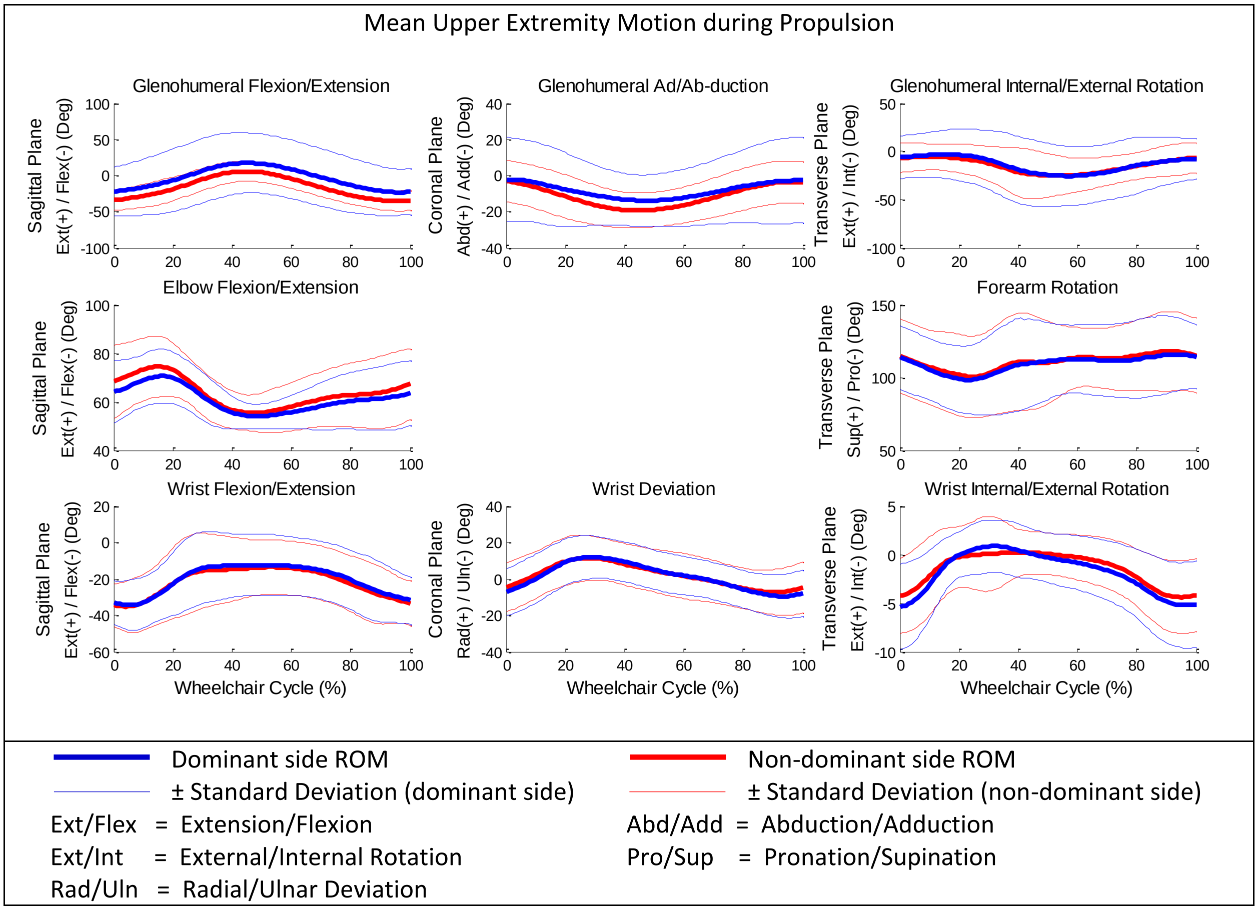


Figure 6: Mean upper extremity motion, reported in degrees (deg), during steady state propulsion are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

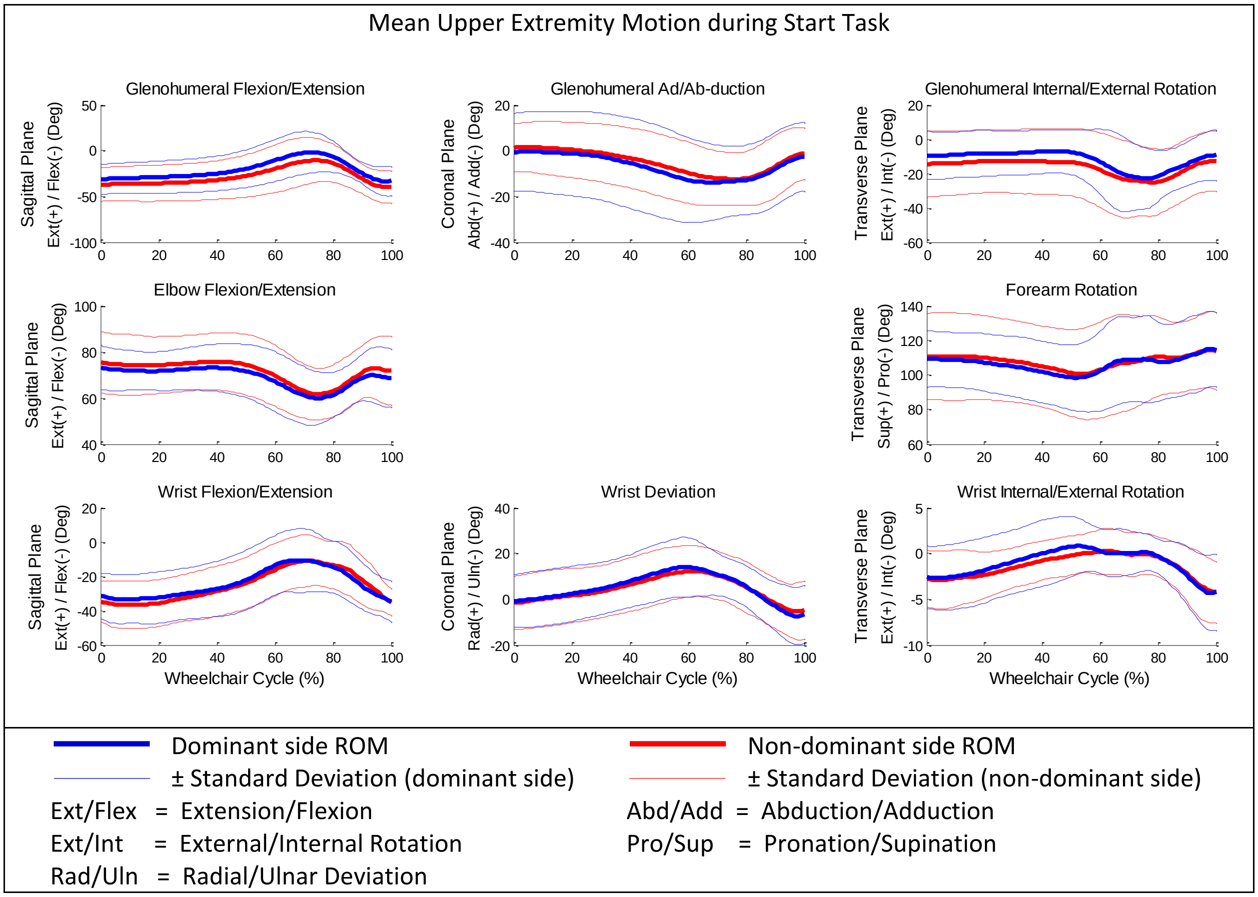


Figure 7: Mean upper extremity motion, reported in degrees (deg), during start task are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

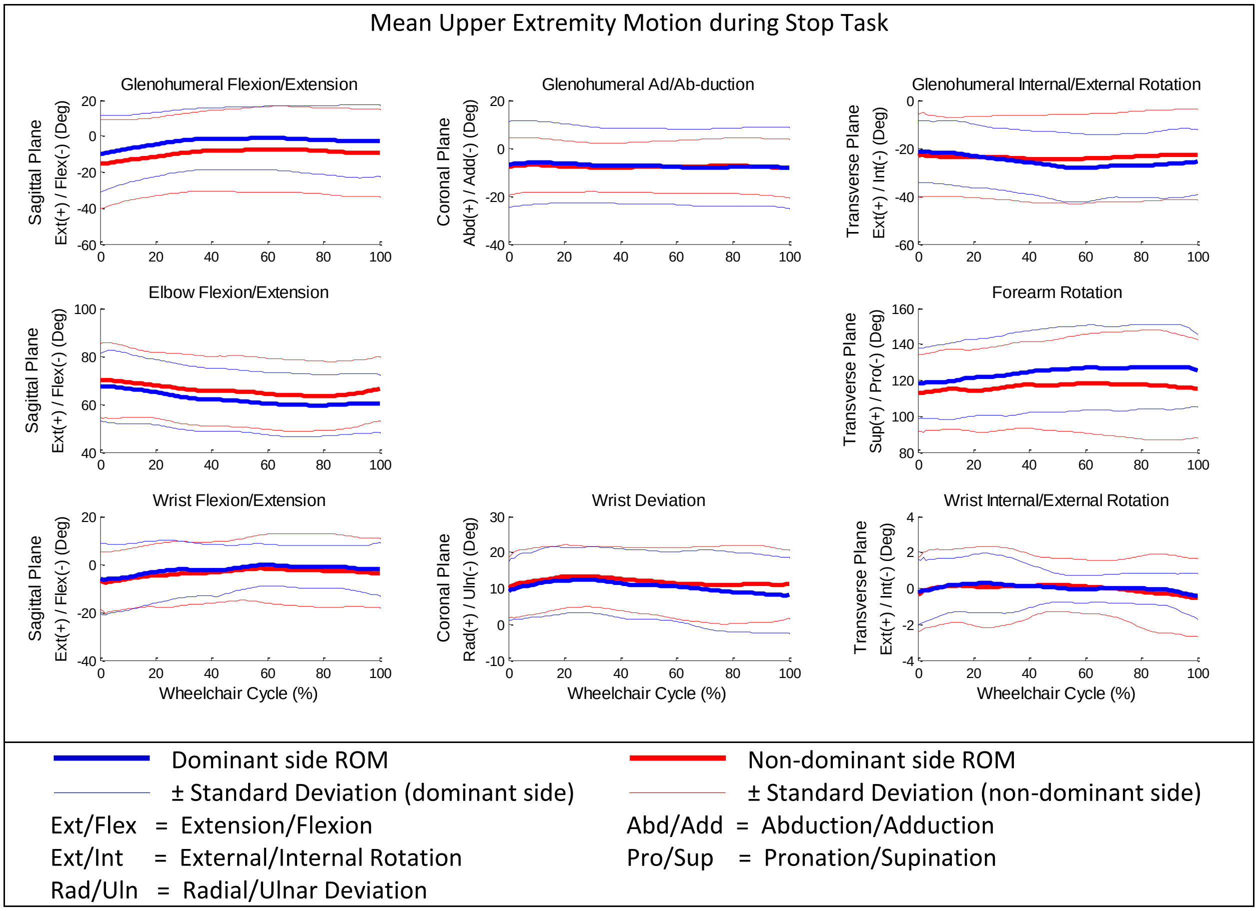


Figure 8: Mean upper extremity motion, reported in degrees (deg), during stop task are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

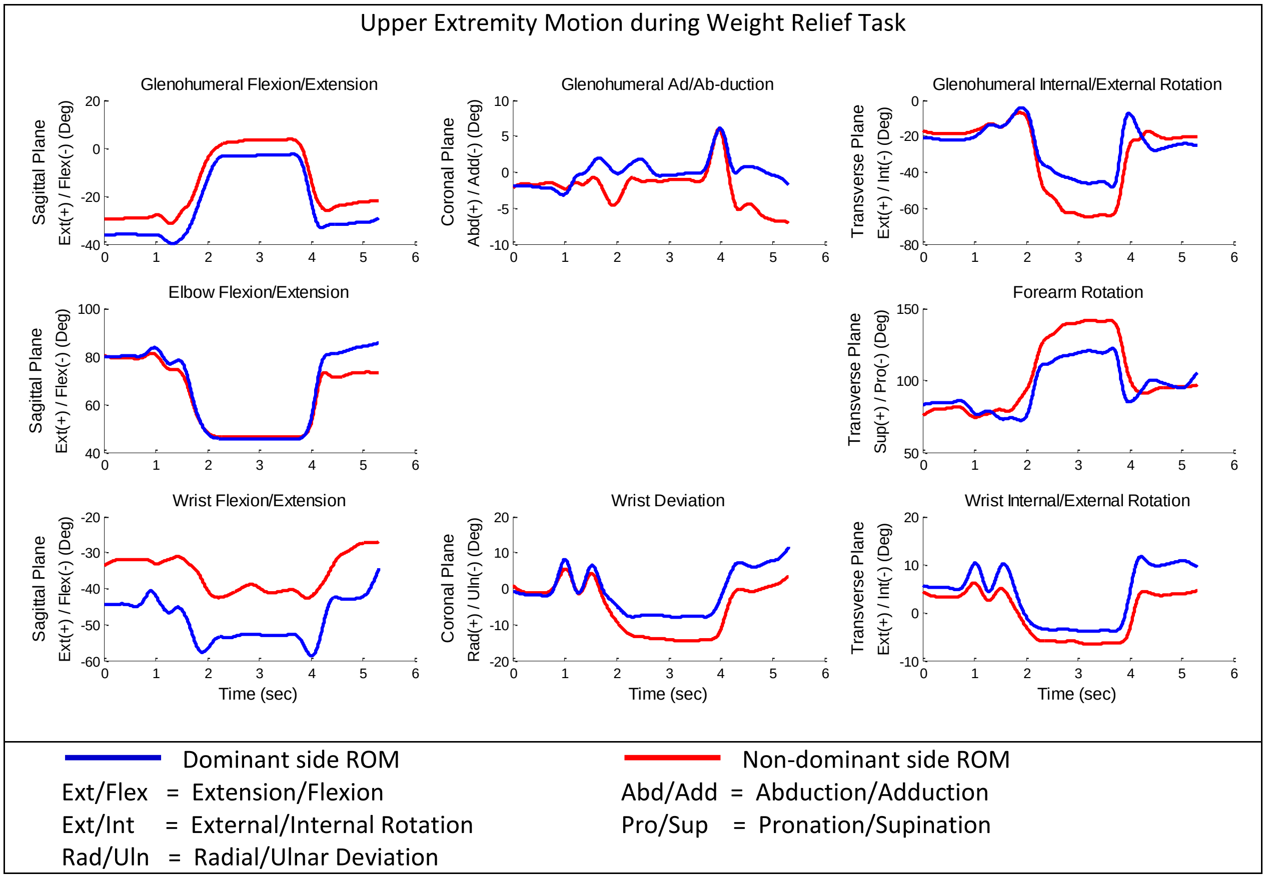


Figure 9: Upper extremity motion, reported in degrees (deg), during stop task are shown for glenohumeral, elbow and wrist joints in three dimensions for a representative trial.

Hypothesis two. Joint forces and moments during propulsion were predicted to be lower than during start, stop and weight relief tasks across all joints and in all directions.

Forces. Mean peak joint forces during propulsion (Table 3) were found to be similar to those during the start task with the exception of significantly higher forces in the medial and superior directions at the wrist. Forces during the stop task, compared to propulsion, were significantly higher in the inferior direction at all three joints. Stop task forces were significantly lower than propulsion forces in the inferior direction at the elbow and in both the medial and lateral directions at the wrist and GH joints. Weight relief forces were significantly higher in nearly all directions at each joint.

Table 3

Mean Peak Joint Forces in Dominant Limb across Functional Activities

		Propulsion		Start		Stop		Weight Relief	
Joint	Direction of Force	Max (%BW)	Min (%BW)	Max (%BW)	Min (%BW)	Max (%BW)	Min (%BW)	Max (%BW)	Min (%BW)
Wrist	Posterior (+)/ Anterior (-)	4.67 ± 3.57	-2.16 ± 1.67	5.56 ± 4.44	-3.49 ± 3.91	2.33 ± 3.42	-1.96 ± 2.38	12.03 ± 12.96**	-7.51 ± 12.35**
	Inferior (+)/ Superior (-)	1.84 ± 0.81	-5.28 ± 4.24	2.04 ± 1.25	-8.30 ± 5.86*	6.04 ± 5.18**	0.25 ± 2.01**	2.22 ± 1.32	-26.26 ± 14.13**
	Medial (+)/ Lateral (-)	3.11 ± 2.71	-2.56 ± 2.27	5.00 ± 4.90*	-2.33 ± 2.07	1.57 ± 1.79	-1.46 ± 1.57**	10.19 ± 5.16**	-1.19 ± 1.28**
Elbow	Posterior (+)/ Anterior (-)	3.16 ± 2.35	-3.42 ± 2.32	3.71 ± 3.22	-5.00 ± 4.69	1.43 ± 3.41	-2.95 ± 2.36	12.03 ± 12.94 **	-7.56 ± 12.34**
	Inferior (+)/ Superior (-)	4.06 ± 1.10	-4.89 ± 4.06	4.49 ± 1.22	-7.90 ± 5.79*	6.88 ± 5.26**	0.75 ± 2.95**	4.02 ± 1.27	-24.50 ± 14.20**
	Medial (+)/ Lateral (-)	3.82 ± 2.84	-3.34 ± 1.88	5.25 ± 4.75*	-3.17 ± 2.11	2.48 ± 2.36*	-0.97 ± 1.93**	10.17 ± 5.16**	-1.17 ± 1.30**
GH	Posterior (+)/ Anterior (-)	1.99 ± 3.29	-6.65 ± 2.14	3.07 ± 4.29	-8.21 ± 3.54	0.14 ± 3.53	-4.48 ± 2.65	12.01 ± 12.95**	-7.65 ± 12.31
	Inferior (+)/ Superior (-)	6.85 ± 1.53	-2.43 ± 3.78	6.74 ± 1.50	-4.59 ± 5.31	9.68 ± 4.89**	3.70 ± 2.10**	7.40 ± 1.30	-21.19 ± 14.35**
	Medial (+)/ Lateral (-)	4.79 ± 2.74	-2.72 ± 1.80	6.59 ± 4.62**	-2.21 ± 2.02	2.45 ± 2.18**	-1.12 ± 1.73**	10.16 ± 5.16**	-1.19 ± 1.31**

Mean peak joint forces ± standard deviation reported as percent body weight (%BW) in the wrist, elbow and glenohumeral (GH) joints across all subjects during propulsion with comparison to each functional task: start, stop and weight relief.

* = p < 0.05 ** = p < 0.01

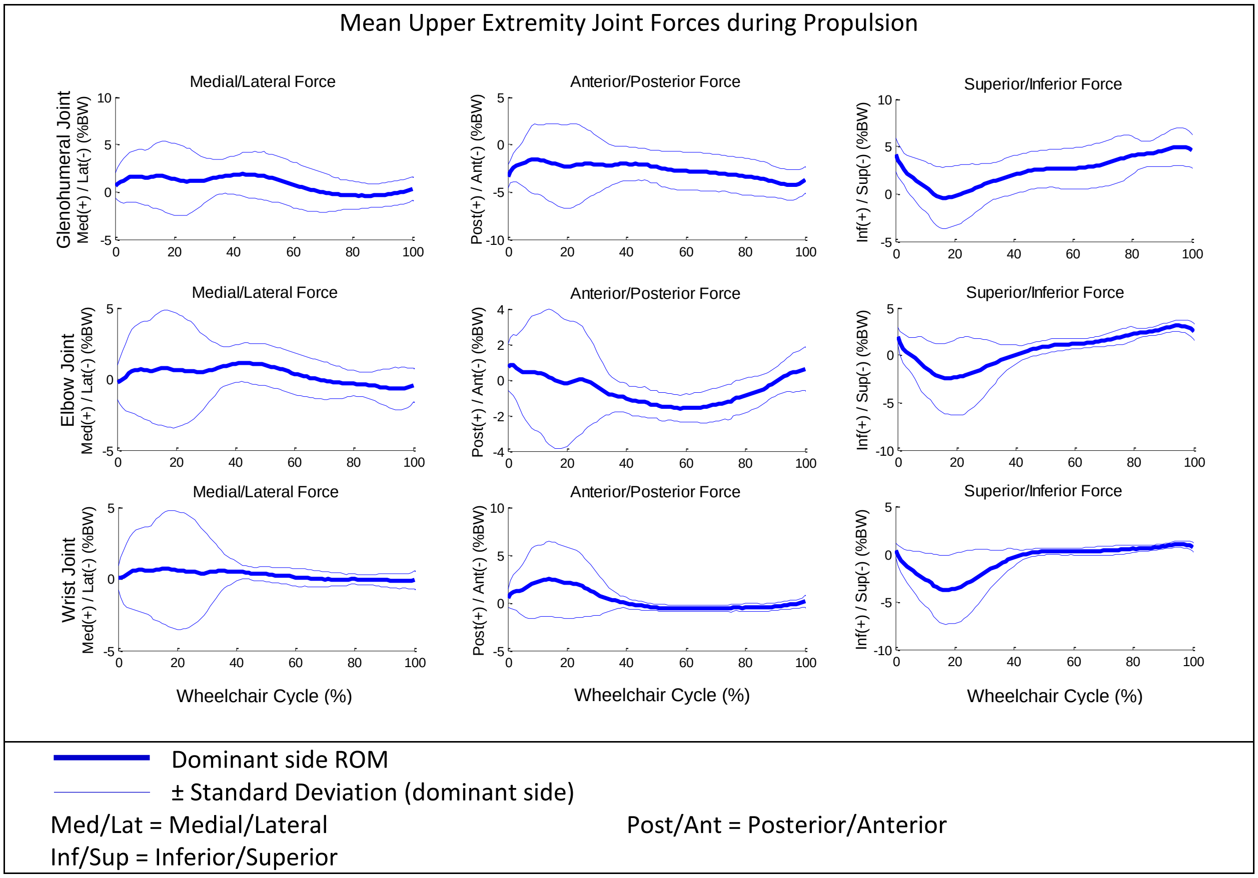


Figure 10: Mean upper extremity joint forces, reported as % body weight (%BW), during steady state propulsion are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

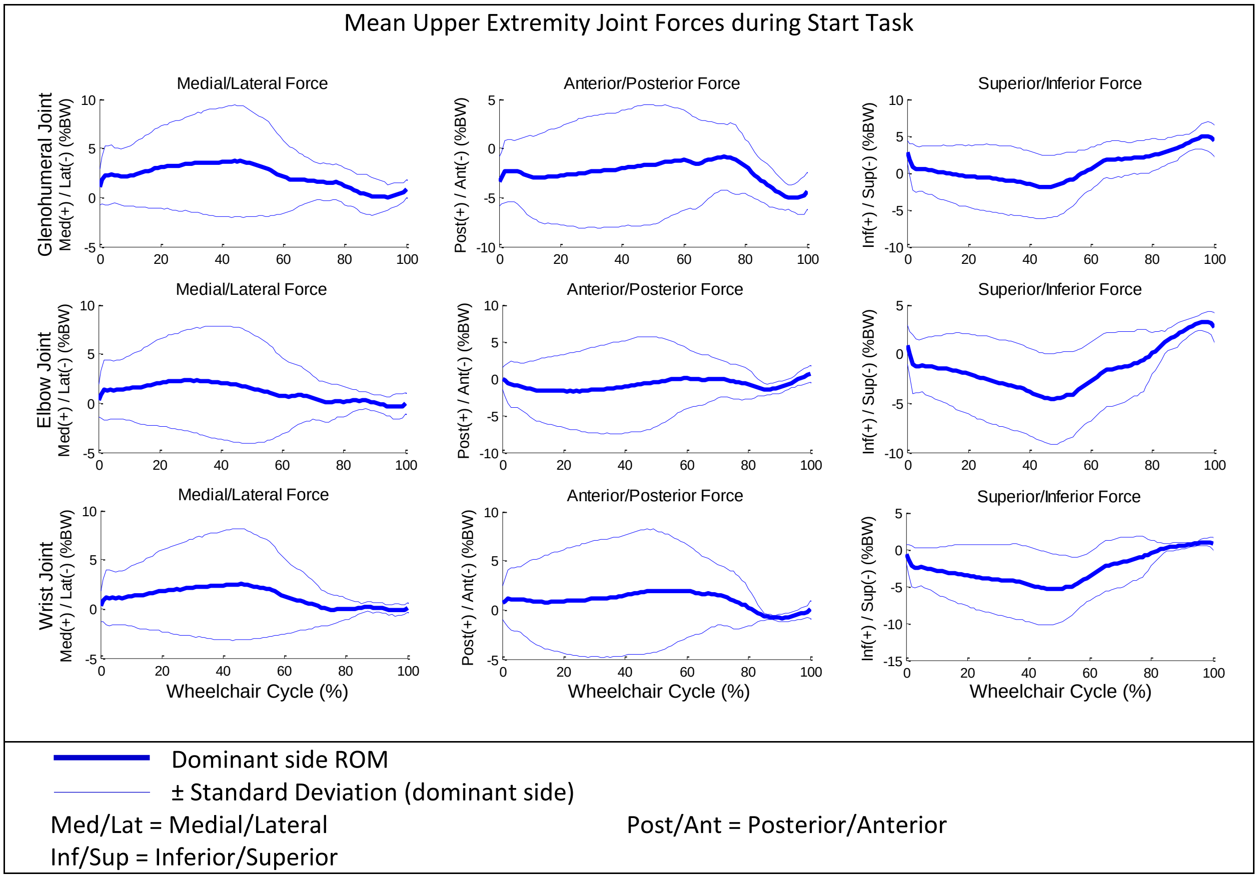


Figure 11: Mean upper extremity joint forces, reported as % body weight (%BW), during start task are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

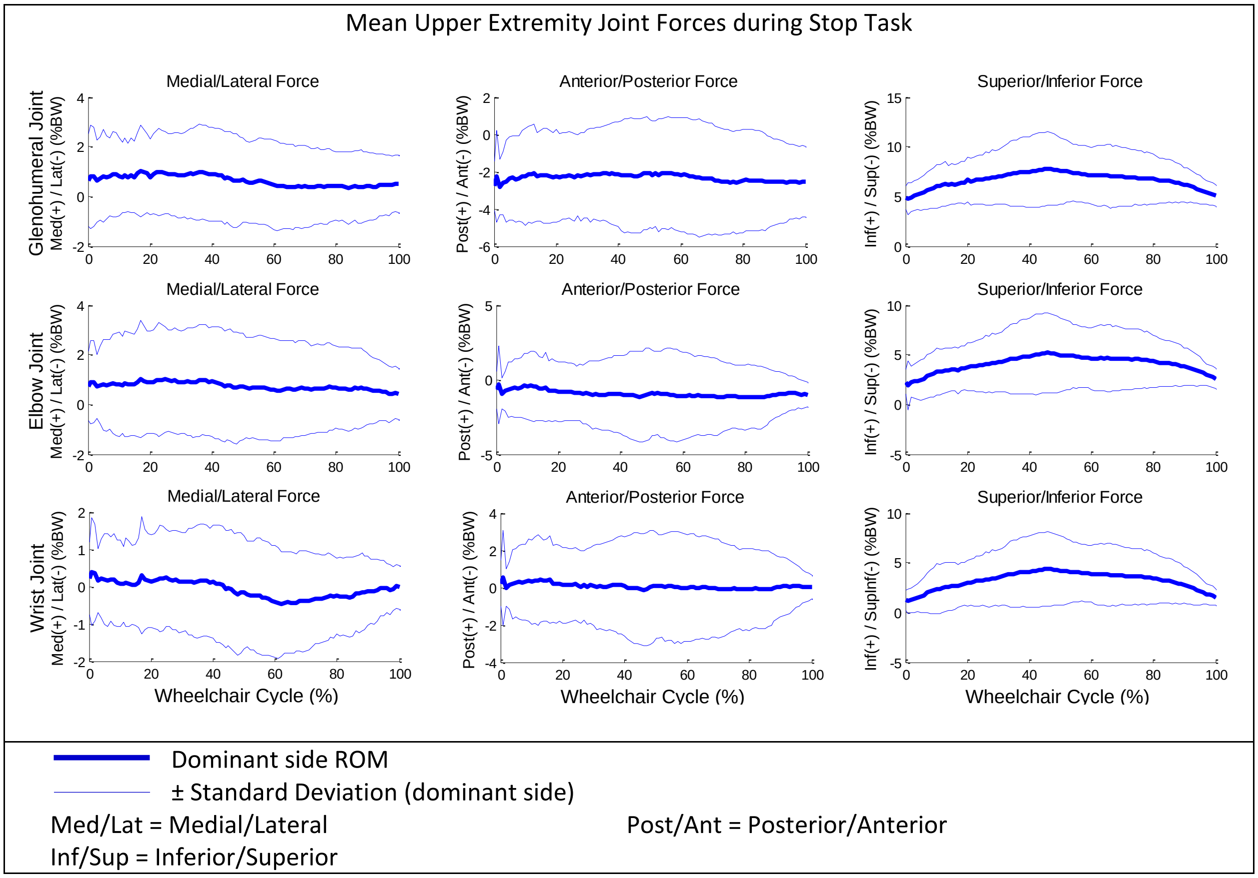


Figure 12: Mean upper extremity joint forces, reported as % body weight (%BW), during stop task are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

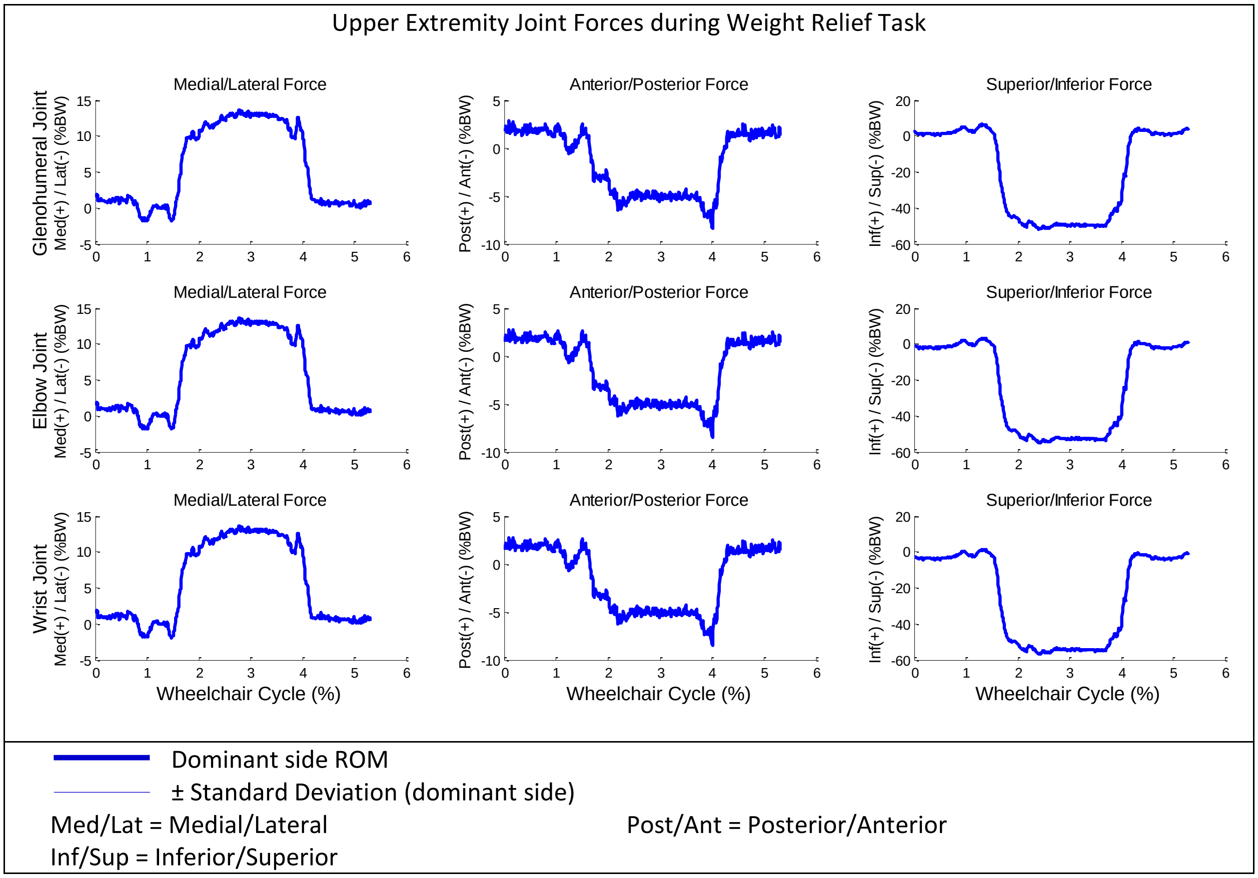


Figure 13: Upper extremity joint forces, reported as % body weight (%BW), during weight relief task are shown for glenohumeral, elbow and wrist joints in three dimensions for a representative trial.

Moments. Mean peak moments at each joint were also calculated for all tasks (Table 4). The peak wrist extension and elbow flexion moments during the start task were found to be significantly higher than during propulsion. Mean wrist and elbow flexion moments, as well as elbow and GH adduction moments during the stop tasks were significantly lower than during propulsion. Stop task extension moments at the wrist and elbow were significantly higher than during propulsion. Weight relief extension moments were found to be higher than during propulsion at all joints.

Table 4

Mean Peak Joint Moments in Dominant Limb across Functional Activities

		Propulsion		Start		Stop		Weight Relief	
Joint	Direction of Moment	Max %BWxH	Min %BWxH	Max %BWxH	Min %BWxH	Max %BWxH	Min %BWxH	Max %BWxH	Min %BWxH
Wrist	Radial (+)/ Ulnar (-) Deviation	0.43 ± 0.36	-0.29 ± 0.31	0.64 ± 0.48	-0.33 ± 0.38	0.21 ± 0.48	-0.48 ± 0.47	0.82 ± 1.11**	-1.34 ± 1.45**
	External (+)/ Internal (-) Rotation	0.50 ± 0.42	-0.20 ± 0.22	0.80 ± 0.72	-0.28 ± 0.38	0.25 ± 0.28	-0.28 ± 0.34	0.75 ± 1.01	-0.60 ± 0.48**
	Extension (+)/ Flexion (-)	0.92 ± 0.69	-0.20 ± 0.16	1.57 ± 1.02**	-0.16 ± 0.13	0.07 ± 0.32**	-1.07 ± 0.96**	3.19 ± 1.62**	-0.13 ± 0.18
Elbow	Abduction (+)/ Adduction (-)	0.76 ± 0.64	-0.61 ± 0.49	0.91 ± 0.80	-0.73 ± 0.58	0.19 ± 0.62*	-0.75 ± 0.76	1.44 ± 2.04**	-2.36 ± 2.27*
	Supination (+)/ Pronation (-)	1.07 ± 4.47	-0.84 ± 4.26	0.50 ± 0.53	-0.26 ± 0.26	0.34 ± 0.44	-0.19 ± 0.28	1.37 ± 1.42	-0.75 ± 0.99
	Extension (+)/ Flexion (-)	1.22 ± 0.96	-0.45 ± 0.31	1.80 ± 1.41**	-0.44 ± 0.32	0.21 ± 0.71**	-1.11 ± 1.04**	3.30 ± 2.13**	-0.75 ± 1.20
GH	Abduction (+)/ Adduction (-)	0.89 ± 0.97	-0.99 ± 0.89	1.07 ± 0.70	-1.31 ± 1.02	0.33 ± 0.72*	-0.52 ± 0.36*	2.17 ± 1.73**	-1.78 ± 1.98**
	External (+)/ Internal (-) Rotation	1.44 ± 4.10	-1.08 ± 3.83	1.16 ± 0.98	-0.77 ± 1.09	0.36 ± 0.56	-0.33 ± 0.30	2.15 ± 1.77	-0.87 ± 1.09
	Extension (+)/ Flexion (-)	0.87 ± 0.92	-1.20 ± 0.76	0.99 ± 1.25	-1.13 ± 0.52	0.69 ± 0.62	-0.43 ± 0.60**	2.57 ± 3.07**	-1.87 ± 1.79**

Mean peak moments ± standard deviation reported as percent body weight x height (%BWxH) at the wrist, elbow and glenohumeral (GH) joints across all subjects during propulsion with comparison to each functional task: start, stop and weight relief.

* = $p < 0.05$ ** = $p < 0.01$

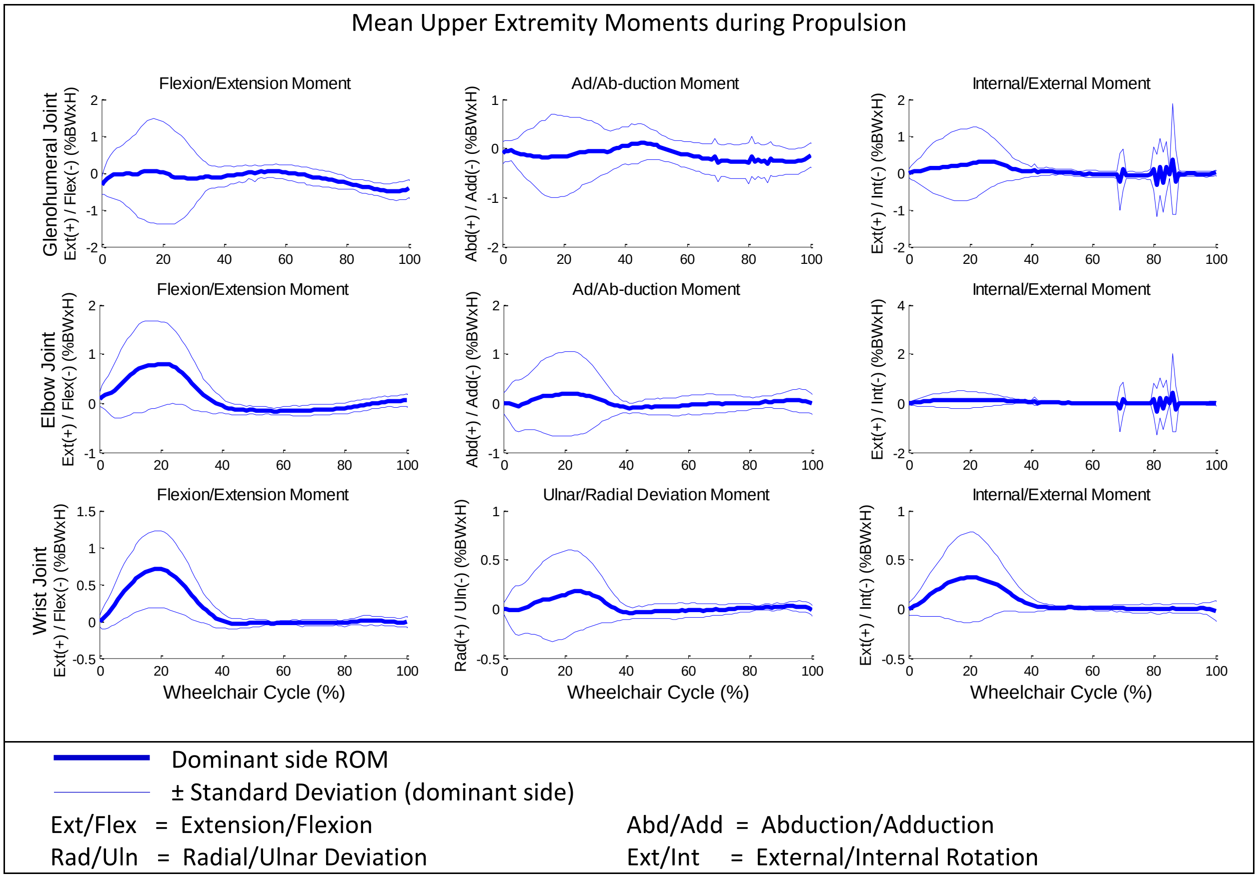


Figure 14: Mean upper extremity moments during propulsion, reported in % body weight x height (%BWxH), are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

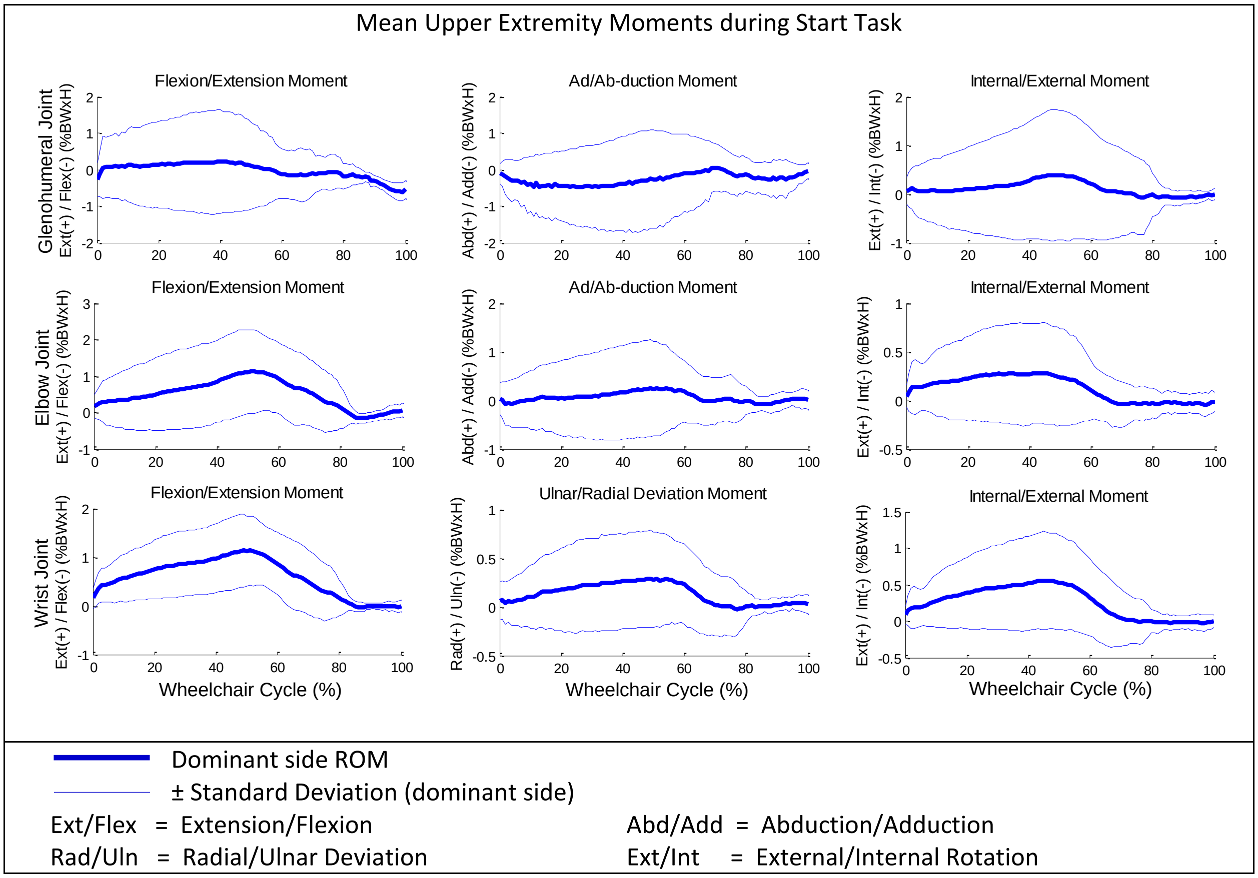


Figure 15: Mean upper extremity moments during start task, reported in % body weight x height (%BWxH), are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

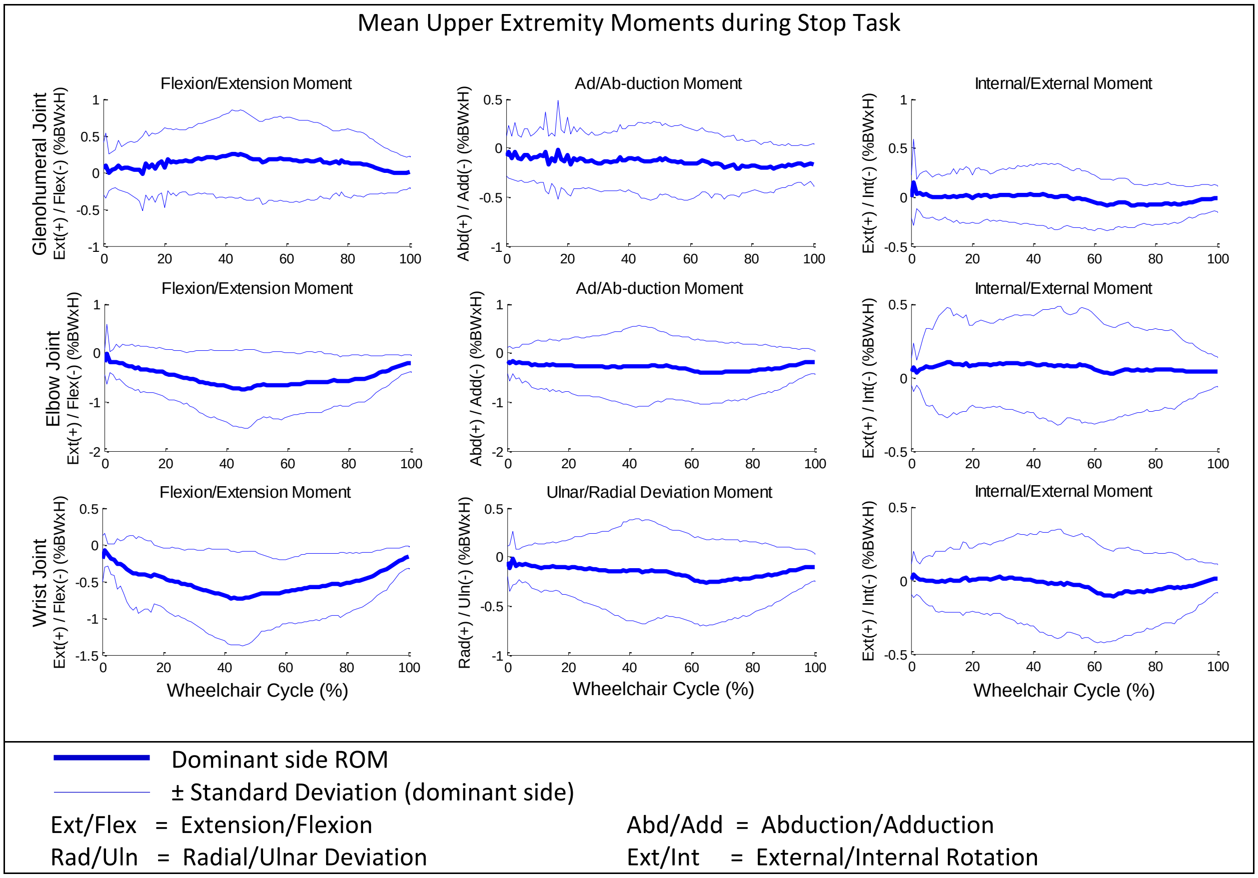


Figure 16: Mean upper extremity moments during stop task, reported in % body weight x height (%BWxH), are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

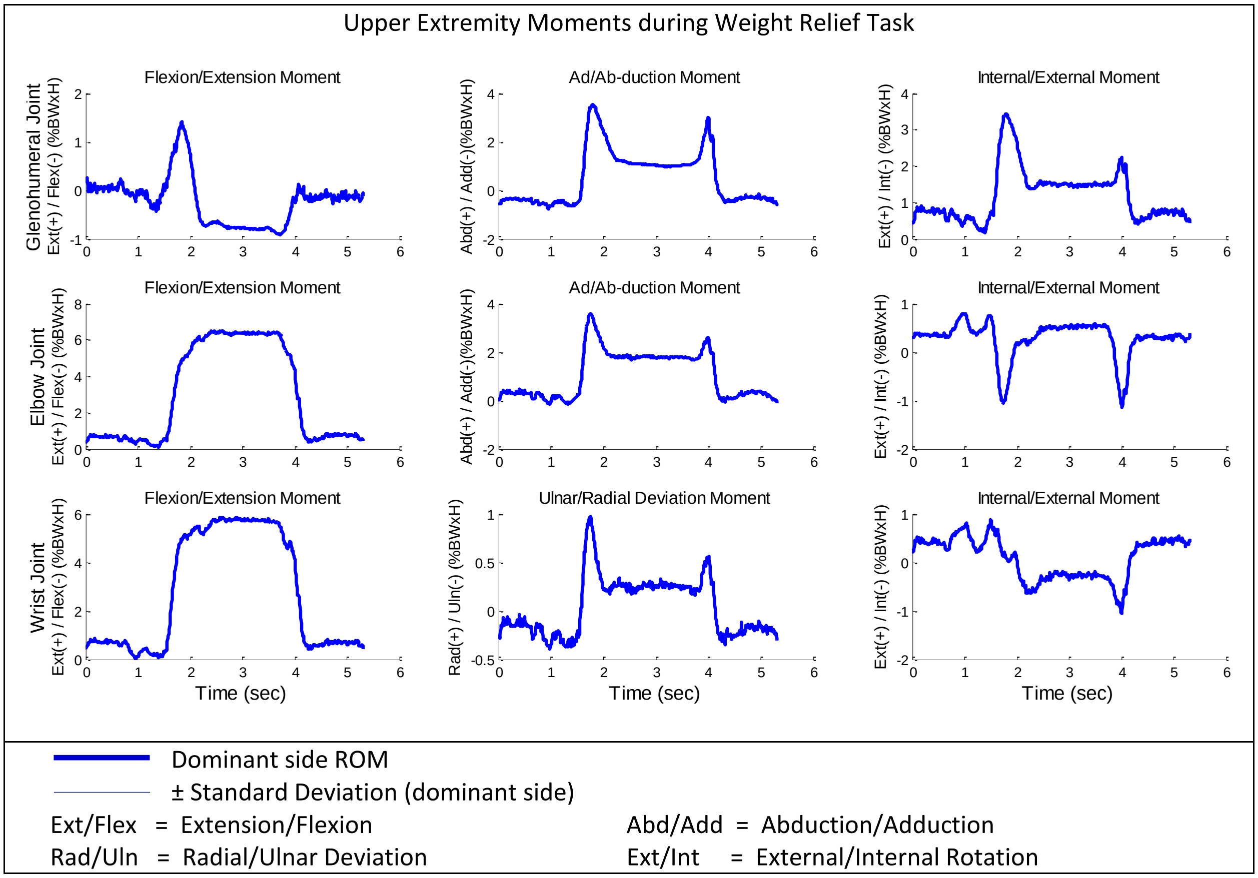


Figure 17: Upper extremity moments during weight relief task are reported in % body weight x height (%BWxH) for glenohumeral, elbow and wrist joints in three dimensions for a representative trial.

Hypothesis three. Forces and moments at the GH joint were expected to be greater in all directions than forces and moments at the elbow and wrist joints.

Forces.

Propulsion. Joint forces during each task were analyzed separately to allow for comparison of GH forces to elbow and wrist forces (**Error! Reference source not found.**). Mean joint forces during propulsion are presented in **Error! Reference source not found.**. While posterior and superior forces at the elbow and wrist were found to be higher than at the GH joint, all other forces at the elbow and wrist joints were lower than at the GH joint.

Start task. Superior forces at the elbow and wrist as well as posterior forces at the wrist were found to be higher than those at the GH joint. Anterior and inferior forces at both the elbow and the wrist were found to be significantly lower than at the GH joint.

Stop task. Posterior wrist force was higher than at the GH joint while anterior, inferior and superior forces were found to be significantly lower at the elbow and wrist when compared to the GH joint.

Weight relief task. Nearly all forces at the GH, elbow and wrist joints were found to be statistically similar. Inferior forces at the elbow and wrist were found to significantly smaller than the inferior force at the GH joint.

Table 5

Mean Peak Joint Forces during Functional Tasks across Upper Extremity Joints

a) Propulsion Forces

	Mean Force (%BW)		
Direction of Force	GH	Elbow	Wrist
Posterior (+)	1.99 ± 3.29	3.16 ± 2.35**	4.67 ± 12.74**
Anterior (-)	-6.65 ± 2.14	-3.42 ± 5.39**	-2.16 ± 2.79**
Inferior (+)	6.85 ± 1.53	4.06 ± 1.10**	1.84 ± 0.81**
Superior (-)	-2.43 ± 3.78	-4.89 ± 4.06**	-5.28 ± 4.24**
Medial (+)	4.79 ± 2.74	3.82 ± 2.84**	3.11 ± 2.71**
Lateral (-)	-2.72 ± 1.80	-3.34 ± 1.88*	-2.56 ± 2.27

b) Start Task Forces

	Mean Force (%BW)		
Direction of Force	GH	Elbow	Wrist
Posterior (+)	3.07 ± 4.29	3.71 ± 3.22	5.56 ± 4.44**
Anterior (-)	-8.21 ± 3.54	-5.00 ± 21.96**	-3.49 ± 3.91**
Inferior (+)	6.74 ± 1.50	4.49 ± 1.22**	2.04 ± 1.55**
Superior (-)	-4.59 ± 5.31	-7.90 ± 5.79*	-8.30 ± 5.86**
Medial (+)	6.59 ± 4.62	5.25 ± 4.75	5.00 ± 4.90
Lateral (-)	-2.21 ± 2.02	-3.17 ± 2.11	-2.33 ± 2.07

c) Stop Task Forces

	Mean Force (%BW)		
Direction of Force	GH	Elbow	Wrist
Posterior (+)	0.14 ± 3.53	1.43 ± 3.41	2.33 ± 3.42**
Anterior (-)	-4.48 ± 2.65	-2.95 ± 2.36*	-1.96 ± 2.38**
Inferior (+)	9.68 ± 4.89	6.88 ± 5.26*	6.04 ± 5.18**
Superior (-)	3.70 ± 2.10	0.75 ± 2.95**	0.25 ± 2.01**
Medial (+)	2.45 ± 2.18	2.48 ± 2.36	1.57 ± 1.79*
Lateral (-)	-1.12 ± 1.73	-0.97 ± 1.93	-1.46 ± 1.57

d) Weight Relief Task Forces

	Mean Force (%BW)		
Direction of Force	GH	Elbow	Wrist
Posterior (+)	12.01 ± 12.95	12.03 ± 12.94	12.03 ± 12.96
Anterior (-)	-7.65 ± 12.31	-7.56 ± 12.34	-7.51 ± 12.35
Inferior (+)	7.40 ± 1.30	4.02 ± 1.27**	2.22 ± 1.32**
Superior (-)	-21.19 ± 14.35	-24.50 ± 14.20	-26.26 ± 14.13**
Medial (+)	10.16 ± 5.16	10.17 ± 5.16	10.19 ± 5.16
Lateral (-)	-1.19 ± 1.31	-1.17 ± 1.30	-1.19 ± 1.28

Mean peak joint force ± standard deviation reported as percent body weight (%BW) during a) propulsion, b) start, c) stop and d) weight relief. Glenohumeral (GH) joint forces are compared to elbow and wrist joint forces in each direction.

* = $p < 0.05$ ** = $p < 0.01$

Moments.

Propulsion.

Start task. Moments in nearly all directions at the elbow and wrist were found to be lower at the elbow and wrist when compared to the GH joint. The moment in flexion at the elbow was found to be higher than flexion at the GH joint (Table 7).

Stop task. Flexion moments at the elbow and wrist were significantly lower than at the GH joint. Extension moments at the elbow and wrist were significantly higher than at the GH joint (Table 8).

Weight relief task. Moments at the GH joint during the weight relief task were significantly higher than those at the elbow in extension as well as those at the wrist in ulnar deviation, internal rotation and extension (Table 9).

Table 6

Mean Peak Moments in Dominant Limb during Propulsion across Upper Extremity Joints

GH		Elbow		Wrist	
Direction of Moment	Mean Moment (%BWxH)	Direction of Moment	Mean Moment (%BWxH)	Direction of Moment	Mean Moment (%BWxH)
Abduction (+)	0.89 ± 0.97	Abduction (+)	0.76 ± 0.64	Radial Deviation (+)	0.43 ± 0.36**
Adduction (-)	-0.99 ± 0.89	Adduction (-)	-0.61 ± 0.49*	Ulnar Deviation (-)	-0.29 ± 0.31**
External Rotation (+)	1.44 ± 4.10	Supination (+)	1.07 ± 4.47	External Rotation (+)	0.51 ± 0.42
Internal Rotation (-)	-1.08 ± 3.83	Pronation (-)	-0.84 ± 4.26	Internal Rotation (-)	-0.20 ± 0.22
Extension (+)	0.87 ± 0.92	Extension (+)	1.22 ± 0.96**	Extension (+)	0.92 ± 0.69
Flexion (-)	-1.20 ± 0.76	Flexion (-)	-0.45 ± 0.31**	Flexion (-)	-0.20 ± 0.16**

Mean peak moments ± standard deviation reported as percent body weight x height (%BWxH) during propulsion. Moments at the GH joint are compared to moments at the elbow and wrist in each direction. Note that wrist internal/external rotation and elbow adduction/abduction moments are not reported due to anatomical constraints.

* = $p < 0.05$ ** = $p < 0.01$

Table 7

Mean Peak Moments in Dominant Limb during Start across Upper Extremity Joints

GH		Elbow		Wrist	
Direction of Moment	Mean Moment (%BWxH)	Direction of Moment	Mean Moment (%BWxH)	Direction of Moment	Mean Moment (%BWxH)
Abduction (+)	1.07 ± 0.70	Abduction (+)	0.91 ± 0.80	Radial Deviation (+)	0.64 ± 0.48**
Adduction (-)	-1.31 ± 1.02	Adduction (-)	-0.73 ± 0.58	Ulnar Deviation (-)	-0.35 ± 0.39**
External Rotation (+)	1.16 ± 0.98	Supination (+)	0.50 ± 0.53**	External Rotation (+)	0.80 ± 0.72
Internal Rotation (-)	-0.77 ± 1.09	Pronation (-)	-0.26 ± 0.26**	Internal Rotation (-)	-0.28 ± 0.38
Extension (+)	0.99 ± 1.25	Extension (+)	1.80 ± 1.41*	Extension (+)	1.57 ± 1.02
Flexion (-)	-1.13 ± 0.52	Flexion (-)	-0.44 ± 0.32**	Flexion (-)	-0.16 ± 0.13**

Mean peak moments ± standard deviation reported as percent body weight x height (%BWxH) during the start task. Moments at the GH joint are compared to moments at the elbow and wrist in each direction. Note that wrist internal/external rotation and elbow adduction/abduction moments are not reported due to anatomical constraints.

* = $p < 0.05$ ** = $p < 0.01$

Table 8

Mean Peak Moments in Dominant Limb during Stop across Upper Extremity Joints

GH		Elbow		Wrist	
Direction of Moment	Mean Moment (%BWxH)	Direction of Moment	Mean Moment (%BWxH)	Direction of Moment	Mean Moment (%BWxH)
Abduction (+)	0.33 ± 0.72	Abduction (+)	0.19 ± 0.62	Radial Deviation (+)	0.21 ± 0.48
Adduction (-)	-0.52 ± 0.36	Adduction (-)	-0.75 ± 0.76	Ulnar Deviation (-)	-0.48 ± 0.47
External Rotation (+)	0.36 ± 0.56	Supination (+)	0.34 ± 0.44	External Rotation (+)	0.25 ± 0.28
Internal Rotation (-)	-0.33 ± 0.30	Pronation (-)	-0.19 ± 0.28**	Internal Rotation (-)	-0.28 ± 0.34**
Extension (+)	0.69 ± 0.62	Extension (+)	0.21 ± 0.71**	Extension (+)	0.07 ±0.32
Flexion (-)	-0.43 ± 0.60	Flexion (-)	-1.11 ± 1.04**	Flexion (-)	-1.07 ± 0.96**

Mean peak moments ± standard deviation reported as percent body weight x height (%BWxH) during the stop task. Moments at the glenohumeral (GH) joint are compared to moments at the elbow and wrist in each direction. Note that wrist internal/external rotation and elbow adduction/abduction moments are not reported due to anatomical constraints.

* = $p < 0.05$ ** = $p < 0.01$

Table 9

Mean Peak Moments in Dominant Limb during Weight Relief across Upper Extremity Joints

GH		Elbow		Wrist	
Direction of Moment	Mean Moment (%BWxH)	Direction of Moment	Mean Moment (%BWxH)	Direction of Moment	Mean Moment (%BWxH)
Abduction (+)	2.17 ± 1.73	Abduction (+)	1.44 ± 2.04	Radial Deviation (+)	0.82 ± 1.11**
Adduction (-)	-1.78 ± 1.98	Adduction (-)	-2.36 ± 2.27	Ulnar Deviation (-)	-1.34 ± 1.45
External Rotation (+)	2.15 ± 1.77	Supination (+)	1.37 ± 1.42*	External Rotation (+)	0.75 ± 1.01**
Internal Rotation (-)	-0.87 ± 1.09	Pronation (-)	-0.75 ± 0.99	Internal Rotation (-)	-0.59 ± 0.48
Extension (+)	2.57 ± 3.07	Extension (+)	3.30 ± 2.13	Extension (+)	3.19 ± 1.62
Flexion (-)	-1.87 ± 1.79	Flexion (-)	-0.75 ± 1.20*	Flexion (-)	-0.13 ± 0.18**

Mean peak moments ± standard deviation reported as percent body weight x height (%BWxH) during the weight relief task. Moments at the GH joint are compared to moments at the elbow and wrist in each direction. Note that wrist internal/external rotation and elbow adduction/abduction moments are not reported due to anatomical constraints.

* = $p < 0.05$ ** = $p < 0.01$

Pain and health-related quality of life. One subject reported a pain level of 15 out of a possible 100 on the VAS while all other subjects reported no pain, or zero. Mean PCS and MCS scores resulting from the SF-12 were 44.3 and 56.3 respectively (Figure 18). A Pearson's correlation was performed to compare mean peak three dimensional forces and moments at the wrist, elbow and GH joints to PCS and MCS scores at the person level. Among kinetic data, strong positive correlations were found between MCS and flexion moments at the wrist (r = 0.56, p = 0.05) and elbow (r = 0.55, p = 0.05). A strong negative correlation was found between GH lateral force and MCS (r = -0.66, p = 0.01).

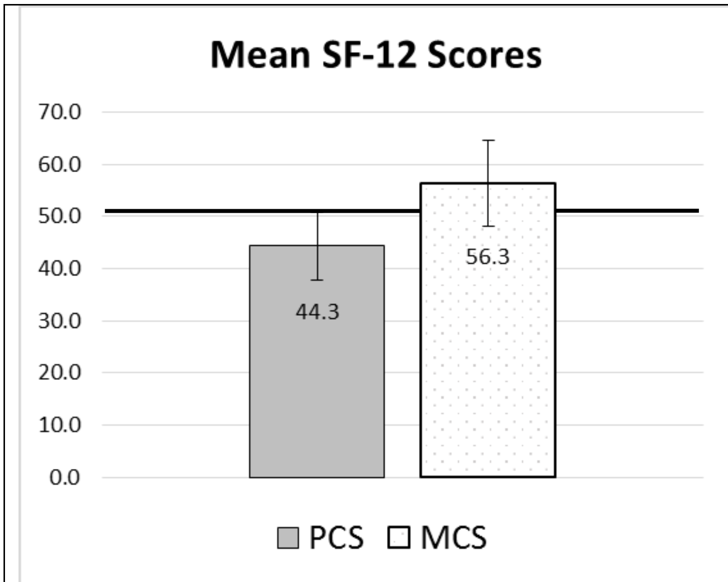


Figure 18: Mean Short Form 12 Health Questionnaire (SF-12) Scores of pediatric manual wheelchair users. Physical composite score (PCS) and mental health composite score (MCS) across all subjects is reported here with one standard deviation. The norm for both scores (50) is shown in bold.

Discussion

This study was successful in quantifying UE joint kinematics and kinetics in MWC users. Although other studies have accomplished this with an adult population, this is the first known study to investigate functional tasks with pediatric MWC users. Children are unique from adults as they have yet to fully grow and develop adult proportions and muscle mass (Jensen, 1989). These physical differences may account for some of the biomechanical data found here. Children are anecdotally known to be flexible and creative in their ability to find solutions to physical limitations. This may mean that training regarding MWC use will be effective and well-received by this population, resulting in improved long-term outcomes and reduced risk of pain and overuse injury.

Kinematic and Kinetic Graphs.

Kinematics during the wheelchair cycle across all subjects are shown in Figure 6, 7 and 8 for propulsion, start and stop tasks respectively. Similar graphs show forces in Figure 10, 11 and 12 and moments in Figures 15, 16 and 17, also normalized to percent wheelchair cycle. The large standard deviations indicate that there are important differences in the way that each subject propels their MWC. While the peak kinematics and kinetics reported here have been determined for each individual subject and trial prior to calculating the mean, it is important to note that the variances between subjects mean that simply combining data from all trials may not accurately portray what is happening throughout the cycle.

Comparison of tasks.

Propulsion vs start task. The start task was found to be significantly different from propulsion with an increased medial force at the wrist and an increased wrist extension moment. There was no increase in moments at the GH joint during the start task, a surprising finding considering that clinical experience has shown that some MWC users may lean forward to use their upper body weight to begin movement from a static position. This may be related to the pathology studied here, as SCI is often associated with muscle weakness and decreased stamina (Pendleton & Schultz-Krohn, 2013). A study by Morrow et al. (2010) found that adult MWC users with SCI demonstrated an increase in posterior force at the GH joint during the start task when compared to steady state propulsion. No other differences in forces were found between these two tasks. The lack of increased GH joint forces during the start task reported here may mean that children with SCI demonstrate a decrease in physical ability when compared to adults such as capacity to recruit additional muscles. It is interesting to note, however, that some increased force at the wrist was found here, indicating that the techniques used by the pediatric population during start or propulsion may differ from what is seen in the adult population and may be related to differences in physical proportionality (Jensen, 1989).

Propulsion vs stop. Stop task ROM was significantly lower in all directions measured at the wrist, elbow and GH joints when compared to propulsion. Although the forces and moments reported here indicate that the stop task requires an increased load in the inferior direction at these joints, a decreased load was experienced in the anterior direction, consistent with the nature of the stop task. It is interesting to note that it does not appear to be posterior force, rather inferior force that is primarily used to complete the stop, indicating that the subject's hand position may be on the anterior portion of the wheel as they grasp the hand rim.

Propulsion vs weight relief. Ranges of motion in the GH and elbow joints were higher during weight relief as the subjects were asked to lock their elbows during the weight relief task. This maneuver may aid in reducing muscle fatigue, meaning that a large ROM in elbow extension may not be an undesired outcome during this task.

Forces and moments found at all joints during weight relief are notably significant when compared to the results found during propulsion (Table 3 &Table 4). While Morrow et al. (2010) also found weight relief to require a very high load on the GH joint, they have reported superior GH joint forces to be three times greater during weight relief than during propulsion. Superior forces on the GH among our pediatric population were found to be more than nine times greater during weight relief (21.19 %BW) than during propulsion (2.43 %BW). This is concerning for many reasons, including the age of our population and the nature of a SCI diagnosis. A child who is currently using a MWC for mobility will likely continue to use this type of device long-term, thereby increasing the risk of developing injuries. Children who have been diagnosed with SCI often experience physical limitations such as decreased muscle strength and ROM in the UEs

(Pendleton & Schultz-Krohn, 2013). UE injuries could result in additional limitations that would affect the child's ability to be independent in activities of daily living, including mobility.

Based on the high forces and moments reported here, it is clinically relevant to rethink the way that therapists train MWC users to complete weight relief maneuvers. While the push-up style maneuver may have long been the preferred method, a safer option may be to educate pediatric patients to use a lateral and anterior lean method. This method has not been tested here; however, it is recommended as an alternative to the weight relief push up (Rehabilitation Engineering & Assistive Technology & Society of North America, 2008). Dynamic seating options may present another alternative to the weight relief push-up. These have been shown to redistribute pressure and allow for adequate tissue perfusion, though the cost of such systems may prove to be a barrier to individuals with SCI (Makhsous et al., 2007).

Comparison of joints within tasks.

Propulsion. Elbow and wrist forces were found to be higher in posterior and superior directions when compared to the GH joint. Despite the proximal joint being the largest and assumed to take a larger load during tasks, it is apparent that the distal joints are sustaining large loading as well. It is therefore important to consider the health and safety risks of joint loading at the elbow and wrist as well as at the GH joint. Propulsion demands may be reduced by adjusting the fit of a person's MWC, specifically the axle position. Boninger, Baldwin, Cooper, Koontz and Chan (2000) suggest that a more forward axle position may reduce peak forces during MWC propulsion and may also reduce the number of strokes needed to go the same speed, though this may compromise stability. While the findings of this study may provide helpful suggestions, we cannot assume that the differences in the biomechanics of children will allow for a similar adjustment to yield the same results as in the adult population.

The SmartWheel was used in this study as a research tool. It is commercially available and may also be used clinically to provide feedback to MWC users immediately following completion of a task or activity of daily living. While the SmartWheel reports three-dimensional forces and moments at the hand rim and does not provide data for individual joints when used on its own, the use of this tool in a clinical training program may allow clinicians to identify problem areas and determine the need for a more in-depth analysis.

Start task. The joint forces during the start tasks are most notably higher in the superior direction at the elbow and wrist when compared to the GH joint with an increased extension moment observed at the elbow. This finding is consistent with earlier discussion of start technique, as it is possible that the participants in this study are not flexing at the hip or leaning forward to use their upper body weight to begin movement. If this were the case, we would expect to see higher GH loading in the superior direction. While the goal of clinical intervention is usually to reduce joint loading, this may be a situation where shifting the burden of force from the elbow and wrist to the GH joint may be helpful. Ideally, all forces would be as low as possible while still enabling the individual to successfully participate in mobility. Redistributing forces and moments so that the proximal joints are taking on slightly more work than the distal joints may be one way to aide in preventing injury as these larger joints are usually better suited to carry a load.

Stop task. Forces exhibited at the elbow and wrist during stopping were lower those at the GH joint with the exception of posterior force at the wrist (2.33 %BW). Posterior force at the GH joint was nearly zero (0.14 %BW). More significant than this is the high force in the inferior direction at the GH joint (9.68 %BW). This supports the clinical observation that subjects are grasping the hand rim to stop the MWC on the anterior portion of the wheel, resulting in an inferior force used to stop in contrast to the posterior force that may be expected. The higher force in the inferior direction at the GH joint may be reduced by training the individual to hold the hand rim in a position that is slightly closer to their body.

Weight relief task. High force demands were observed in the superior direction at the GH joint (21.19 %BW), the elbow (24.50 %BW) and the wrist (26.26 %BW). Although not significant, the force at the GH is slightly lower than at the distal joints. It has been established that the superior force at the GH joint was found to be more than nine times higher than during propulsion and the elbow and wrist force also indicate a high risk of overuse injury. Adult populations have also exhibited high superior forces at the elbow during this task and similar recommendations may apply (Gagnon, Nadeau, Noreau, Dehail, & Piotte, 2008). Pediatric populations appear to demonstrate high loading at all UE joints when completing a weight relief push-up. This, along with clinical recommendations to complete weight relief maneuvers every fifteen minutes, supports the need for implementing alternative weight relief strategies. High loading and frequent repetition increase the risk of UE injury.

Pain and health-related quality of life (HRQoL). Average daily pain was reported as zero for all but one subject, who reported a 15 out of 100 pain score on the

VAS. Previous work also found that a relatively low level of pain was reported across pediatric patients with four orthopaedic disabilities: cerebral palsy, myelomeningocele, spinal cord injury and osteogenesis imperfecta (Aurit, Schnorenberg, Slavens, & Smith, 2013). Subjects in this study used a MWC, walker or crutches for mobility. Of the 46 subjects in this study, six reported pain with the mean VAS score being 28.8 (SD 19.6) (Aurit et al., 2013). These findings may be indicative of a lower incidence of UE overuse syndrome in the pediatric population among mobility device users. It may also suggest that children are able to adapt to device use, finding the least demanding way to accomplish mobility through their own means. It is important to note that while very little pain was reported using the VAS, there are other measures available that may be more sensitive to detecting pain. The Brief Pain Inventory reports on duration, intensity and location of pain across activities and environments and may provide additional insight to this population (Tan, Jensen, Thornby, & Shanti, 2004).

The mean PCS and MCS scores reported here, 44.3 and 56.3 respectively, are similar to those reported by Aurit, et al. (2013). Mean PCS (43.0) and MCS (59.0) were reported for 46 subjects with orthopaedic disabilities using assistive devices for functional mobility. It is notable that the national norm score for both PCS and MCS is 50, placing both groups below average in physical health and above average in mental health (Utah Department of Health, 2001). It is expected that children with SCI would report physical health that is different from healthy individuals. Occupational therapists are uniquely equipped to address both physical and mental health domains and using the SF-12 for guidance, may begin to address low-scoring areas with each individual.

Correlations between MCS and biomechanical data were found for lateral force at the GH joint and flexion moments at the elbow and wrist. The clinical relevance of this finding is unclear, as the MCS reports on a mental health domain and biomechanics describe physical characteristics. Further investigation with additional outcomes tools may provide further insight into the validity of this relationship.

Interestingly, no correlation was found between biomechanical outcomes and PCS. We have yet to fully explore the possibility that biomechanics are indicative of HRQoL. A larger sample size and additional HRQoL measures may allow for a stronger analysis and more concrete conclusions. Alternative HRQoL measures developed for the pediatric population are also available. The Pediatric Quality of Life Inventory has been validated for use with children ages 2 to 18 years and includes questions related to community, home and school environments, offering the potential to explore potential biomechanical correlations with factors that are unique to this population.

IV. Conclusion

Children who use a manual wheelchair for functional mobility demonstrate high ranges of motion, forces and moments at the UE joints that may contribute to the risk of overuse syndromes. The distribution and intensity of the forces and moments found in this study suggest that loading at the elbow and wrist joints is similar to loading at the GH joint during some tasks and in some cases exceeds these loads. This demonstrates the need for therapists to focus on joint protection techniques in all UE joints when developing training protocols in order to reduce risk pathologies at the elbow and wrist such as arthritis, lateral epicondylitis and carpal tunnel syndrome.

Joint protection can be achieved through activity modification or by using low or high tech assistive devices for support. The joint loading observed during MWC propulsion may be reduced through training methods to allow for smoother movements that are less biomechanically demanding. Monitoring propulsion patterns through motion analysis may be also be an effective tool in developing and executing training protocols. MWC fitting and set up may be explored in the future to offer additional recommendations for reducing the physical demands of functional mobility while using a MWC.

Occupational therapists are uniquely suited to manage not only the biomechanical and assistive technology aspects of assisted mobility, but also the environmental and interpersonal factors involved. The findings of this study may aid in increasing participation and independence by helping therapists to identify and address areas of concern through client-centered goals and interventions. Occupational therapists may be able to reduce the biomechanical demands of MWC use through environmental modification and by developing appropriate training methods for use with the pediatric population.

Future Directions

Continued work with the pediatric population should include the development and testing of a training protocol for manual wheelchair use. Training and education may aid in reducing high forces, moments and ranges of motion with the goal of decreasing risk of UE overuse syndromes.

In the current model, pronation and supination of the forearm is included in the elbow segment (Schnorenberg et al., 2014). Clinically, pronation and supination is measured at the wrist. It is pertinent to consider a change in the model to align clinical practice and research protocols. This may aid in establishing better communication between clinicians and researchers and allow this work to be described in a more clinically relevant way.

Future studies may investigate relevant relationships between joint angles and loading to determine if certain positions are increasing risk of injury during functional activities. The results reported here may indicate a unique pattern of forces seen during each task that may be better understood with continued research to explore contributions of each muscle using musculoskeletal modeling and electromyography. In addition to further biomechanical analysis, future work is warranted to further investigate correlations among biomechanics and outcome of pain and HRQoL.

In summary, this work supports the use of clinical interventions to aide in reducing the biomechanical demands of pediatric MWC use. Although the start tasks appears to be of the least concern, the weight relief task demonstrated the highest biomechanical demands. Clinical interventions including the use of a SmartWheel to supplement training and aid in identifying and reducing peak forces and moments exerted during functional tasks may be warranted. Clinicians should also monitor and reduce duration of MWC use through activity analysis and modification to reduce risk of injury and preserve function and independence. Clinical guidelines should include educating patients to use caution when completing weight relief tasks and to use alternative techniques when possible to reduce their risk of injury.

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Appendix A: Text Descriptions

Figure 1: International Classification of Functioning (ICF)

Brief Description: International Classification of Functioning (ICF) codes are given for each impairment description as they relate to the diagnosis of SCI (Hyung Seok Nam, 2012).

Figure 2: Visual Analog Scale (VAS)

Brief Description: Visual analog scale (VAS) for pain (Wewers & Lowe, 1990). Subjects were asked to mark their average daily pain with 0 being no pain at all and 100 being the worst pain you can imagine.

Figure 3: Upper Extremity Marker Set

Brief Description: Upper extremity marker set used in biomechanical analysis (A.J. Schnorenberg et al., 2013).

Figure 4: Subject Propulsion Patterns

Brief Description: Self-selected propulsion patterns exhibited by each subject were identified according to Boninger et al. (2004).

Figure 5: Direction of Internal Joint Force

Brief Description: Direction of internal forces for wrist, elbow and GH joints are shown in relation to an individual using a manual wheelchair. Internal joint force is described as the force acting on the joint while external joint force is the interaction of the joint with the environment external to the body.

Figure 6: Mean Upper Extremity Motion during Propulsion

Brief Description: Mean upper extremity motion, reported in degrees (deg), during steady state propulsion are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

Figure 7: Mean Upper Extremity Motion during Start Task

Brief Description: Mean upper extremity motion, reported in degrees (deg), during start task are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

Figure 8: Mean Upper Extremity Motion during Stop Task

Brief Description: Mean upper extremity motion, reported in degrees (deg), during stop task are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

Figure 9: Upper Extremity Motion during Weight Relief Task

Brief Description: Upper extremity motion, reported in degrees (deg), during stop task are shown for glenohumeral, elbow and wrist joints in three dimensions for a representative trial.

Figure 10: Mean Upper Extremity Joint Forces during Propulsion

Brief Description: Mean upper extremity joint forces, reported as % body weight (%BW), during steady state propulsion are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

Figure 11: Mean Upper Extremity Joint Forces during Start Task

Brief Description: Mean upper extremity joint forces, reported as % body weight (%BW), during start task are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

Figure 12: Mean Upper Extremity Joint Forces during Stop Task

Brief Description: Mean upper extremity joint forces, reported as % body weight (%BW), during stop task are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

Figure 13: Upper Extremity Joint Forces during Weight Relief Task

Brief Description: Upper extremity joint forces, reported as % body weight (%BW), during weight relief task are shown for glenohumeral, elbow and wrist joints in three dimensions for a representative trial.

Figure 14: Mean Upper Extremity Moments during Propulsion

Brief Description: Mean upper extremity moments during propulsion, reported in % body weight x height (%BWxH), are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

Figure 15: Mean Upper Extremity Moments during Start Task

Brief Description: Mean upper extremity moments during start task, reported in % body weight x height (%BWxH), are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

Figure 16: Mean Upper Extremity Moments during Stop Task

Brief Description: Mean upper extremity moments during stop task, reported in % body weight x height (%BWxH), are shown for glenohumeral, elbow and wrist joints in three dimensions. Each stroke has been normalized to % wheelchair cycle to allow for data analysis across all 14 subjects.

Figure 17: Upper Extremity Moments during Weight Relief Task

Brief Description: Upper extremity moments during weight relief task are reported in % body weight x height (%BWxH) for glenohumeral, elbow and wrist joints in three dimensions for a representative trial.

Figure 18: Mean Short Form 12 Health Questionnaire (SF-12) Scores

Brief Description: Scores of pediatric manual wheelchair users. Physical composite score (PCS) and mental health composite score (MCS) across all subjects is reported here with one standard deviation. The norm for both scores (50) is shown in bold.

Table 1: Subject Demographics

Brief Description: Subject age, limb dominance, gender, height and weight are reported for all fourteen participants in this study.

Table 2: Mean Peak Ranges of Motion in Dominant Limb across Functional Activities

Brief Description: Mean ranges of motion (ROM) in the wrist, elbow and glenohumeral (GH) joints across all subjects during propulsion with comparison to each functional task: start, stop and weight relief.

Table 3: Mean Peak Joint Forces in Dominant Limb across Functional Activities

Brief Description: Mean peak joint force reported as percent body weight (%BW) in the wrist, elbow and glenohumeral (GH) joints across all subjects during propulsion with comparison to each functional task: start, stop and weight relief.

Table 4: Mean Peak Joint Moments in Dominant Limb across Functional Activities

Brief Description: Mean peak moments reported as percent body weight x height (%BWxH) at the wrist, elbow and glenohumeral (GH) joints across all subjects during propulsion with comparison to each functional task: start, stop and weight relief. Note that wrist internal/external rotation and elbow adduction/abduction moments are not reported due to anatomical constraints.

Table 5: Mean Peak Joint Forces during Functional Tasks across Upper Extremity Joints

Brief Description: Mean peak joint force reported as percent body weight (%BW) during a) propulsion, b) start, c) stop and d) weight relief. Glenohumeral (GH) joint forces are compared to elbow and wrist joint forces in each direction.

Table 6: Mean Peak Moments in Dominant Limb during Propulsion across Upper Extremity Joints

Brief Description: Mean peak moments reported as percent body weight x height (%BWxH) during propulsion. Moments at the GH joint are compared to moments at the elbow and wrist in each direction. Note that wrist internal/external rotation and elbow adduction/abduction moments are not reported due to anatomical constraints.

Table 7: Mean Peak Moments in Dominant Limb during Start across Upper Extremity Joints

Brief Description: Mean peak moments reported as percent body weight x height (%BWxH) during the start task. Moments at the GH joint are compared to moments at the elbow and wrist in each direction. Note that wrist internal/external rotation and elbow adduction/abduction moments are not reported due to anatomical constraints.

Table 8: Mean Peak Moments in Dominant Limb during Stop across Upper Extremity Joints

Brief Description: Mean peak moments reported as percent body weight x height (%BWxH) during the stop task. Moments at the glenohumeral (GH) joint are compared to moments at the elbow and wrist in each direction. Note that wrist internal/external rotation and elbow adduction/abduction moments are not reported due to anatomical constraints.

Table 9: Mean Peak Moments in Dominant Limb during Weight Relief across Upper Extremity Joints

Brief Description: Mean peak moments reported as percent body weight x height (%BWxH) during the weight relief task. Moments at the GH joint are compared to moments at the elbow and wrist in each direction. Note that wrist internal/external rotation and elbow adduction/abduction moments are not reported due to anatomical constraints.

Appendix B: Short Form 12 Health Questionnaire

The SF-12 Short-Form Health Survey — Name:

Instructions: This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to complete your usual activities. Please mark each response with an X. If you are unsure about how to answer a question, please give the best answer you can.

1. In general, would you say your health is: ☐ Excellent ☐ Very Good ☐ Good ☐ Fair ☐ Poor

2. The following questions are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
a. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf.	☐	☐	☐
b. Climbing several flights of stairs.	☐	☐	☐

3. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

	Yes	No
a. **Accomplished less** than you would have liked?	☐	☐
b. Were limited in the **kind** of work or other activities?	☐	☐

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

	Yes	No
a. **Accomplished less** than you would have liked?	☐	☐
b. Didn't do work or other activities as carefully as usual?	☐	☐

5. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

☐ Not at All ☐ A little bit ☐ Moderately ☐ Quite a bit ☐ Extremely

6. These questions are about how you feel and how things have been with you *during the past 4 weeks.* For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks?

	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
a. Have you felt calm and peaceful?	☐	☐	☐	☐	☐	☐
b. Did you have a lot of energy?	☐	☐	☐	☐	☐	☐
c. Have you felt downhearted and blue?	☐	☐	☐	☐	☐	☐

7. During the past 4 weeks, how much of the time has your physical health or emotional problems interferred with your social activities (like visiting with friends, relatives, etc)?

☐ All of the time ☐ Most of the time ☐ Some of the time ☐ A little of the time ☐ None of the time

HSS ☐☐ - ☐☐ - ☐☐ 5 3028334496

Appendix C: Assent Form

Shriners Hospitals for Children-Chicago
Assent Form
(For Children Ages 7-13)

Study Title:

R4 - Advanced Mobility Modeling to Improve Function and Longer Term Transitional Care of Children with Orthopedic Disabilities

<u>Who we are and why are we meeting with you?</u>
Our names are Drs. Peter Smith and Gerald Harris. We work at Shriners Hospitals for Children-Chicago. Our research associates and I want to tell you about a research study that involves children like yourself. We want to see if you would like to participate in this research study.

<u>Why are we doing this study?</u>
This study is to learn more about how children with cerebral palsy (CP), myelomeningocele (MM), spinal cord injury (SCI), and osteogenesis imperfecta (OI) are able to move their bodies to get around. This may be with a wheelchair, walker or crutches. We want to understand how you use your arms and body to help you move and how we can make it easier for you.

We also want to study the legs and lower body of children with certain foot conditions so we can improve the ways we treat them.

<u>What will happen to you if you are in the study?</u>
The study will take place at the Shriners Hospitals for Children-Chicago.

If we are studying your arms and upper body, you will come to the hospital for one visit. You will be asked to do activities that measure your arm strength and look at how you walk or use a wheelchair, crutches or walker. We will do this by having you sit in a special chair that has an arm rest that can measure how hard you push against it. We will also be measuring the way you move by using special cameras in our lab. To do this we will place reflective (shiny) markers on your body using stickers that go on your shoulders and arms. We will also place some small "muscle microphones" on your skin that tell us when your muscles are on or off. These microphones will also be placed on your arms and shoulders using tape. You will be wearing shorts and a tank top that we will provide to you. We will also ask you questions about your level of pain, activity and participation in everyday activities using questionnaires.

If we are studying your legs and lower body, you will come to the hospital for three visits: one before your surgery, one a year after your surgery, and one 2 years after your surgery. At each visit we will take x-rays of your feet while you are standing still or walking and ask you to fill out questionnaires.

Also, we will ask your parent or guardian to answer some questions about you.

Will any part of the study hurt?
No part of this study should hurt. You may get tired during testing, but you can rest. A staff person will help you if you are not feeling well.

Who will know that you are in the study?
There are only a few people that will know you are in the study. Including us, they are people helping with the study who are researchers at the hospital.

Do you have to be in this study?
No, you don't. We hope this study will help us do a better job in taking care of children who come to the hospital. You don't have to participate, and no one will get angry or upset if you don't want to be in the study. And remember, you can change your mind later if you decide you don't want to be in the study anymore.

Do you have any questions?
You can ask questions any time. You can ask now or later. You can talk to any one of us at the hospital. Here are our phone numbers:

Peter Smith, MD, Principle Investigator (773) 622-5400
Saar Hassani, MS, Co-Investigator (773) 622-5400
Gerald Harris, PhD, PE Co-Investigator (773) 622-5400

_________________________________ ______________
Sign Your Name Date

_________________________________ ______________
Principal Investigator/Co-Investigator Date

_________________________________ ______________
Translator Date

Appendix D: Consent Form

SHRINERS HOSPITALS FOR CHILDREN-CHICAGO
INFORMED CONSENT TO PARTICIPATE IN RESEARCH PROJECT OR STUDY

Participant Name ______________________________ Date: ______________

Co-PIs: Gerald Harris, PhD, Peter Smith, MD

Investigators/Key Personnel: Jason Long, PhD, Brooke Slavens, PhD, Sahar Hassani, MS, Adam Graf, MS, Joseph Krzak, PT, Kathryn Reiners
Title of Project or Study: R4 - Advanced Mobility Modeling to Improve Function and Longer Term Transitional Care of Children with Orthopedic Disabilities

If you are the parent/guardian of a minor, when we refer to "you" and "your," we mean either you or your child.

You have been invited to join this research study. Before you agree to join, it is important that you read and understand the following information. It tells how and why the study will be done. It also tells about the good things that could be learned from the study. Possible risks or things that may hurt or be uncomfortable are described and the different kinds of medical treatment that may also help you are explained.

It is important to know that no promises can be made about the results of the study. You can drop out of the study at any time without penalty.

Please ask questions about anything that you do not understand before deciding whether or not to participate.

The National Institute on Disability and Rehabilitation Research (NIDRR) is sponsoring this study through Marquette University. Shriners Hospital for Children – Chicago is one of the performance sites participating in this study.

1. **PURPOSE:** I agree to the participation of __________________ in this research study being conducted by Gerald Harris, PhD, Peter Smith, MD and/or their assistants.

There are 3 groups in this study. The first group includes children 6-18 years of age with cerebral palsy (CP), myelomeningocele (MM), spinal cord injury (SCI), and osteogenesis imperfecta (OI). We want to study how these children are able to move their bodies to get around. This may be with a wheelchair, walker or crutches. We want to understand how they use their arms and upper body to help them move and how we can make it easier for them.

The second group includes children with certain foot conditions who are going to have surgery. We will study their legs and lower body so we can improve the ways we treat them.

The third group consists of typically developing children ages 6-18 years of age with no orthopaedic disabilities or conditions which would prevent them from using both arms to freely propel a wheelchair.

2. **PROCEDURE:** The study will be done at Shriners Hospital for Children in Chicago, IL. You will need to be screened by a physician and have his/her approval to participate in this study.

If we are studying your arms and upper body, you will come to the hospital for one visit. You will be asked to do activities that measure your arm strength and look at how you walk or use a wheelchair, crutches or walker. We will do this by having you sit in a special chair that has an arm rest that can measure how hard you push against it. We will also be measuring how you move using a special camera system in our lab. To do this, we will place reflective markers on your body using stickers that go on your shoulders and arms. We will also record your muscle activity by placing small electrodes on the surface of your skin that can "listen" for when your muscles are on or off. These will be taped onto the skin on top of a muscle on your arm or shoulder. You will be wearing shorts and a tank top that we will provide to you. We will also ask you questions about your level of pain, activity and participation in everyday activities using questionnaires called the Visual Analog Scale (VAS) and the Short Form-12 (SF-12).

If we are studying your legs and lower body, you will come to the hospital for three visits: one before your surgery, one a year after your surgery, and one 2 years after your surgery. The surgery is not part of this study. We are studying the results from your surgery. You will be asked to sign a separate consent for the surgery. At each visit we will ask you to walk in the Motion Analysis Laboratory, take x-rays of your feet while you are standing still or walking, and ask you to fill out the following questionnaires:

- AOFAS midfoot and hindfoot scales
- Child Health Questionnaire (CHQ)
- Foot Function Index-Revised (FFI-Revised)
- Pediatric Outcomes Data Collection Instrument (PODCI).

Also, we will ask your parent or guardian to answer some questions about you.

3. **EXPERIMENTAL PROCEDURES:** There are no experimental procedures used in this study. We are only gathering and studying information.

4. **RISKS:** The risks or discomforts that we know about that you might experience as a result of participating in this research study are:

(1) The inconvenience of evaluation and travel.
(2) Time and energy of being tested.

(3) The risk of mechanical malfunction, electric shock from the walkway force plates, force transducers, and gait laboratory walkway hazards (for example, falling).
(4) Not feeling comfortable answering questions.
(5) Falling.
(6) Radiation exposure from x-rays.

What we do to keep you safe:

(1) All evaluations or tests performed are entirely non-invasive and performed by trained professionals.
(2) You will have contact with low voltage devices and biomedically approved instruments only.
(3) Routine electrical safety inspection.
(4) We will try to make sure that you are comfortable during testing.
(5) Mechanical design of measurement systems and examinations to provide comfort, to prevent tripping and/or loss of balance.
(6) Staff supervision.
(7) A psychologist at our hospital is available to consult with you.
(8) You do not have to answer any question that makes you feel uncomfortable.
(9) A trained radiologist will perform all x-rays and ensure that radiation exposure is kept to a minimum and be within the established standards.

If you are pregnant, it is possible that the x-ray radiation could pose risks to your unborn child and you cannot participate if you are in the leg/lower body group. If you are pregnant or if it is possible that you are pregnant, it is important that you tell one of the investigators immediately.

Since this is a research study, there may be additional risks or side effects that we do not know about at this time, but which might occur during the study or later.

5. **DURATION:** If you are in the arm/upper body group, you will be in this study for one day. If you are in the leg/lower body group, you will be in this study for about two years.

6. **ALTERNATIVES:** You can choose not to participate in this study.

7. **BENEFITS:** No promises are being made that you personally will benefit from this study, but you and other patients may benefit later from what we learn.

8. **CONFIDENTIALITY/HIPAA PRIVACY**

Your participation in this study and your medical records will be kept confidential in accordance with applicable state and federal laws. No information identifying you will be released without your permission unless it is subject to a subpoena or court order.

Your information will be combined with information from other people taking part in the study. A statistical report of this research project or study, which may include slides or photographs that do not identify you (your head and face will be excluded) may be printed in a scientific paper or presented at a professional meeting.

Participants in this study will not be identified by name. Confidentiality in all record keeping will be maintained by assigning a unique number to each study participant. All data will be stored in a locked office in the research department and will only be accessible to research personnel.

Authorization to Use and Disclose Protected Health Information for Research Purposes

The privacy law, Health Insurance Portability & Accountability Act (HIPAA), protects your individually identifiable health information (*protected health information). The privacy law requires you to sign an authorization (or agreement) in order for researchers to be able to use or disclose your protected health information for research purposes for this study.

You authorize investigators for this study and their research staff to use and disclose your protected health information for the purposes described below. You also permit your doctors and other health care providers to disclose your protected health information for the purposes described below.

Your protected health information* that may be used and disclosed includes:

Age, height, weight, initials, whole body pictures, body composition, motion (arm and leg movement) data including joint angles and forces, physical exam measures including range of motion and strength, and outcome/psychological questionnaires results.

Your protected health information will be used for:

Helping to improve the technology used to assess the functional ability of children with orthopedic disabilities. This will be done by improving the mathematical models used to evaluate the motion of the upper extremities (arms) using assistive devices and the lower extremities while walking. We will establish the relationship among joint forces, pathology, assistive device, function, and pain.

The data that does not have your name or any information that could identify you will be stored in a password protected electronic database. Locally, the clinical investigator, patient physicians, study coordinator, physical therapists, and motion lab staff will have access to the collected data.

The Researchers may use and share your health information with the following, but they are all required to keep your records confidential:

- The Institutional Review Board at RUSH University Medical Center
- Shriners Hospitals for Children – Chicago
- Medical College of Wisconsin

- Orthopaedic Rehabilitation and Engineering Center (OREC)
- University of Wisconsin – Milwaukee
- RUSH Medical Center
- Government representatives, when required by law
- Hospital representatives if applicable

The researchers agree to protect your health information by using and disclosing it only as permitted by you in this Authorization and as directed by state and federal law. Some of these people may share your health information with someone else. If they do, the same laws that this hospital must obey may not protect your health information.

You do not have to sign this Authorization. If you decide not to sign the Authorization:

- You will not be allowed to participate in the research study.

After signing the Authorization, you can change your mind and:

- Not let the researchers disclose or use your protected health information (revoke the Authorization).
- If you revoke the Authorization, you must send a written letter to: Peter Smith, MD, Shriners Hospitals for Children-Chicago, 2211 North Oak Park Ave, Chicago, IL 60707 to inform him of your decision.
- If you revoke this Authorization, researchers may only use and disclose the protected health information **already** collected for this research study.
- If you revoke this Authorization, your protected health information may still be used and disclosed should you have an adverse event (a bad effect).
- If you change your mind and withdraw the authorization, you may not be allowed to continue to participate in the study.

You will not be allowed to review the information collected for the research until after the study is completed. When the study is over, you will have the right to access the information.

If you have not already received a copy of the Privacy Notice, you may request one. If you have any questions or concerns about your privacy rights, you should contact the Privacy Manager at Shriners Hospitals for Children-Chicago, Delphine Brown, at 773-385-5489.

9. **QUESTIONS:** If you have any questions, please ask us. If you have any questions later, please call Dr. Gerald Harris at 773-385-5457.

You can contact Arlette Grubbe at 773-385-5449 for answers to questions you might have about research and about your rights as a research participant.

In the event of an undesirable reaction or research-related injury, please call Peter Smith, MD at 773-622-5400.

10. **COMPENSATION:** For each visit in this study that you complete, Marquette University will mail you a check to your home in the amount of $50.

Any physical injuries or adverse reactions arising from participation in the research project can be treated either by providing those medical services that are customarily available at the Shriners Hospitals for Children or by a combination of medical services at the Shriners Hospitals for Children and any other hospital you choose. To the extent the Shriners Hospitals for Children provides medical services at its facility, those will be at no cost, while the cost at the other hospital will be based on your personal insurance coverage. Shriners Hospitals for Children has no program for financial compensation or other forms of compensation for any injury or undesirable reaction which you may experience as a result of participating in this study. By signing this form, you are not giving up any legal rights that you may have.

11. **WITHDRAWAL FROM THE STUDY:**

Your participation in this research study is voluntary. If you decide not to participate, there will be no penalty and you will not lose any benefits you would otherwise receive. If you change your mind after you volunteer for this study, you may withdraw from this study and stop participating at any time without penalty or loss of benefits you would otherwise receive. If you currently receive treatment you will continue to receive your usual care at Shriners Hospitals for Children-Chicago.

There are no consequences if you decide to withdraw from this research study. If you wish to withdraw from this study, please contact Dr. Gerald Harris at 773-385-5457.

12. **COMMERCIAL PRODUCTS:**

Information and data gathered during this study may be used for research and development purposes. You will not have any property rights or ownership interest in products or data which may result from your participation in this study.

13. **GENERAL INFORMATION:**

If the investigator feels that this study is not appropriate for you or that you have not followed directions, you will be dropped from the study.

You will be advised if significant information is developed during the course of this research that may affect your willingness to continue to participate.

There will be 140 participants involved in this study.

Your signature, below, will indicate that you have decided to volunteer as a research participant, that you have had an opportunity to ask questions and all of your questions have been answered, and that you have read and understood the information provided above. You will be given a signed copy of this informed consent form which is yours to keep. This Authorization does not have an expiration date.

____________________________ ___________

Signature of Parent or Legal Guardian Date

__________________________ __________

Signature of Witness Date

(Signature of both parents should be obtained where possible and signature of patient should be requested if 14 years of age or over).

....

Using language that is understandable and appropriate, I have discussed this project and the items listed above with the participant.

____ ________________

Signature of Principal Investigator or Co-Investigator Date

The undersigned interpreted, to the best of my ability, the informed consent discussion between the investigator and the patient and/or the patient's parent(s) or legal guardian(s).

____________________ ________________

Signature of Interpreter Date

____________________ _______________________________

Printed Name Title

Appendix E: Protocols and Checklists

Weight Relief Protocol

1. Smart wheel should be installed on the participant's wheelchair on their dominant side. Install hand rim cover and calibrate Smart wheel per the instruction manual. Reflective markers should be applied using the upper extremity model...
2. Direct participant to the center of the capture area and ask them to lock the wheels on their wheelchair.
3. Explain the weight relief protocol using the following script:
    - "We are going to record you as you use your arms and hands to lift your bottom off of the wheelchair seat. You will place your hands on the rim of the wheels. (Show participant where to place their hands.) You will push up and straighten your arms as much as you can and count to 2. You can then lower yourself gently back to your seat. You will be given time to practice until you feel comfortable with this task. We will then record this tasks 3 times. Do you have any questions?"
    - Answer any questions that the participant might have.
4. Allow the participant to complete a practice trial, repeating the practice trial until they feel comfortable completing the task. Observe the participant carefully and count the 2 second pause out loud if necessary.
5. When the participant is ready, use the following script:

- "We will now start recording your weight relief task. You may begin when we say start. We will take a break between tasks for you to rest your arms; you can rest for as long as you need to."
- Complete 3 lift trials, with a minimum of a 20 second rest between trials.

Testing Protocol and Marker Placement Checklist

1) Testing Set-up
    a. Prior to subject arrival
    b. Set-up the laptop close enough to main desk so trigger cable may connect the systems.
    c. Plug in trigger cable
        i. 25 pin parallel plug into the port on the back of the SmartWheel (SW) laptop.
        ii. If not already done, attach the bnc adapter to the bnc port on the other end of the cable.
        iii. Connect the ground and signal wires of the AD panel to the black and red connectors of the adapter. Black should be ground and red should be signal (channel 51 I think, Adam please check).
            1. If the wires are connected in the other order, the polarity of the signal flips, and the trigger will not work properly. This is the first place to check if the trigger from the SmartWheel does not start data capture on the Vicon system.
    d. Plug in the Zyair USB plug for wireless communication between the laptop and SMARTWheel.
    e. Open the SmartWheel Software via the shortcut on the desktop of the SW latoptop.
        i. A reminder to tighten down the axles will pop up, click ok (or cool beans).
        ii. The SMARTWheel Session Wizard welcome page will open.
            1. This is where the clinical version of the software is run, which we do not use here; however this screen must be open for the software to run, closing this shuts down the SMARTWheel software.
        iii. In the desktop tool bar, bottom right-hand side, near the time, there should be an out-front logo (blue circle on white background). Right click on it and five options are available

1. SW Session Wizard – the clinical tool as previously mentioned, which will not be discussed here.
2. SW Research – where we collect our data
3. SW Data Analyzer Tool – For analyzing a SW data file. Feel free to try it when you have time and examine all of the data it provides. It is a drag and drop window, that creates a new folder with the analysis results of the file, so there is no overwriting of the original file.
4. Settings – Calibration constants, sampling rate, SW volume, Triggering set-up etc. are located here. Should not have to change items here, except for which side of the wheelchair the SW is located (if two are used, you designate which SW is on the left and which is on the right).
    a. If a change is applied, the SW will play a little song notifying you it has received the update.
5. Exit

iv. Choose the Settings option. Double check that settings are correct for the SW being used (or for each SW if two are being used).
1. Under the Parallel Port Triggering area, make sure that the correct output pin is selected. The cord you currently have has the output signal soldered to pin #2.
2. Also make sure that the correct side of the wheelchair is selected for SW location.
3. If changes are made hit apply/ok and the SW will play a tune notifying you of a successful update.
4. Once done, or if no changes are made hit cancel to leave the settings window.

v. Right click on the out-front icon on the desktop toolbar again, and this time select the SW Research option.
1. A live feed in bar graphing form should be displayed for each SW connected. These bars simplistically show the forces and moments being applied to the SW hand rim in real-time.
    a. When the subject is sitting still without touching the hand rims, all values should be close to zero (very little blue bar showing).
    b. Additionally there is a bar graph for the angle of the wheel. As the subject propels the wheelchair this bar graph will fill up and start over with each 360 degree turn of the wheel.
2. In the bottom left hand corner of the window there is text telling you which SMARTWheels are connected or not connected and how many samples have been collected, which updates in real-time during a trial.

3. In the bottom center of the window are two buttons: save to file & mark event.
    a. The save to file button will start data capture when clicked.
        i. In turn a stop trial button will appear in its place which may be clicked when the trial is completed.

f. Open the Vicon Nexus software.
    i. There are no force plates or other data capturing devices used for this data capture.
    ii. Calibrate the cameras, per usual. See Jessica's gait protocol if assistance with camera calibration is required.
    iii. Only the raw c3d file is required by Alyssa. She can reconstruct the files and process all. No models will be linked to the subject, no labeling is required.
    iv. Under the Window menu, choose the communications option.
        1. This will open a window at the bottom of the Vicon window, under the camera view(s).
        2. From the drop down menu in the communications pane, choose the SW trigger setting that should already be saved. This allows the SW to trigger the Vicon system to begin data capture.
        3. Once this is chosen the system is ready to go
        4. Test to make sure the trigger is working (and therefore that wires of the trigger cable a properly patched into the Vicon patch panel).
            a. Turn on the SW via the switch on the SW hub.
            b. Open the Research window of the SW software on the SW laptop, as described earlier.
            c. Click the Save to File button on the Research window.
            d. If the Vicon system begins data capture at the same time, the trigger is working properly. If not, try switching the connection of the two cable wires. Then repeat the trigger check.
            e. TURN OFF SW once satisfied with trigger check.

2) Subject Arrival
    a. Follow all ISB requirements; describe testing to subject and guardian and obtain informed consent.
    b. Perform functional outcomes questionnaires.
    c. Have subject transfer out of the wheelchair (assist if required).
    d. Put the SMARTWheel(s) on the subject's wheelchair, on dominant side. (NOTE THIS BELOW)
    e. Have subject transfer back into their wheelchair.

3) Subject Marker Placement by segment (46 total, with 41 on the subject and 5 on the wheelchair):

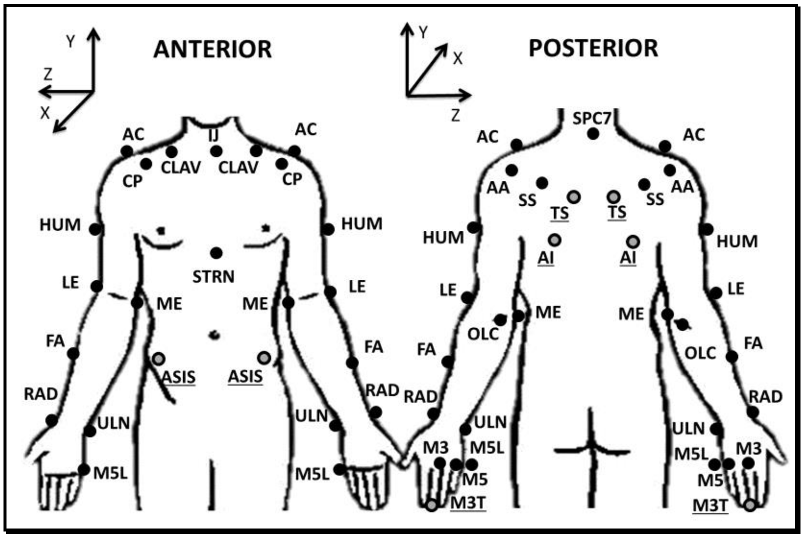
Subject Marker Placement by segment (46 total, with 41 on the subject and 5 on the wheelchair):

Bony Landmark	Marker Location	Left	Right	Diameter of the Marker
C7 Vertebral Process (SPC7)	Most protruding vertebra on neck			mm
Xiphoid process (STRN)	Lowest point on the sternum			mm
Incisura Jugularis (IJ)	Top of the sternum, between the clavicular notches			mm
Anterior Superior Illiac Spine (ASIS)	Bony prominence of top, front portion of pelvis			mm
Clavicles (CLAV)	Mid-point of clavicles			mm
Acromion Process (AC)	Bony prominence at the top of shoulder			mm

Coracoid Process (CP)	Hook-like structure on lateral edge of superior, anterior portion of scapula			mm
Acromial Angle (AA)	Point at junction of acromion and scapular spine			mm
Trigonum Spinae (TS)	Most lateral-dorsal point of the scapula			mm
Inferior Angle (AI)	Lowest part of the scapula			mm
Scapular Spine (SS)	On the scapular spine, halfway between the AA and TS markers			mm
Humerus (HUM)	Mid-point of the humerus, placed laterally			mm
Lateral Epicondyle (LE)	Lateral elbow			mm
Medial Epicondyle (ME)	Medial Elbow			mm
Olecranon Process (OLC)	The bony point of the elbow (proximal end of the ulna)			mm
Forearm (FA)	Mid-point of the radius			mm
Ulnar Styloid	Medial wrist bone			mm

(ULN)				
Radial Styloid (RAD)	Lateral wrist bone			mm
3rd Metacarpal (M3)	Head of the middle finger			mm
5th Metacarpal (M5)	Head of the fifth (little) finger			mm
5th Metacarpal (lateral) (M5L)	Side of the head of the little finger			mm
3rd Distal Phalanx (M3T)	Tip of 3rd finger, on the nail			mm
Back of Wheelchair Frame (TOPC)	Top corner of the wheelchair back on the frame			mm
Back of Wheelchair Frame (BOTC)	Bottom corners of the wheelchair back on the frame			mm
Wheel axle (WHEEL)	Center of the SMARTWheel hub (or axle of the dominant side wheel)			mm

Upper Extremity Marker Setup



*** Underlined markers (ASIS, TS, AI and M3T) are ONLY required during the static trial(s). Please remove these markers before beginning dynamic trials. ***

Final Checklist for Wheelchair Testing

Setup Procedures (before subject arrives)

____ 1. Check that VICON is setup correctly and ready for the experiment.

____ a. Appropriate System Setup file is selected "Wheelchair Testing", and data is in correct data management folder.

____ b. Vicon Camera Calibration is finished.

____ c. SmartWheel laptop set up with correct settings.

Set-Up Procedures (once subject arrives)

____ 1. Check Measurements:

a. Body
b. SmartWheel

____ 2. Check Markers:

a. Body
b. SMARTWheel and wheelchair

Test Procedures (during motion analysis)

____ 1. Check after static trial, that all required markers are present in Vicon capture.

____ 2. Check, after every trial, for marker dropout in the upper extremity.

____ 3. Check SmartWheel laptop to verify data was collected.

____ 4. Verify 5 trials per task meet requirements of 1 and 2.

Post Test Procedures (after motion analysis)

____ 1. Check that all forms are filled out and signed.

____ a. Laboratory Checklist

____ b. Subject Information Form

____ c. Outcomes Forms

____ d. Consent/Assent Forms

____ 2. Check that all test session information is uploaded to the FTP and UWM is notified.

____ a. VICON files

____ b. SmartWheel files

____ c. Measurement sheets

____ d. Subject Pictures

____ e. Subject Video

Measurement Sheet and Trial Collection Form

Subject Measurement

a. Collect the following subject specific measurements:
   i. SMARTWheel Location (**circle one**): RIGHT LEFT **Size** = 22 24 25 26
   ii. Date of Birth =
   iii. Weight (pounds) =
   iv. Height (meters) =
   v. Shoulder Measurements (mm)
      1. Length from the shoulder joint center to the elbow joint center
         a. Right =
         b. Left =
      2. Shoulder circumference
         a. Right =
         b. Left =
      3. Maximum humerus circumference
         a. Right =
         b. Left =
      4. Elbow circumference
         a. Right =
         b. Left =
      5. Elbow diameter (ME to LE – M/L direction)
         a. Right =
         b. Left =
      6. Elbow diameter (olecranon to elbow pit – A/P direction)
         a. Right =
         b. Left =
   vi. Forearm Measurements (mm)
      1. Length from the elbow joint center to the wrist joint center
         a. Right =
         b. Left =
      2. Maximum forearm circumference
         a. Right =
         b. Left =
      3. Wrist circumference
         a. Right =
         b. Left =
   vii. Hand Measurements (mm)
      1. Length from the wrist joint to the tip of third phalange
         a. Right =
         b. Left =
      2. Metacarpal-phalangeal joint circumference

    a. Right =
    b. Left =
3. Hand width (or thickness, in A/P direction)
    a. Right =
    b. Left =

- For each trial be sure to record the direction of travel in the global x-axis (+ or -).

Trial Number	Trial Name in Vicon	Direction of Travel (+/- global x-axis)	Trial Comments
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
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37			
38			

39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			

4) Double check all data/measurements have been collected and are reasonable before subject leaves.

Appendix F: Publications

Functional Outcomes and Joint Pain Assessment of Children with Orthopaedic Disabilities

Aurit, C., Paul, A.J., and Slavens, B.A. Presented (poster) at University of Wisconsin-Milwaukee College of Health Sciences Research Symposium. Milwaukee, WI. December 7, 2012.

Abstract: Children who have sustained an injury to the spinal cord may use a manual wheelchair for mobility. Repetitive motion and increased forces on the upper extremities (UE) put manual wheelchair users at a high risk of musculoskeletal injuries. The aim of this study was to quantify three-dimensional (3D) joint dynamics of the wrist, elbow and shoulder during manual wheelchair propulsion with pediatric patients diagnosed with spinal cord injury (SCI).

Data was collected at Shriners Hospitals for Children-Chicago with four male subjects (mean age 15 years) with SCI. Sagittal plane kinematics were most notable with mean ranges of motion for the dominant UE at 26.9 deg, 27.5 deg and 37.3 deg for the wrist, elbow, and glenohumeral joints, respectively. The superior and anterior joint forces were most clinically significant showing a mean maximum force of 5.09% body weight (%BW) at the wrist 3.70 %BW at the elbow and 5.55 %BW at the glenohumeral joint.

Increased ranges of motion and forces on these joints put manual wheelchair users at a high risk of injuries such as carpal tunnel syndrome and arthritis. Further research is underway with a larger population of wheelchair users to investigate the relationships among biomechanics, pain, and functional outcomes.

Upper Extremity Dynamics of Children with Orthopaedic Disabilities during Wheelchair Mobility

Aurit, C., Paul, A.J., and Slavens, B.A. Presented (poster) at University of Wisconsin-Milwaukee Office of Undergraduate Research, Research Symposium. Milwaukee, WI. April 19, 2013.

Abstract: Children who have sustained an injury to the spinal cord often use a device such as a manual wheelchair for functional and community mobility. Repetitive motion and increased forces on the upper extremities put manual wheelchair users at a greater risk of pain and musculoskeletal injuries. The aim of this study was to quantify three-dimensional (3D) joint dynamics, specifically the forces exerted on the wrist, elbow and shoulder during manual wheelchair propulsion with pediatric patients diagnosed with spinal cord injury (SCI).

Data was collected at Shriners Hospitals for Children-Chicago using a 14-camera Vicon MX motion analysis system and SmartWheel system to measure 3D forces and

moments. Four male subjects (mean age 15 years) with SCI propelled their own wheelchair using a self-selected speed. The bilateral, inverse dynamics model used include thorax, clavicle, scapula, upper arm, forearm, and hand segments. Participant data for all subjects was normalized to percent stroke cycle and force data was also normalized to body weight.

Sagittal plane kinematics were most notable. The mean ranges of motion for the dominant upper extremity in the sagittal plane were 26.9 deg, 27.5 deg and 37.3 deg for the wrist, elbow, and glenohumeral joints, respectively. The superior and anterior joint forces were most clinically significant. The mean maximum force of the wrist was 5.09% body weight (%BW), while the elbow and glenohumeral joints were 3.70 %BW and 5.55 %BW respectively.

Increased ranges of motion and forces on the wrist, elbow, and glenohumeral joints put pediatric manual wheelchair users at a high risk of musculoskeletal injuries such as carpal tunnel syndrome, arthritis, and shoulder impingement. Further research is underway to investigate a larger population of wheelchair users and correlate the biomechanical metrics to functional and pain outcomes.

Biomechanical Assessment of Upper Extremity Joint Forces during Pediatric Wheelchair Mobility

Aurit, C., Paul, A.J., and Slavens, B.A. Presented (poster) at University of Wisconsin-Milwaukee College of Health Sciences Research Symposium. Milwaukee, WI. May 3, 2013.

Abstract: Children who have sustained an injury to the spinal cord often use a device such as a manual wheelchair for functional and community mobility. Repetitive motion and increased forces on the upper extremities put manual wheelchair users at a greater risk of pain and musculoskeletal injuries. The aim of this study was to quantify three-dimensional (3D) joint dynamics, specifically the forces exerted on the wrist, elbow and shoulder during manual wheelchair propulsion with pediatric patients diagnosed with spinal cord injury (SCI).

Data was collected at Shriners Hospitals for Children-Chicago using a Vicon MX motion analysis system and SmartWheel system to measure 3D forces and moments. Four male subjects (mean age of 15 years) with SCI propelled their own wheelchair using a self-selected pace and propulsion pattern down a 15 meter walkway. Two participants identified themselves as right-side dominant and two as left-side dominant. Our custom upper extremity inverse dynamics model was applied to determine joint dynamics. The bilateral model includes thorax, clavicle, scapula, upper arm, forearm, and hand segments. Participant data for all subjects was normalized to percent stroke cycle and force data was also normalized to body weight.

Sagittal plane kinematics were most notable. The mean ranges of motion for the dominant upper extremity (UE) in the sagittal plane were 26.9 deg, 27.5 deg and 37.3 deg for the wrist, elbow, and glenohumeral joints, respectively. Ranges of 27.5 deg, 25.4 deg and 43.3 deg for the wrist, elbow, and glenohumeral joints were calculated. The superior

and anterior joint forces were most clinically relevant. The mean maximum force of the wrist was 5.09% body weight (%BW) directed anteriorly occurring at 19% of the stroke cycle, during the push phase. The mean maximum force of the elbow was 3.70 %BW directed superiorly. The mean maximum glenohumeral joint force was 5.55 %BW superiorly directed.

Increased ranges of motion and forces on the wrist, elbow, and glenohumeral joints put pediatric manual wheelchair users at a greater risk of musculoskeletal injuries such as carpal tunnel syndrome, arthritis, and shoulder impingement. Further research is underway to investigate a larger population of wheelchair users and correlate the biomechanical metrics to functional and pain outcomes. Additional areas of interest include quantifying functional force demands for pediatric manual wheelchair propulsion to assist in determining the need for transition to powered mobility.

Upper Extremity Dynamics of Children with Spinal Cord Injury during Wheelchair Mobility

Aurit, C., Schnorenberg, A.J., Slavens, B.A., Graf, A., Krzak, J., Vogel, L., Smith, P., and Harris, G. Presented (poster) at American Academy for Cerebral Palsy and Developmental Medicine Annual Conference. Oconomowoc, WI. October 16-19 2013 and University of Wisconsin-Milwaukee Pi Theda Epsilon Evening with a Leader, Milwaukee, WI. November 5, 2013.

Abstract: Children who have sustained an injury to the spinal cord may use a manual wheelchair for mobility. Repetitive motion and increased forces on the upper extremities (UE) put manual wheelchair users at a high risk of musculoskeletal injuries. The aim of this study was to quantify three-dimensional (3D) joint dynamics of the wrist, elbow and shoulder during manual wheelchair propulsion with pediatric patients diagnosed with spinal cord injury (SCI).

Data was collected at Shriners Hospitals for Children-Chicago with four male subjects (mean age 15 years) with SCI. Sagittal plane kinematics were most notable with mean ranges of motion for the dominant UE at 26.9 deg, 27.5 deg and 37.3 deg for the wrist, elbow, and glenohumeral joints, respectively. The superior and anterior joint forces were most clinically significant showing a mean maximum force of 5.09% body weight (%BW) at the wrist 3.70 %BW at the elbow and 5.55 %BW at the glenohumeral joint.

Increased ranges of motion and forces on these joints put manual wheelchair users at a high risk of injuries such as carpal tunnel syndrome and arthritis. Further research is underway with a larger population of wheelchair users to investigate the relationships among biomechanics, pain, and functional outcomes.

Pain and Health Outcomes of Pediatric Assistive Mobility Device Users with Orthopaedic Disabilities

Aurit, C., Schnorenberg, A.J., Krzak, J., Graf, A., Smith, P., and Slavens, B.A.
Abstract submitted to University of Wisconsin-Milwaukee College of Health Sciences Research Symposium. Milwaukee, WI. October, 2013.

Abstract: Children diagnosed with orthopaedic disabilities often have significant motor impairments such as muscle weakness, impaired balance, and limited mobility that require use of assistive mobility technologies for everyday function. Commonly used assistive devices, such as walkers, wheelchairs and Lofstrand crutches, may contribute to secondary musculoskeletal pathology due to forces exerted on the upper extremities during ambulation and mobility. Conditions such as carpal tunnel syndrome, osteoarthritis and upper extremity joint pain are common with these long-term assistive device users. While it is possible to accurately measure joint demands, it is difficult to objectively measure an individual's pain, health, and quality of life. This study investigated outcomes of two valid and reliable assessment tools used to evaluate health and pain in pediatric assistive mobility device users: the Short Form 12 Health Questionnaire (SF-12) and the Visual Analog Scale (VAS).

Forty-six children participated in the study, aged 9 to 18 years, at Shriners Hospital for Children-Chicago. Subjects were diagnosed with cerebral palsy (CP), myelomeningocele (MM), spinal cord injury (SCI) or osteogenesis imperfecta (OI) and used a walker, wheelchair or Lofstrand crutches for mobility. SF-12 and VAS were administered to assess health and pain. The SF-12 reported a physical composite score (PCS) and a mental health composite score (MCS) on a scale of 0-100, with the national norm score for healthy individuals being 50. The VAS was used to report pain from 0-100 on a 100 mm line.

Forty (40) of the subjects reported no pain, while six (6) subjects reported average daily pain ranging from 3 to 60 on the VAS. Low levels of reported pain may be related to the young age of participants or the sensitivity of the measure.

Subjects scored a mean MCS of 59 on the SF-12. This is above the national norm, indicating no decline in mental health. The mean PCS across all subjects was 43, demonstrating a level of physical function below the national norm. These results are consistent with our biomechanical findings.

This study warrants additional sensitive outcomes measures to be investigated. Research is underway correlating pain and health with biomechanical metrics of range of motion and peak joint forces and moments to provide further insight to improve prescription and training paradigms in long-term assistive device users. This work may contribute to the development of evidence-based interventions for rehabilitation and prevention of pain and secondary pathologies associated with long-term mobility device usage and transitional care.

Upper Extremity Dynamics of Children with Spinal Cord Injury during Wheelchair Mobility

Aurit, C., Paul, A.J., and Slavens, B.A. Presented (poster) at Wisconsin Occupational Therapy Association Annual Conference. Oconomowoc, WI. March 2013.

Abstract: Children who have sustained an injury to the spinal cord may use a manual wheelchair for mobility. Repetitive motion and increased forces on the upper extremities (UE) put manual wheelchair users at a high risk of musculoskeletal injuries. The aim of this study was to quantify three-dimensional (3D) joint dynamics of the wrist, elbow and shoulder during manual wheelchair propulsion with pediatric patients diagnosed with spinal cord injury (SCI).

Data was collected at Shriners Hospitals for Children-Chicago with four male subjects (mean age 15 years) with SCI. Sagittal plane kinematics were most notable with mean ranges of motion for the dominant UE at 26.9 deg, 27.5 deg and 37.3 deg for the wrist, elbow, and glenohumeral joints, respectively. The superior and anterior joint forces were most clinically significant showing a mean maximum force of 5.09% body weight (%BW) at the wrist 3.70 %BW at the elbow and 5.55 %BW at the glenohumeral joint.

Increased ranges of motion and forces on these joints put manual wheelchair users at a high risk of injuries such as carpal tunnel syndrome and arthritis. Further research is underway with a larger population of wheelchair users to investigate the relationships among biomechanics, pain, and functional outcomes.

Upper Extremity Biomechanical and Functional Outcomes Assessment during Wheelchair Mobility in Children with Spinal Cord Injury

Christine M. Aurit, BS, Alyssa J. Schnorenberg, MS, and Brooke A. Slavens, PhD. Abstract accepted (poster) For American Occupational Therapy Association Annual Conference. Baltimore, MD. April 2014.

Abstract:

Objective: To assess wrist, elbow, and glenohumeral (GH) joint biomechanics and functional outcomes during manual wheelchair propulsion of pediatric patients diagnosed with spinal cord injury (SCI). This work may improve pediatric wheelchair prescription, training and usage.

Background: Children who have sustained an SCI often use a manual wheelchair (MWC) for mobility. However, repetitive motion, high ranges of motion (ROM) and large joint demands on the upper extremity (UE) place manual wheelchair users (MWU) at a high risk of developing musculoskeletal pain and pathology.

Methods: Four male MWUs with SCI, aged 9 to 17 years participated in the study. Biomechanical data was collected at Shriners' Hospitals for Children-Chicago using a 14-camera Vicon MX motion analysis system and a SmartWheel instrumented hand rim system. Each participant propelled their own wheelchair using a self-selected

speed and stroke pattern. Participant health-related quality of life was assessed using the Short Form 12 Health Survey (SF-12).

Intervention: N/A

Results/Limitations/Conclusions: Sagittal plane kinematics were most notable of the three planes of motion. The mean across all subjects showed peak joint angles of 33.6 deg, 85.3 deg and 41.7 deg for wrist extension, elbow flexion, and GH joint extension, respectively. The superior and anterior joint forces were most clinically relevant. The mean maximum force of the wrist was 5.1% body weight (%BW) directed anteriorly, the elbow was 3.7 %BW directed superiorly and the GH joint force was 5.6 %BW superiorly directed. Participants had an average physical composite score (PCS) of 42.6 and a psychosocial composite score (MCS) of 58.7 on the SF-12 compared to an average healthy score of 50. Increased ROM and forces on the wrist, elbow, and GH joints demonstrate longer term concern for pediatric MWU to develop musculoskeletal pathologies such as carpal tunnel syndrome, arthritis, and shoulder impingement. Quantification of three-dimensional joint dynamics, pain and functional outcomes is underway in a larger population of pediatric wheelchair users to provide insight to clinicians and therapists to improve rehabilitative treatment and wheelchair selection and training.

References

Morrow, M.M.B., et al. (2010). *J Electromyogr Kinesiol, 20*(1), 61-67.
Slavens, B., et al. (2013). Conf Proc Occ Thpy Summit of Scholars. Chi, IL.
Paul, A., et al. (2012). Proc Hwd H Steel Conf: Ped Sp Crd Injry & Dysfunctn, L Buena Vista, FL.

Appendix G: MatLab Code

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%          Use to Process Weight Relief Trials          %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Max force/moment at hand rim and each joint
% Joint angles (min&max) at max force/moment
% ROM for each joint

% Enter file path for INPUT to read in .xls for each trial
FilePath = 'C:\R4 Study Data\03 - Modeling Results\Subject\';
FileName = 'Subject Trial 11 Results';
FileExt = '.xls';
headernum = 1;
% Enter last row # from Excel input file
excelend = 526;
% Enter file path for Excel OUTPUT file
fileout = 'C:\R4 Study Data\03 - Modeling
Results\Subject\SubjectAvgDataVTr#11.xls';

%Please enter what side of the Wheelchair the SmartWheel is on:
    %Enter 1 for Right side
    %Enter 2 for Left Side
SWSide = 1;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
%                      DO NOT EDIT BELOW THIS LINE
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%

% read in data from Excel File
% Setup xlsread1

filepath = strcat(FilePath,FileName,FileExt);
    Excel = actxserver('Excel.Application');
    Excel.Workbooks.Open(filepath);
    Excel.Workbooks.Item(FileName).RunAutoMacros(1);
    File = filepath;
        if ~exist(File,'file')
            ExcelWorkbook = Excel.Workbooks.Add;
            ExcelWorkbook.SaveAs(File,1);
            ExcelWorkbook.Close(false);
        end
    Excel.Workbooks.Open(File);


%%%%%%%%%%% Read in right side angles %%%%%%%%%%%

% Right Wrist
```

```
RWrist_AngX = xlsread1(filepath,'Right
Wrist',strcat('C',num2str(headernum+1),':','C',num2str(excelend)));
RWrist_AngY = xlsread1(filepath,'Right
Wrist',strcat('D',num2str(headernum+1),':','D',num2str(excelend)));
RWrist_AngZ = xlsread1(filepath,'Right
Wrist',strcat('E',num2str(headernum+1),':','E',num2str(excelend)));

%%%%%%%%%%% Read in left side angles %%%%%%%%%%%

% Left Wrist
LWrist_AngX = xlsread1(filepath,'Left
Wrist',strcat('C',num2str(headernum+1),':','C',num2str(excelend)));
LWrist_AngY = xlsread1(filepath,'Left
Wrist',strcat('D',num2str(headernum+1),':','D',num2str(excelend)));
LWrist_AngZ = xlsread1(filepath,'Left
Wrist',strcat('E',num2str(headernum+1),':','E',num2str(excelend)));


%%%%%%%%%% Read in dominant side forces and moments %%%%%%%%%%%

if SWSide==1
    % Right Wrist
    RWrist_ForceX = xlsread1(filepath,'Right
Wrist',strcat('L',num2str(headernum+1),':','L',num2str(excelend)));
    RWrist_ForceY = xlsread1(filepath,'Right
Wrist',strcat('M',num2str(headernum+1),':','M',num2str(excelend)));
    RWrist_ForceZ = xlsread1(filepath,'Right
Wrist',strcat('N',num2str(headernum+1),':','N',num2str(excelend)));
    RWrist_NormForceX = xlsread1(filepath,'Right
Wrist',strcat('O',num2str(headernum+1),':','O',num2str(excelend)));
    RWrist_NormForceY = xlsread1(filepath,'Right
Wrist',strcat('P',num2str(headernum+1),':','P',num2str(excelend)));
    RWrist_NormForceZ = xlsread1(filepath,'Right
Wrist',strcat('Q',num2str(headernum+1),':','Q',num2str(excelend)));
    RWrist_MomentX = xlsread1(filepath,'Right
Wrist',strcat('R',num2str(headernum+1),':','R',num2str(excelend)));
    RWrist_MomentY = xlsread1(filepath,'Right
Wrist',strcat('S',num2str(headernum+1),':','S',num2str(excelend)));
    RWrist_MomentZ = xlsread1(filepath,'Right
Wrist',strcat('T',num2str(headernum+1),':','T',num2str(excelend)));
    RWrist_NormMomentX = xlsread1(filepath,'Right
Wrist',strcat('U',num2str(headernum+1),':','U',num2str(excelend)));
    RWrist_NormMomentY = xlsread1(filepath,'Right
Wrist',strcat('V',num2str(headernum+1),':','V',num2str(excelend)));
    RWrist_NormMomentZ = xlsread1(filepath,'Right
Wrist',strcat('W',num2str(headernum+1),':','W',num2str(excelend)));


elseif SWSide == 2

    % Left Wrist
    LWrist_ForceX = xlsread1(filepath,'Left
Wrist',strcat('L',num2str(headernum+1),':','L',num2str(excelend)));
```

```
    LWrist_ForceY = xlsread1(filepath,'Left
Wrist',strcat('M',num2str(headernum+1),':','M',num2str(excelend)));
    LWrist_ForceZ = xlsread1(filepath,'Left
Wrist',strcat('N',num2str(headernum+1),':','N',num2str(excelend)));
    LWrist_NormForceX = xlsread1(filepath,'Left
Wrist',strcat('O',num2str(headernum+1),':','O',num2str(excelend)));
    LWrist_NormForceY = xlsread1(filepath,'Left
Wrist',strcat('P',num2str(headernum+1),':','P',num2str(excelend)));
    LWrist_NormForceZ = xlsread1(filepath,'Left
Wrist',strcat('Q',num2str(headernum+1),':','Q',num2str(excelend)));
    LWrist_MomentX = xlsread1(filepath,'Left
Wrist',strcat('R',num2str(headernum+1),':','R',num2str(excelend)));
    LWrist_MomentY = xlsread1(filepath,'Left
Wrist',strcat('S',num2str(headernum+1),':','S',num2str(excelend)));
    LWrist_MomentZ = xlsread1(filepath,'Left
Wrist',strcat('T',num2str(headernum+1),':','T',num2str(excelend)));
    LWrist_NormMomentX = xlsread1(filepath,'Left
Wrist',strcat('U',num2str(headernum+1),':','U',num2str(excelend)));
    LWrist_NormMomentY = xlsread1(filepath,'Left
Wrist',strcat('V',num2str(headernum+1),':','V',num2str(excelend)));
    LWrist_NormMomentZ = xlsread1(filepath,'Left
Wrist',strcat('W',num2str(headernum+1),':','W',num2str(excelend)));


end

%Excel.ActiveWorkbook.Save;
    Excel.Quit
    Excel.delete
    clear Excel

%%%%%% Done reading in data %%%%%%

%%%%%%%%%%%%%% Calculate angle stats %%%%%%%%%%%%%%

% Right Wrist
MaxRWrist_AngX = max(RWrist_AngX);
MinRWrist_AngX = min(RWrist_AngX);
ROMRWrist_AngX = (MaxRWrist_AngX-MinRWrist_AngX);
MaxRWrist_AngY = max(RWrist_AngY);
MinRWrist_AngY = min(RWrist_AngY);
ROMRWrist_AngY = (MaxRWrist_AngY-MinRWrist_AngY);
MaxRWrist_AngZ = max(RWrist_AngZ);
MinRWrist_AngZ = min(RWrist_AngZ);
ROMRWrist_AngZ = (MaxRWrist_AngZ-MinRWrist_AngZ);



% Left Wrist
MaxLWrist_AngX = max(LWrist_AngX);
MinLWrist_AngX = min(LWrist_AngX);
ROMLWrist_AngX = (MaxLWrist_AngX-MinLWrist_AngX);
MaxLWrist_AngY = max(LWrist_AngY);
```

```
MinLWrist_AngY = min(LWrist_AngY);
ROMLWrist_AngY = (MaxLWrist_AngY-MinLWrist_AngY);
MaxLWrist_AngZ = max(LWrist_AngZ);
MinLWrist_AngZ = min(LWrist_AngZ);
ROMLWrist_AngZ = (MaxLWrist_AngZ-MinLWrist_AngZ);



%%%%%%%%%%%%%% Calculate force and moment stats %%%%%%%%%%%%%%

if SWSide == 1

    % Right Wrist
    [MaxRWrist_ForceX,MaxRWr_FX_Loc] = max(RWrist_ForceX);
        RWristAngX_MaxFX = RWrist_AngX(MaxRWr_FX_Loc);
    [MinRWrist_ForceX,MinRWr_FX_Loc] = min(RWrist_ForceX);
        RWristAngX_MinFX = RWrist_AngX(MinRWr_FX_Loc);
    [MaxRWrist_ForceY,MaxRWr_FY_Loc] = max(RWrist_ForceY);
        RWristAngY_MaxFY = RWrist_AngY(MaxRWr_FY_Loc);
    [MinRWrist_ForceY,MinRWr_FY_Loc] = min(RWrist_ForceY);
        RWristAngY_MinFY = RWrist_AngY(MinRWr_FY_Loc);
    [MaxRWrist_ForceZ,MaxRWr_FZ_Loc] = max(RWrist_ForceZ);
        RWristAngZ_MaxFZ = RWrist_AngZ(MaxRWr_FZ_Loc);
    [MinRWrist_ForceZ,MinRWr_FZ_Loc] = min(RWrist_ForceZ);
        RWristAngZ_MinFZ = RWrist_AngZ(MinRWr_FZ_Loc);

    [MaxRWrist_NormForceX,MaxRWr_NormFX_Loc] = max(RWrist_NormForceX);
        RWristAngX_MaxNormFX = RWrist_AngX(MaxRWr_NormFX_Loc);
    [MinRWrist_NormForceX,MinRWr_NormFX_Loc] = min(RWrist_NormForceX);
        RWristAngX_MinNormFX = RWrist_AngX(MinRWr_NormFX_Loc);
    [MaxRWrist_NormForceY,MaxRWr_NormFY_Loc] = max(RWrist_NormForceY);
        RWristAngY_MaxNormFY = RWrist_AngY(MaxRWr_NormFY_Loc);
    [MinRWrist_NormForceY,MinRWr_NormFY_Loc] = min(RWrist_NormForceY);
        RWristAngY_MinNormFY = RWrist_AngY(MinRWr_NormFY_Loc);
    [MaxRWrist_NormForceZ,MaxRWr_NormFZ_Loc] = max(RWrist_NormForceZ);
        RWristAngZ_MaxNormFZ = RWrist_AngZ(MaxRWr_NormFZ_Loc);
    [MinRWrist_NormForceZ,MinRWr_NormFZ_Loc] = min(RWrist_NormForceZ);
        RWristAngZ_MinNormFZ = RWrist_AngZ(MinRWr_NormFZ_Loc);

    RWrist_ResultNormForce = (sqrt(RWrist_NormForceX.^2 +
RWrist_NormForceY .^2 + RWrist_NormForceZ .^2));
        [MaxRWrist_ResultNormForce, MaxRWr_ResNormForce_Loc] =
max(RWrist_ResultNormForce);
        [MinRWrist_ResultNormForce, MinRWr_ResNormForce_Loc] =
min(RWrist_ResultNormForce);

    [MaxRWrist_MomentX,MaxRWr_MomX_Loc] = max(RWrist_MomentX);
        RWristAngX_MaxMomX = RWrist_AngX(MaxRWr_MomX_Loc);
    [MinRWrist_MomentX,MinRWr_MomX_Loc] = min(RWrist_MomentX);
        RWristAngX_MinMomX = RWrist_AngY(MinRWr_MomX_Loc);
    [MaxRWrist_MomentY,MaxRWr_MomY_Loc] = max(RWrist_MomentY);
        RWristAngY_MaxMomY = RWrist_AngY(MaxRWr_MomY_Loc);
    [MinRWrist_MomentY,MinRWr_MomY_Loc] = min(RWrist_MomentY);
```

```
        RWristAngY_MinMomY = RWrist_AngY(MinRWr_MomY_Loc);
    [MaxRWrist_MomentZ,MaxRWr_MomZ_Loc] = max(RWrist_MomentZ);
        RWristAngZ_MaxMomZ = RWrist_AngZ(MaxRWr_MomZ_Loc);
    [MinRWrist_MomentZ,MinRWr_MomZ_Loc] = min(RWrist_MomentZ);
        RWristAngZ_MinMomZ = RWrist_AngZ(MinRWr_MomZ_Loc);

    [MaxRWrist_NormMomentX,MaxRWr_NormMomX_Loc] =
max(RWrist_NormMomentX);
        RWristAngX_MaxNormMomX = RWrist_AngX(MaxRWr_NormMomX_Loc);
    [MinRWrist_NormMomentX,MinRWr_NormMomX_Loc] =
min(RWrist_NormMomentX);
        RWristAngX_MinNormMomX = RWrist_AngX(MinRWr_NormMomX_Loc);
    [MaxRWrist_NormMomentY,MaxRWr_NormMomY_Loc] =
max(RWrist_NormMomentY);
        RWristAngY_MaxNormMomY = RWrist_AngY(MaxRWr_NormMomY_Loc);
    [MinRWrist_NormMomentY,MinRWr_NormMomY_Loc] =
min(RWrist_NormMomentY);
        RWristAngY_MinNormMomY = RWrist_AngY(MinRWr_NormMomY_Loc);
    [MaxRWrist_NormMomentZ,MaxRWr_NormMomZ_Loc] =
max(RWrist_NormMomentZ);
        RWristAngZ_MaxNormMomZ = RWrist_AngZ(MaxRWr_NormMomZ_Loc);
    [MinRWrist_NormMomentZ,MinRWr_NormMomZ_Loc] =
min(RWrist_NormMomentZ);
        RWristAngZ_MinNormMomZ = RWrist_AngZ(MinRWr_NormMomZ_Loc);

    RWrist_ResultNormMoment = (sqrt(RWrist_NormMomentX.^2 +
RWrist_NormMomentY .^2 + RWrist_NormMomentZ .^2));
        [MaxRWrist_ResultNormMoment, MaxRWr_ResNormMoment_Loc] =
max(RWrist_ResultNormMoment);
        [MinRWrist_ResultNormMomemt, MinRWr_ResNormMoment_Loc] =
min(RWrist_ResultNormMoment);



elseif SWSide == 2

    % Left Wrist
    [MaxLWrist_ForceX,MaxLWr_FX_Loc] = max(LWrist_ForceX);
        LWristAngX_MaxFX = LWrist_AngX(MaxLWr_FX_Loc);
    [MinLWrist_ForceX,MinLWr_FX_Loc] = min(LWrist_ForceX);
        LWristAngX_MinFX = LWrist_AngX(MinLWr_FX_Loc);
    [MaxLWrist_ForceY,MaxLWr_FY_Loc] = max(LWrist_ForceY);
        LWristAngY_MaxFY = LWrist_AngY(MaxLWr_FY_Loc);
    [MinLWrist_ForceY,MinLWr_FY_Loc] = min(LWrist_ForceY);
        LWristAngY_MinFY = LWrist_AngY(MinLWr_FY_Loc);
    [MaxLWrist_ForceZ,MaxLWr_FZ_Loc] = max(LWrist_ForceZ);
        LWristAngZ_MaxFZ = LWrist_AngZ(MaxLWr_FZ_Loc);
    [MinLWrist_ForceZ,MinLWr_FZ_Loc] = min(LWrist_ForceZ);
        LWristAngZ_MinFZ = LWrist_AngZ(MinLWr_FZ_Loc);

    [MaxLWrist_NormForceX,MaxLWr_NormFX_Loc] = max(LWrist_NormForceX);
        LWristAngX_MaxNormFX = LWrist_AngX(MaxLWr_NormFX_Loc);
    [MinLWrist_NormForceX,MinLWr_NormFX_Loc] = min(LWrist_NormForceX);
        LWristAngX_MinNormFX = LWrist_AngX(MinLWr_NormFX_Loc);
```

```
    [MaxLWrist_NormForceY,MaxLWr_NormFY_Loc] = max(LWrist_NormForceY);
        LWristAngY_MaxNormFY = LWrist_AngY(MaxLWr_NormFY_Loc);
    [MinLWrist_NormForceY,MinLWr_NormFY_Loc] = min(LWrist_NormForceY);
        LWristAngY_MinNormFY = LWrist_AngY(MinLWr_NormFY_Loc);
    [MaxLWrist_NormForceZ,MaxLWr_NormFZ_Loc] = max(LWrist_NormForceZ);
        LWristAngZ_MaxNormFZ = LWrist_AngZ(MaxLWr_NormFZ_Loc);
    [MinLWrist_NormForceZ,MinLWr_NormFZ_Loc] = min(LWrist_NormForceZ);
        LWristAngZ_MinNormFZ = LWrist_AngZ(MinLWr_NormFZ_Loc);

    LWrist_ResultNormForce = (sqrt(LWrist_NormForceX.^2 +
LWrist_NormForceY .^2 + LWrist_NormForceZ .^2));
        [MaxLWrist_ResultNormForce, MaxLWr_ResNormForce_Loc] =
max(LWrist_ResultNormForce);
        [MinLWrist_ResultNormForce, MinLWr_ResNormForce_Loc] =
min(LWrist_ResultNormForce);

    [MaxLWrist_MomentX,MaxLWr_MomX_Loc] = max(LWrist_MomentX);
        LWristAngX_MaxMomX = LWrist_AngX(MaxLWr_MomX_Loc);
    [MinLWrist_MomentX,MinLWr_MomX_Loc] = min(LWrist_MomentX);
        LWristAngX_MinMomX = LWrist_AngY(MinLWr_MomX_Loc);
    [MaxLWrist_MomentY,MaxLWr_MomY_Loc] = max(LWrist_MomentY);
        LWristAngY_MaxMomY = LWrist_AngY(MaxLWr_MomY_Loc);
    [MinLWrist_MomentY,MinLWr_MomY_Loc] = min(LWrist_MomentY);
        LWristAngY_MinMomY = LWrist_AngY(MinLWr_MomY_Loc);
    [MaxLWrist_MomentZ,MaxLWr_MomZ_Loc] = max(LWrist_MomentZ);
        LWristAngZ_MaxMomZ = LWrist_AngZ(MaxLWr_MomZ_Loc);
    [MinLWrist_MomentZ,MinLWr_MomZ_Loc] = min(LWrist_MomentZ);
        LWristAngZ_MinMomZ = LWrist_AngZ(MinLWr_MomZ_Loc);

    [MaxLWrist_NormMomentX,MaxLWr_NormMomX_Loc] =
max(LWrist_NormMomentX);
        LWristAngX_MaxNormMomX = LWrist_AngX(MaxLWr_NormMomX_Loc);
    [MinLWrist_NormMomentX,MinLWr_NormMomX_Loc] =
min(LWrist_NormMomentX);
        LWristAngX_MinNormMomX = LWrist_AngX(MinLWr_NormMomX_Loc);
    [MaxLWrist_NormMomentY,MaxLWr_NormMomY_Loc] =
max(LWrist_NormMomentY);
        LWristAngY_MaxNormMomY = LWrist_AngY(MaxLWr_NormMomY_Loc);
    [MinLWrist_NormMomentY,MinLWr_NormMomY_Loc] =
min(LWrist_NormMomentY);
        LWristAngY_MinNormMomY = LWrist_AngY(MinLWr_NormMomY_Loc);
    [MaxLWrist_NormMomentZ,MaxLWr_NormMomZ_Loc] =
max(LWrist_NormMomentZ);
        LWristAngZ_MaxNormMomZ = LWrist_AngZ(MaxLWr_NormMomZ_Loc);
    [MinLWrist_NormMomentZ,MinLWr_NormMomZ_Loc] =
min(LWrist_NormMomentZ);
        LWristAngZ_MinNormMomZ = LWrist_AngZ(MinLWr_NormMomZ_Loc);

    LWrist_ResultNormMoment = (sqrt(LWrist_NormMomentX.^2 +
LWrist_NormMomentY .^2 + LWrist_NormMomentZ .^2));
        [MaxLWrist_ResultNormMoment, MaxLWr_ResNormMoment_Loc] =
max(LWrist_ResultNormMoment);
        [MinLWrist_ResultNormMomemt, MinLWr_ResNormMoment_Loc] =
min(LWrist_ResultNormMoment);
```

```
end


%%%%%%%%%%%%%%%%% Write Data to Excel File %%%%%%%%%%%%%%%%%%%%%%%%%%

% Output Data to an Excel File
% Setup xlswrite1

Excel = actxserver ('Excel.Application');
File = fileout;
if ~exist(File,'file')
    ExcelWorkbook = Excel.workbooks.Add;
    ExcelWorkbook.SaveAs(File,1);
    ExcelWorkbook.Close(false);
end
Excel.Workbooks.Open(File);

% Create row and column headers

Rightheader = {'RWrist X','RWrist Y','RWrist Z','RElbow X','RElbow
Y','RElbow Z','RGH X','RGH Y','RGH Z','RScap X','RScap Y','RScap
Z','RClav X','RClav Y','RClav Z'};
Leftheader = {'LWrist X','LWrist Y','LWrist Z','LElbow X','LElbow
Y','LElbow Z','LGH X','LGH Y','LGH Z','LScap X','LScap Y','LScap
Z','LClav X','LClav Y','LClav Z'};
Rowheaderdom(1:11,1) = {'Max Angle', 'Min Angle','ROM','Max Normalized
Force','Min Normalized Force','Max Normalized Moment','Min Normalized
Moment','Angle at Max Normalized Force','Angle at Min Normalized
Force','Angle at Max Normalized Moment','Angle at Min Normalized
Moment'};
Rowheadernondom(1:3,1) = {'Max Angle', 'Min Angle','ROM'};

xlswrite1(fileout,Rightheader,'Right Side Stats','B1');
xlswrite1(fileout,Leftheader,'Left Side Stats','B1');

if SWSide == 1
    xlswrite1(fileout,Rowheaderdom,'Right Side Stats','A2');
    xlswrite1(fileout,Rowheadernondom,'Left Side Stats','A2');

elseif SWSide == 2
    xlswrite1(fileout,Rowheadernondom,'Right Side Stats','A2');
    xlswrite1(fileout,Rowheaderdom,'Left Side Stats','A2');

end

%%%%%%%%%%%%%%%% Write angles and ROM to Excel %%%%%%%%%%%%%%%%

% Right Wrist
xlswrite1(fileout,MaxRWrist_AngX,'Right Side Stats','B2');
xlswrite1(fileout,MaxRWrist_AngY,'Right Side Stats','C2');
```

```
xlswrite1(fileout,MaxRWrist_AngZ,'Right Side Stats','D2');
xlswrite1(fileout,MinRWrist_AngX,'Right Side Stats','B3');
xlswrite1(fileout,MinRWrist_AngY,'Right Side Stats','C3');
xlswrite1(fileout,MinRWrist_AngZ,'Right Side Stats','D3');
xlswrite1(fileout,ROMRWrist_AngX,'Right Side Stats','B4');
xlswrite1(fileout,ROMRWrist_AngY,'Right Side Stats','C4');


% Left Wrist
xlswrite1(fileout,MaxLWrist_AngX,'Left Side Stats','B2');
xlswrite1(fileout,MaxLWrist_AngY,'Left Side Stats','C2');
xlswrite1(fileout,MaxLWrist_AngZ,'Left Side Stats','D2');
xlswrite1(fileout,MinLWrist_AngX,'Left Side Stats','B3');
xlswrite1(fileout,MinLWrist_AngY,'Left Side Stats','C3');
xlswrite1(fileout,MinLWrist_AngZ,'Left Side Stats','D3');
xlswrite1(fileout,ROMLWrist_AngX,'Left Side Stats','B4');
xlswrite1(fileout,ROMLWrist_AngY,'Left Side Stats','C4');
xlswrite1(fileout,ROMLWrist_AngZ,'Left Side Stats','D4');


%%%% Write forces/moments/angle at max/min to Excel %%%%

if SWSide == 1
    % Right wrist
    xlswrite1(fileout,MaxRWrist_NormForceX,'Right Side Stats','B5');
    xlswrite1(fileout,MaxRWrist_NormForceY,'Right Side Stats','C5');
    xlswrite1(fileout,MaxRWrist_NormForceZ,'Right Side Stats','D5');
    xlswrite1(fileout,MinRWrist_NormForceX,'Right Side Stats','B6');
    xlswrite1(fileout,MinRWrist_NormForceY,'Right Side Stats','C6');
    xlswrite1(fileout,MinRWrist_NormForceZ,'Right Side Stats','D6');

    xlswrite1(fileout,RWristAngX_MaxNormFX,'Right Side Stats','B9');
    xlswrite1(fileout,RWristAngY_MaxNormFY,'Right Side Stats','C9');
    xlswrite1(fileout,RWristAngZ_MaxNormFZ,'Right Side Stats','D9');
    xlswrite1(fileout,RWristAngX_MinNormFX,'Right Side Stats','B10');
    xlswrite1(fileout,RWristAngY_MinNormFY,'Right Side Stats','C10');
    xlswrite1(fileout,RWristAngZ_MinNormFZ,'Right Side Stats','D10');

    xlswrite1(fileout,MaxRWrist_NormMomentX,'Right Side Stats','B7');
    xlswrite1(fileout,MaxRWrist_NormMomentY,'Right Side Stats','C7');
    xlswrite1(fileout,MaxRWrist_NormMomentZ,'Right Side Stats','D7');
    xlswrite1(fileout,MinRWrist_NormMomentX,'Right Side Stats','B8');
    xlswrite1(fileout,MinRWrist_NormMomentY,'Right Side Stats','C8');
    xlswrite1(fileout,MinRWrist_NormMomentZ,'Right Side Stats','D8');

    xlswrite1(fileout,RWristAngX_MaxNormMomX,'Right Side Stats','B11');
    xlswrite1(fileout,RWristAngY_MaxNormMomY,'Right Side Stats','C11');
    xlswrite1(fileout,RWristAngZ_MaxNormMomZ,'Right Side Stats','D11');
    xlswrite1(fileout,RWristAngX_MinNormMomX,'Right Side Stats','B12');
    xlswrite1(fileout,RWristAngY_MinNormMomY,'Right Side Stats','C12');
    xlswrite1(fileout,RWristAngZ_MinNormMomZ,'Right Side Stats','D12');
```

```
elseif SWSide == 2

    % Left wrist
    xlswrite1(fileout,MaxLWrist_NormForceX,'Left Side Stats','B5');
    xlswrite1(fileout,MaxLWrist_NormForceY,'Left Side Stats','C5');
    xlswrite1(fileout,MaxLWrist_NormForceZ,'Left Side Stats','D5');
    xlswrite1(fileout,MinLWrist_NormForceX,'Left Side Stats','B6');
    xlswrite1(fileout,MinLWrist_NormForceY,'Left Side Stats','C6');
    xlswrite1(fileout,MinLWrist_NormForceZ,'Left Side Stats','D6');

    xlswrite1(fileout,LWristAngX_MaxNormFX,'Left Side Stats','B9');
    xlswrite1(fileout,LWristAngY_MaxNormFY,'Left Side Stats','C9');
    xlswrite1(fileout,LWristAngZ_MaxNormFZ,'Left Side Stats','D9');
    xlswrite1(fileout,LWristAngX_MinNormFX,'Left Side Stats','B10');
    xlswrite1(fileout,LWristAngY_MinNormFY,'Left Side Stats','C10');
    xlswrite1(fileout,LWristAngZ_MinNormFZ,'Left Side Stats','D10');

    xlswrite1(fileout,MaxLWrist_NormMomentX,'Left Side Stats','B7');
    xlswrite1(fileout,MaxLWrist_NormMomentY,'Left Side Stats','C7');
    xlswrite1(fileout,MaxLWrist_NormMomentZ,'Left Side Stats','D7');
    xlswrite1(fileout,MinLWrist_NormMomentX,'Left Side Stats','B8');
    xlswrite1(fileout,MinLWrist_NormMomentY,'Left Side Stats','C8');
    xlswrite1(fileout,MinLWrist_NormMomentZ,'Left Side Stats','D8');

    xlswrite1(fileout,LWristAngX_MaxNormMomX,'Left Side Stats','B11');
    xlswrite1(fileout,LWristAngY_MaxNormMomY,'Left Side Stats','C11');
    xlswrite1(fileout,LWristAngZ_MaxNormMomZ,'Left Side Stats','D11');
    xlswrite1(fileout,LWristAngX_MinNormMomX,'Left Side Stats','B12');
    xlswrite1(fileout,LWristAngY_MinNormMomY,'Left Side Stats','C12');
    xlswrite1(fileout,LWristAngZ_MinNormMomZ,'Left Side Stats','D12');



   % Left Shoulder
    xlswrite1(fileout,MaxLGH_NormForceX,'Left Side Stats','H5');
    xlswrite1(fileout,MaxLGH_NormForceY,'Left Side Stats','I5');
    xlswrite1(fileout,MaxLGH_NormForceZ,'Left Side Stats','J5');
    xlswrite1(fileout,MinLGH_NormForceX,'Left Side Stats','H6');
    xlswrite1(fileout,MinLGH_NormForceY,'Left Side Stats','I6');
    xlswrite1(fileout,MinLGH_NormForceZ,'Left Side Stats','J6');

    xlswrite1(fileout,LGHAngX_MaxNormFX,'Left Side Stats','H9');
    xlswrite1(fileout,LGHAngY_MaxNormFY,'Left Side Stats','I9');
    xlswrite1(fileout,LGHAngZ_MaxNormFZ,'Left Side Stats','J9');
    xlswrite1(fileout,LGHAngX_MinNormFX,'Left Side Stats','H10');
    xlswrite1(fileout,LGHAngY_MinNormFY,'Left Side Stats','I10');
    xlswrite1(fileout,LGHAngZ_MinNormFZ,'Left Side Stats','J10');

    xlswrite1(fileout,MaxLGH_NormMomentX,'Left Side Stats','H7');
    xlswrite1(fileout,MaxLGH_NormMomentY,'Left Side Stats','I7');
    xlswrite1(fileout,MaxLGH_NormMomentZ,'Left Side Stats','J7');
    xlswrite1(fileout,MinLGH_NormMomentX,'Left Side Stats','H8');
```

```
    xlswrite1(fileout,MinLGH_NormMomentY,'Left Side Stats','I8');
    xlswrite1(fileout,MinLGH_NormMomentZ,'Left Side Stats','J8');

    xlswrite1(fileout,LGHAngX_MaxNormMomX,'Left Side Stats','H11');
    xlswrite1(fileout,LGHAngY_MaxNormMomY,'Left Side Stats','I11');
    xlswrite1(fileout,LGHAngZ_MaxNormMomZ,'Left Side Stats','J11');
    xlswrite1(fileout,LGHAngX_MinNormMomX,'Left Side Stats','H12');
    xlswrite1(fileout,LGHAngY_MinNormMomY,'Left Side Stats','I12');
    xlswrite1(fileout,LGHAngZ_MinNormMomZ,'Left Side Stats','J12');



end

Excel.ActiveWorkbook.Save;
Excel.Quit
Excel.delete
clear Excel

fprintf('Weight Relief Processing Complete. \n BAM! \n');
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%     Use to compile data for statistical analysis     %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


% Enter file path for INPUT to read in .xls for trials from avg file
FilePath = 'C:\R4 Study Data\03 - Modeling Results\Subject\Subject
Averages\';
FileName = 'Subject Overall Averages - 10 Cycles';
FileExt = '.xls';

% Enter file path for Excel OUTPUT file
fileout = 'C:\R4 Study Data\03 - Modeling Results\Subject\Subject
Compiled Data for Stats Analysis.xls';

%Please enter what side of the Wheelchair the smartwheel is on:
    %Enter 1 for Right side
    %Enter 2 for Left Side
SWSide = 1;

%%%%%  Please enter Subject specific data %%%%%

%Enter Subject number
    Subject(1:10,1) = {'000'};
% Enter trial type 'Start' 'Stop' or 'Prop'
    TrialType(1:10,1) = {'Prop'};
% Enter date of testing as 'DD/MM/YYYY'
    Date_Test(1:10,1) = {''DD/MM/YYYY '};
% Enter age in years to nearest 10th ex: '12.3'
    Age(1:10,1) = {'0.0};
% Enter dominant limb 'Right' or 'Left'
    LimbDom(1:10,1) = {'Right'};
% Enter gender 'Male' or 'Female'
    Gender(1:10,1) = {'Male'};
% Enter height in cm
    Height(1:10,1) = {'100.0'};
% Enter weight in kg
    Weight(1:10,1) = {'25.0'};



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%                      DO NOT EDIT BELOW THIS LINE
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% read in data from Excel File
% Setup xlsread1

filepath = strcat(FilePath,FileName,FileExt);
    Excel = actxserver('Excel.Application');
    Excel.Workbooks.Open(filepath);
    Excel.Workbooks.Item(FileName).RunAutoMacros(1);
```

```
    File = filepath;
        if ~exist(File,'file')
            ExcelWorkbook = Excel.Workbooks.Add;
            ExcelWorkbook.SaveAs(File,1);
            ExcelWorkbook.Close(false);
        end
    Excel.Workbooks.Open(File);

% Read in ROM data

% Right Wrist
    Max_RWrist_Ang = xlsread1(filepath, 'Right Angle Stats','B3:G12');
    Min_RWrist_Ang = xlsread1(filepath, 'Right Angle Stats','H3:M12');



% Left Wrist
    Max_LWrist_Ang = xlsread1(filepath, 'Left Angle Stats','B3:G12');
    Min_LWrist_Ang = xlsread1(filepath, 'Left Angle Stats','H3:M12');

% Read in dominant side forces/moments

if SWSide==1
    % Right Wrist
    Max_RWrist_Force = xlsread1(filepath,'Right Dynamic
Stats','B3:G12');
    Min_RWrist_Force = xlsread1(filepath,'Right Dynamic
Stats','H3:M12');
    Max_RWrist_Moment = xlsread1(filepath,'Right Dynamic
Stats','AU3:AZ12');
    Min_RWrist_Moment = xlsread1(filepath,'Right Dynamic
Stats','BA3:BF12');

elseif SWSide==2

    % Left Wrist
    Max_LWrist_Force = xlsread1(filepath,'Left Dynamic
Stats','B3:G12');
    Min_LWrist_Force = xlsread1(filepath,'Left Dynamic
Stats','H3:M12');
    Max_LWrist_Moment = xlsread1(filepath,'Left Dynamic
Stats','AU3:AZ12');
    Min_LWrist_Moment = xlsread1(filepath,'Left Dynamic
Stats','BA3:BF12');




    end

%Excel.ActiveWorkbook.Save;
Excel.Quit
Excel.delete
clear Excel
```

```
%%%%%%%%%%% Write out data %%%%%%%%%%%%%
% Setup xlswrite1

Excel = actxserver ('Excel.Application');
File = fileout;
if ~exist(File,'file')
    ExcelWorkbook = Excel.workbooks.Add;
    ExcelWorkbook.SaveAs(File,1);
    ExcelWorkbook.Close(false);
end
Excel.Workbooks.Open(File);

%%%% Subject Specific Data %%%%

xlswrite1(fileout,Subject,'Outcomes','A2');
xlswrite1(fileout,TrialType,'Outcomes','C2');
xlswrite1(fileout,Date_Test,'Outcomes','D2');
xlswrite1(fileout,Age,'Outcomes','E2');
xlswrite1(fileout,LimbDom,'Outcomes','F2');
xlswrite1(fileout,Gender,'Outcomes','G2');
xlswrite1(fileout,Height,'Outcomes','H2');
xlswrite1(fileout,Weight,'Outcomes','I2');


ColumnHeader = {'Subject #','Cycle #','Type of Cycle','Date of
testing','Age','Limb dominance','Gender','Height','Weight','Propulsion
Pattern','Max Wrist Fx Dominant','Max Wrist Fx Dominant % Cycle','Max
Wrist Fy Dominant','Max Wrist Fy Dominant % Cycle','Max Wrist Fz
Dominant','Max Wrist Fz Dominant % Cycle','Min Wrist Fx Dominant','Min
Wrist Fx Dominant % Cycle','Min Wrist Fy Dominant','Min Wrist Fy
Dominant % Cycle','Min Wrist Fz Dominant','Min Wrist Fz Dominant %
Cycle','Max Wrist Mx Dominant','Max Wrist Mx Dominant % Cycle','Max
Wrist My Dominant','Max Wrist My Dominant % Cycle','Max Wrist Mz
Dominant','Max Wrist Mz Dominant % Cycle','Min Wrist Mx Dominant','Min
Wrist Mx Dominant % Cycle','Min Wrist My Dominant','Min Wrist My
Dominant % Cycle','Min Wrist Mz Dominant','Min Wrist Mz Dominant %
Cycle','Max Wrist angle in x Dominant','Max Wrist angle in x Dominant %
Cycle','Max Wrist angle in y Dominant','Max Wrist angle in y Dominant %
Cycle','Max Wrist angle in z Dominant','Max Wrist angle in z Dominant %
Cycle','Min Wrist angle in x Dominant','Min Wrist angle in x Dominant %
Cycle','Min Wrist angle in y Dominant','Min Wrist angle in y Dominant %
Cycle','Min Wrist angle in z Dominant','Min Wrist angle in z Dominant %
Cycle','Max Wrist angle in x Non Dominant','Max Wrist angle in x Non
Dominant % Cycle','Max Wrist angle in y Non Dominant','Max Wrist angle
in y Non Dominant % Cycle','Max Wrist angle in z Non Dominant','Max
Wrist angle in z Non Dominant % Cycle','Min Wrist angle in x Non
Dominant','Min Wrist angle in x Non Dominant % Cycle','Min Wrist angle
in y Non Dominant','Min Wrist angle in y Non Dominant % Cycle','Min
Wrist angle in z Non Dominant','Min Wrist angle in z Non Dominant %
```

```
Cycle','Max Elbow Fx Dominant','Max Elbow Fx Dominant % Cycle','Max
Elbow Fy Dominant','Max Elbow Fy Dominant % Cycle','Max Elbow Fz
Dominant','Max Elbow Fz Dominant % Cycle','Min Elbow Fx Dominant','Min
Elbow Fx Dominant % Cycle','Min Elbow Fy Dominant','Min Elbow Fy
Dominant % Cycle','Min Elbow Fz Dominant','Min Elbow Fz Dominant %
Cycle','Max Elbow Mx Dominant','Max Elbow Mx Dominant % Cycle','Max
Elbow My Dominant','Max Elbow My Dominant % Cycle','Max Elbow Mz
Dominant','Max Elbow Mz Dominant % Cycle','Min Elbow Mx Dominant','Min
Elbow Mx Dominant % Cycle','Min Elbow My Dominant','Min Elbow My
Dominant % Cycle','Min Elbow Mz Dominant','Min Elbow Mz Dominant %
Cycle','Max Elbow angle in x Dominant','Max Elbow angle in x Dominant %
Cycle','Max Elbow angle in y Dominant','Max Elbow angle in y Dominant %
Cycle','Max Elbow angle in z Dominant','Max Elbow angle in z Dominant %
Cycle','Min Elbow angle in x Dominant','Min Elbow angle in x Dominant %
Cycle','Min Elbow angle in y Dominant','Min Elbow angle in y Dominant %
Cycle','Min Elbow angle in z Dominant','Min Elbow angle in z Dominant %
Cycle','Max Elbow angle in x Non Dominant','Max Elbow angle in x Non
Dominant % Cycle','Max Elbow angle in y Non Dominant','Max Elbow angle
in y Non Dominant % Cycle','Max Elbow angle in z Non Dominant','Max
Elbow angle in z Non Dominant % Cycle','Min Elbow angle in x Non
Dominant','Min Elbow angle in x Non Dominant % Cycle','Min Elbow angle
in y Non Dominant','Min Elbow angle in y Non Dominant % Cycle','Min
Elbow angle in z Non Dominant','Min Elbow angle in z Non Dominant %
Cycle','Max GH Fx Dominant','Max GH Fx Dominant % Cycle','Max GH Fy
Dominant','Max GH Fy Dominant % Cycle','Max GH Fz Dominant','Max GH Fz
Dominant % Cycle','Min GH Fx Dominant','Min GH Fx Dominant %
Cycle','Min GH Fy Dominant','Min GH Fy Dominant % Cycle','Min GH Fz
Dominant','Min GH Fz Dominant % Cycle','Max GH Mx Dominant','Max GH Mx
Dominant % Cycle','Max GH My Dominant','Max GH My Dominant %
Cycle','Max GH Mz Dominant','Max GH Mz Dominant % Cycle','Min GH Mx
Dominant','Min GH Mx Dominant % Cycle','Min GH My Dominant','Min GH My
Dominant % Cycle','Min GH Mz Dominant','Min GH Mz Dominant %
Cycle','Max GH angle in x Dominant','Max GH angle in x Dominant %
Cycle','Max GH angle in y Dominant','Max GH angle in y Dominant %
Cycle','Max GH angle in z Dominant','Max GH angle in z Dominant %
Cycle','Min GH angle in x Dominant','Min GH angle in x Dominant %
Cycle','Min GH angle in y Dominant','Min GH angle in y Dominant %
Cycle','Min GH angle in z Dominant','Min GH angle in z Dominant %
Cycle','Max GH angle in x Non Dominant','Max GH angle in x Non Dominant
% Cycle','Max GH angle in y Non Dominant','Max GH angle in y Non
Dominant % Cycle','Max GH angle in z Non Dominant','Max GH angle in z
Non Dominant % Cycle','Min GH angle in x Non Dominant','Min GH angle in
x Non Dominant % Cycle','Min GH angle in y Non Dominant','Min GH angle
in y Non Dominant % Cycle','Min GH angle in z Non Dominant','Min GH
angle in z Non Dominant %
Cycle','VAS','PCS','MCS','GH01','PF02','PF04','RP02','RP03','RE02','RE0
3','BP02','MH03','VT02','MH04','SF02','PF','RP','BP','GH','VT','SF','RE
','MH','PF_NBS','RP_NBS','BP_NBS','GH_NBS','VT_NBS','SF_NBS','RE_NBS','
MH_NBS'};

xlswrite1(fileout,ColumnHeader,'Outcomes','A1');

%%%% Angles %%%%
```

```
if SWSide==1

% Right Wrist (Dominant)
xlswrite1(fileout,Max_RWrist_Ang,'Outcomes','AI2:AN11');
xlswrite1(fileout,Min_RWrist_Ang,'Outcomes','AO2:AT11');

% Left Wrist (Non-Dominant)
xlswrite1(fileout,Max_LWrist_Ang,'Outcomes','AU2:AZ11');
xlswrite1(fileout,Min_LWrist_Ang,'Outcomes','BA2:BF11');

elseif SWSide==2

% Left Wrist (Dominant)
xlswrite1(fileout,Max_LWrist_Ang,'Outcomes','AI2:AN11');
xlswrite1(fileout,Min_RWrist_Ang,'Outcomes','AO2:AT11');


% Right Wrist (Non-Dominant)
xlswrite1(fileout,Max_RWrist_Ang,'Outcomes','AU2:AZ11');
xlswrite1(fileout,Min_RWrist_Ang,'Outcomes','BA2:BF11');


end


%%%% Forces and Moments %%%%

if SWSide==1

% Right Wrist
    xlswrite1(fileout,Max_RWrist_Force,'Outcomes','K2:P11');
    xlswrite1(fileout,Min_RWrist_Force,'Outcomes','Q2:V11');
    xlswrite1(fileout,Max_RWrist_Moment,'Outcomes','W2:AB11');
    xlswrite1(fileout,Min_RWrist_Moment,'Outcomes','AC2:AH11');

elseif SWSide==2

% Left Wrist
    xlswrite1(fileout,Max_LWrist_Force,'Outcomes','K2:P11');
    xlswrite1(fileout,Min_LWrist_Force,'Outcomes','Q2:V11');
    xlswrite1(fileout,Max_LWrist_Moment,'Outcomes','W2:AB11');
    xlswrite1(fileout,Min_LWrist_Moment,'Outcomes','AC2:AH11');

end

Excel.ActiveWorkbook.Save;
Excel.Quit
Excel.delete
clear Excel
```

```
fprintf('Statistical Analysis Code Complete. \n WINNER! \n');
```

Appendix H: Pearson's Correlation Results

===

The analysis of Max.Fx.Dominant; task = Prop; joint = w.
The correlation between Max.Fx.Dominant and PCS is -0.1204; the CI is -0.6119 to 0.4382; P-value = 0.6818.The correlation between Max.Fx.Dominant and MCS is -0.1088; the CI is -0.6045 to 0.4476; P-value = 0.7111.

===

The analysis of Max.Fy.Dominant; task = Prop; joint = w.
The correlation between Max.Fy.Dominant and PCS is 0.1809; the CI is -0.3868 to 0.6491; P-value = 0.5361.The correlation between Max.Fy.Dominant and MCS is 0.1928; the CI is -0.3763 to 0.6562; P-value = 0.509.

===

The analysis of Max.Fz.Dominant; task = Prop; joint = w.
The correlation between Max.Fz.Dominant and PCS is 0.2586; the CI is -0.3153 to 0.6939; P-value = 0.3721.The correlation between Max.Fz.Dominant and MCS is -0.266; the CI is -0.6981 to 0.3081; P-value = 0.358.

==

The analysis of Min.Fx.Dominant; task = Prop; joint = w.
The correlation between Min.Fx.Dominant and PCS is -0.163; the CI is -0.6384 to 0.4024; P-value = 0.5777.The correlation between Min.Fx.Dominant and MCS is 0.028; the CI is -0.5102 to 0.5504; P-value = 0.9243.

==

The analysis of Min.Fy.Dominant; task = Prop; joint = w.
The correlation between Min.Fy.Dominant and PCS is 0.0693; the CI is -0.4789 to 0.5786; P-value = 0.8138.The correlation between Min.Fy.Dominant and MCS is 0.3193; the CI is -0.2543 to 0.7268; P-value = 0.2658.

==

The analysis of Min.Fz.Dominant; task = Prop; joint = w.
The correlation between Min.Fz.Dominant and PCS is -0.0407; the CI is -0.5592 to 0.5007; P-value = 0.89.The correlation between Min.Fz.Dominant and MCS is -0.3388; the CI is -0.7369 to 0.2338; P-value = 0.236.

==

The analysis of Max.Mx.Dominant; task = Prop; joint = w.
The correlation between Max.Mx.Dominant and PCS is 0.3172; the CI is -0.2566 to 0.7256; P-value = 0.2692.The correlation between Max.Mx.Dominant and MCS is 0.0396; the CI is -0.5016 to 0.5584; P-value = 0.8932.

==

The analysis of Max.My.Dominant; task = Prop; joint = w.
The correlation between Max.My.Dominant and PCS is 0.2556; the CI is -0.3182 to 0.6923; P-value = 0.3779.The correlation between Max.My.Dominant and MCS is 0.0816; the CI is -0.4693 to 0.5868; P-value = 0.7815.

==
The analysis of Max.Mz.Dominant; task = Prop; joint = w.
The correlation between Max.Mz.Dominant and PCS is -0.2134; the CI is -0.6683 to 0.3576; P-value = 0.4637.The correlation between Max.Mz.Dominant and MCS is -0.1217; the CI is -0.6127 to 0.4371; P-value = 0.6785.
==
The analysis of Min.Mx.Dominant; task = Prop; joint = w.
The correlation between Min.Mx.Dominant and PCS is -0.0456; the CI is -0.5625 to 0.497; P-value = 0.8771.The correlation between Min.Mx.Dominant and MCS is 0.0934; the CI is -0.46 to 0.5945; P-value = 0.7509.
==
The analysis of Min.My.Dominant; task = Prop; joint = w.
The correlation between Min.My.Dominant and PCS is 0.0972; the CI is -0.4569 to 0.597; P-value = 0.7409.The correlation between Min.My.Dominant and MCS is -0.1177; the CI is -0.6102 to 0.4404; P-value = 0.6887.
==
The analysis of Min.Mz.Dominant; task = Prop; joint = w.
The correlation between Min.Mz.Dominant and PCS is -0.1667; the CI is -0.6406 to 0.3992; P-value = 0.569.The correlation between Min.Mz.Dominant and MCS is 0.1561; the CI is -0.4083 to 0.6341; P-value = 0.5941.
==
The analysis of Max.Fx.Dominant; task = Prop; joint = e.
The correlation between Max.Fx.Dominant and PCS is -0.0818; the CI is -0.5869 to 0.4692; P-value = 0.7811.The correlation between Max.Fx.Dominant and MCS is -0.0153; the CI is -0.5415 to 0.5195; P-value = 0.9585.
==
The analysis of Max.Fy.Dominant; task = Prop; joint = e.
The correlation between Max.Fy.Dominant and PCS is 0.4219; the CI is -0.14 to 0.7783; P-value = 0.1329.The correlation between Max.Fy.Dominant and MCS is -0.0129; the CI is -0.5398 to 0.5212; P-value = 0.965.
==
The analysis of Max.Fz.Dominant; task = Prop; joint = e.
The correlation between Max.Fz.Dominant and PCS is 0.3238; the CI is -0.2496 to 0.7291; P-value = 0.2587.The correlation between Max.Fz.Dominant and MCS is -0.2926; the CI is -0.7126 to 0.2817; P-value = 0.31.
==
The analysis of Min.Fx.Dominant; task = Prop; joint = e.
The correlation between Min.Fx.Dominant and PCS is -0.0911; the CI is -0.593 to 0.4618; P-value = 0.7567.The correlation between Min.Fx.Dominant and MCS is 0.2344; the CI is -0.3382 to 0.6804; P-value = 0.4198.
==
The analysis of Min.Fy.Dominant; task = Prop; joint = e.

The correlation between Min.Fy.Dominant and PCS is 0.1257; the CI is -0.4338 to 0.6152; P-value = 0.6686.The correlation between Min.Fy.Dominant and MCS is 0.131; the CI is -0.4294 to 0.6186; P-value = 0.6554.

===
The analysis of Min.Fz.Dominant; task = Prop; joint = e.
The correlation between Min.Fz.Dominant and PCS is 0.0273; the CI is -0.5107 to 0.5499; P-value = 0.9263.The correlation between Min.Fz.Dominant and MCS is -0.3325; the CI is -0.7336 to 0.2405; P-value = 0.2454.
===
The analysis of Max.Mx.Dominant; task = Prop; joint = e.
The correlation between Max.Mx.Dominant and PCS is 0.2025; the CI is -0.3676 to 0.662; P-value = 0.4875.The correlation between Max.Mx.Dominant and MCS is 0.1184; the CI is -0.4398 to 0.6106; P-value = 0.6869.
===
The analysis of Max.My.Dominant; task = Prop; joint = e.
The correlation between Max.My.Dominant and PCS is 0.0525; the CI is -0.4918 to 0.5673; P-value = 0.8585.The correlation between Max.My.Dominant and MCS is 0.3232; the CI is -0.2503 to 0.7288; P-value = 0.2596.
===
The analysis of Max.Mz.Dominant; task = Prop; joint = e.
The correlation between Max.Mz.Dominant and PCS is -0.1943; the CI is -0.6572 to 0.3749; P-value = 0.5056.The correlation between Max.Mz.Dominant and MCS is 0.0186; the CI is -0.5171 to 0.5438; P-value = 0.9496.
===
The analysis of Min.Mx.Dominant; task = Prop; joint = e.
The correlation between Min.Mx.Dominant and PCS is -0.2733; the CI is -0.7021 to 0.3009; P-value = 0.3444.The correlation between Min.Mx.Dominant and MCS is 0.226; the CI is -0.346 to 0.6756; P-value = 0.4371.
===
The analysis of Min.My.Dominant; task = Prop; joint = e.
The correlation between Min.My.Dominant and PCS is 0.1699; the CI is -0.3964 to 0.6426; P-value = 0.5613.The correlation between Min.My.Dominant and MCS is -0.4952; the CI is -0.8124 to 0.0479; P-value = 0.0718.
===
The analysis of Min.Mz.Dominant; task = Prop; joint = e.
The correlation between Min.Mz.Dominant and PCS is -0.0857; the CI is -0.5895 to 0.466; P-value = 0.7707.The correlation between Min.Mz.Dominant and MCS is 0.1676; the CI is -0.3984 to 0.6412; P-value = 0.5667.
===
The analysis of Max.Fx.Dominant; task = Prop; joint = g.
The correlation between Max.Fx.Dominant and PCS is -0.1889; the CI is -0.6539 to 0.3798; P-value = 0.5179.The correlation between Max.Fx.Dominant and MCS is 0.1047; the CI is -0.451 to 0.6018; P-value = 0.7218.
===

The analysis of Max.Fy.Dominant; task = Prop; joint = g.
The correlation between Max.Fy.Dominant and PCS is 0.1646; the CI is -0.401 to 0.6393; P-value = 0.5739.The correlation between Max.Fy.Dominant and MCS is -0.3643; the CI is -0.7499 to 0.2062; P-value = 0.2004.

==
The analysis of Max.Fz.Dominant; task = Prop; joint = g.
The correlation between Max.Fz.Dominant and PCS is 0.2995; the CI is -0.2747 to 0.7163; P-value = 0.2982.The correlation between Max.Fz.Dominant and MCS is -0.3064; the CI is -0.72 to 0.2677; P-value = 0.2866.
==
The analysis of Min.Fx.Dominant; task = Prop; joint = g.
The correlation between Min.Fx.Dominant and PCS is -0.1847; the CI is -0.6514 to 0.3835; P-value = 0.5273.The correlation between Min.Fx.Dominant and MCS is 0.1082; the CI is -0.4481 to 0.6041; P-value = 0.7127.
==
The analysis of Min.Fy.Dominant; task = Prop; joint = g.
The correlation between Min.Fy.Dominant and PCS is 0.1287; the CI is -0.4313 to 0.6171; P-value = 0.661.The correlation between Min.Fy.Dominant and MCS is 0.1999; the CI is -0.3699 to 0.6604; P-value = 0.4932.
==
The analysis of Min.Fz.Dominant; task = Prop; joint = g.
The correlation between Min.Fz.Dominant and PCS is 0.1494; the CI is -0.414 to 0.63; P-value = 0.6103.The correlation between Min.Fz.Dominant and MCS is -0.6647; the CI is -0.8836 to -0.2072; P-value = 0.0095.
==
The analysis of Max.Mx.Dominant; task = Prop; joint = g.
The correlation between Max.Mx.Dominant and PCS is -0.1274; the CI is -0.6163 to 0.4324; P-value = 0.6644.The correlation between Max.Mx.Dominant and MCS is 0.3851; the CI is -0.1828 to 0.7603; P-value = 0.1739.
==
The analysis of Max.My.Dominant; task = Prop; joint = g.
The correlation between Max.My.Dominant and PCS is 0.0947; the CI is -0.4589 to 0.5954; P-value = 0.7474.The correlation between Max.My.Dominant and MCS is 0.3211; the CI is -0.2525 to 0.7277; P-value = 0.2629.
==
The analysis of Max.Mz.Dominant; task = Prop; joint = g.
The correlation between Max.Mz.Dominant and PCS is 0.0493; the CI is -0.4942 to 0.5651; P-value = 0.8671.The correlation between Max.Mz.Dominant and MCS is -0.3052; the CI is -0.7193 to 0.2689; P-value = 0.2887.
==
The analysis of Min.Mx.Dominant; task = Prop; joint = g.
The correlation between Min.Mx.Dominant and PCS is 0.0186; the CI is -0.5171 to 0.5438; P-value = 0.9496.The correlation between Min.Mx.Dominant and MCS is 0.1435; the CI is -0.419 to 0.6264; P-value = 0.6245.

==
The analysis of Min.My.Dominant; task = Prop; joint = g.
The correlation between Min.My.Dominant and PCS is 0.2745; the CI is -0.2997 to 0.7028; P-value = 0.3422.The correlation between Min.My.Dominant and MCS is -0.3828; the CI is -0.7592 to 0.1854; P-value = 0.1767.

==
The analysis of Min.Mz.Dominant; task = Prop; joint = g.
The correlation between Min.Mz.Dominant and PCS is -0.1245; the CI is -0.6145 to 0.4348; P-value = 0.6716.The correlation between Min.Mz.Dominant and MCS is -0.1815; the CI is -0.6496 to 0.3862; P-value = 0.5345.
==
The analysis of Max.Fx.Dominant; task = Start; joint = w.
The correlation between Max.Fx.Dominant and PCS is -0.4433; the CI is -0.7991 to 0.1425; P-value = 0.1292.The correlation between Max.Fx.Dominant and MCS is 0.0846; the CI is -0.4892 to 0.6073; P-value = 0.7834.
==
The analysis of Max.Fy.Dominant; task = Start; joint = w.
The correlation between Max.Fy.Dominant and PCS is -0.3632; the CI is -0.7617 to 0.2348; P-value = 0.2226.The correlation between Max.Fy.Dominant and MCS is 0.0729; the CI is -0.4981 to 0.5998; P-value = 0.8128.
==
The analysis of Max.Fz.Dominant; task = Start; joint = w.
The correlation between Max.Fz.Dominant and PCS is 0.3066; the CI is -0.2941 to 0.7336; P-value = 0.3083.The correlation between Max.Fz.Dominant and MCS is -0.3549; the CI is -0.7577 to 0.2438; P-value = 0.2341.
==
The analysis of Min.Fx.Dominant; task = Start; joint = w.
The correlation between Min.Fx.Dominant and PCS is -0.3172; the CI is -0.739 to 0.2833; P-value = 0.291.The correlation between Min.Fx.Dominant and MCS is 0.2301; the CI is -0.3675 to 0.6932; P-value = 0.4495.
==
The analysis of Min.Fy.Dominant; task = Start; joint = w.
The correlation between Min.Fy.Dominant and PCS is -0.0036; the CI is -0.5535 to 0.5485; P-value = 0.9907.The correlation between Min.Fy.Dominant and MCS is 0.4387; the CI is -0.1481 to 0.797; P-value = 0.1337.
==
The analysis of Min.Fz.Dominant; task = Start; joint = w.
The correlation between Min.Fz.Dominant and PCS is -0.008; the CI is -0.5565 to 0.5454; P-value = 0.9793.The correlation between Min.Fz.Dominant and MCS is -0.1892; the CI is -0.6703 to 0.4039; P-value = 0.5358.
==
The analysis of Max.Mx.Dominant; task = Start; joint = w.

The correlation between Max.Mx.Dominant and PCS is 0.3605; the CI is -0.2377 to 0.7604; P-value = 0.2263.The correlation between Max.Mx.Dominant and MCS is -0.2018; the CI is -0.6775 to 0.3928; P-value = 0.5084.

==

The analysis of Max.My.Dominant; task = Start; joint = w.

The correlation between Max.My.Dominant and PCS is 0.4036; the CI is -0.1896 to 0.7809; P-value = 0.1715.The correlation between Max.My.Dominant and MCS is -0.1715; the CI is -0.6601 to 0.4191; P-value = 0.5753.

==

The analysis of Max.Mz.Dominant; task = Start; joint = w.

The correlation between Max.Mz.Dominant and PCS is -0.2019; the CI is -0.6775 to 0.3928; P-value = 0.5084.The correlation between Max.Mz.Dominant and MCS is -0.24; the CI is -0.6986 to 0.3584; P-value = 0.4296.

==

The analysis of Min.Mx.Dominant; task = Start; joint = w.

The correlation between Min.Mx.Dominant and PCS is 0.1448; the CI is -0.4414 to 0.6444; P-value = 0.6368.The correlation between Min.Mx.Dominant and MCS is 0.2708; the CI is -0.3293 to 0.7151; P-value = 0.3708.

==

The analysis of Min.My.Dominant; task = Start; joint = w.

The correlation between Min.My.Dominant and PCS is 0.3104; the CI is -0.2902 to 0.7356; P-value = 0.302.The correlation between Min.My.Dominant and MCS is -0.0837; the CI is -0.6067 to 0.4898; P-value = 0.7856.

==

The analysis of Min.Mz.Dominant; task = Start; joint = w.

The correlation between Min.Mz.Dominant and PCS is 0.0619; the CI is -0.5064 to 0.5927; P-value = 0.8408.The correlation between Min.Mz.Dominant and MCS is 0.5593; the CI is 0.012 to 0.8487; P-value = 0.0469.

==

The analysis of Max.Fx.Dominant; task = Start; joint = e.

The correlation between Max.Fx.Dominant and PCS is -0.4364; the CI is -0.796 to 0.1509; P-value = 0.136.The correlation between Max.Fx.Dominant and MCS is 0.061; the CI is -0.507 to 0.5921; P-value = 0.843.

==

The analysis of Max.Fy.Dominant; task = Start; joint = e.

The correlation between Max.Fy.Dominant and PCS is 0.2762; the CI is -0.3241 to 0.7179; P-value = 0.361.The correlation between Max.Fy.Dominant and MCS is 0.172; the CI is -0.4187 to 0.6604; P-value = 0.5742.

==

The analysis of Max.Fz.Dominant; task = Start; joint = e.

The correlation between Max.Fz.Dominant and PCS is 0.3113; the CI is -0.2893 to 0.7361; P-value = 0.3004.The correlation between Max.Fz.Dominant and MCS is -0.3788; the CI is -0.7692 to 0.2176; P-value = 0.2018.

==

The analysis of Min.Fx.Dominant; task = Start; joint = e.
The correlation between Min.Fx.Dominant and PCS is -0.2305; the CI is -0.6934 to 0.3671; P-value = 0.4488.The correlation between Min.Fx.Dominant and MCS is 0.4048; the CI is -0.1881 to 0.7815; P-value = 0.17.
==
The analysis of Min.Fy.Dominant; task = Start; joint = e.
The correlation between Min.Fy.Dominant and PCS is 0.1783; the CI is -0.4133 to 0.6641; P-value = 0.56.The correlation between Min.Fy.Dominant and MCS is 0.2401; the CI is -0.3583 to 0.6986; P-value = 0.4295.

==
The analysis of Min.Fz.Dominant; task = Start; joint = e.
The correlation between Min.Fz.Dominant and PCS is 0.0738; the CI is -0.4974 to 0.6004; P-value = 0.8106.The correlation between Min.Fz.Dominant and MCS is -0.0041; the CI is -0.5538 to 0.5482; P-value = 0.9895.
==
The analysis of Max.Mx.Dominant; task = Start; joint = e.
The correlation between Max.Mx.Dominant and PCS is 0.0242; the CI is -0.5339 to 0.5676; P-value = 0.9375.The correlation between Max.Mx.Dominant and MCS is -0.1; the CI is -0.617 to 0.4773; P-value = 0.7453.
==
The analysis of Max.My.Dominant; task = Start; joint = e.
The correlation between Max.My.Dominant and PCS is 0.08; the CI is -0.4927 to 0.6044; P-value = 0.7949.The correlation between Max.My.Dominant and MCS is -0.2101; the CI is -0.6821 to 0.3855; P-value = 0.4908.
==
The analysis of Max.Mz.Dominant; task = Start; joint = e.
The correlation between Max.Mz.Dominant and PCS is -0.2921; the CI is -0.7262 to 0.3086; P-value = 0.3329.The correlation between Max.Mz.Dominant and MCS is 0.0456; the CI is -0.5184 to 0.582; P-value = 0.8824.
==
The analysis of Min.Mx.Dominant; task = Start; joint = e.
The correlation between Min.Mx.Dominant and PCS is -0.0219; the CI is -0.5661 to 0.5355; P-value = 0.9433.The correlation between Min.Mx.Dominant and MCS is 0.4146; the CI is -0.1768 to 0.786; P-value = 0.159.
==
The analysis of Min.My.Dominant; task = Start; joint = e.
The correlation between Min.My.Dominant and PCS is 0.2263; the CI is -0.3709 to 0.6911; P-value = 0.4572.The correlation between Min.My.Dominant and MCS is -0.003; the CI is -0.553 to 0.5489; P-value = 0.9924.
==
The analysis of Min.Mz.Dominant; task = Start; joint = e.
The correlation between Min.Mz.Dominant and PCS is -0.213; the CI is -0.6837 to 0.383; P-value = 0.4848.The correlation between Min.Mz.Dominant and MCS is 0.5464; the CI is -0.0066 to 0.8435; P-value = 0.0534.

==
The analysis of Max.Fx.Dominant; task = Start; joint = g.
The correlation between Max.Fx.Dominant and PCS is -0.1437; the CI is -0.6437 to 0.4423; P-value = 0.6394.The correlation between Max.Fx.Dominant and MCS is 0.0404; the CI is -0.5222 to 0.5785; P-value = 0.8958.
==
The analysis of Max.Fy.Dominant; task = Start; joint = g.
The correlation between Max.Fy.Dominant and PCS is 0.4301; the CI is -0.1584 to 0.7931; P-value = 0.1424.The correlation between Max.Fy.Dominant and MCS is -0.1463; the CI is -0.6452 to 0.4402; P-value = 0.6335.

==
The analysis of Max.Fz.Dominant; task = Start; joint = g.
The correlation between Max.Fz.Dominant and PCS is 0.0787; the CI is -0.4937 to 0.6035; P-value = 0.7984.The correlation between Max.Fz.Dominant and MCS is -0.4038; the CI is -0.781 to 0.1894; P-value = 0.1713.
==
The analysis of Min.Fx.Dominant; task = Start; joint = g.
The correlation between Min.Fx.Dominant and PCS is -0.1652; the CI is -0.6564 to 0.4244; P-value = 0.5896.The correlation between Min.Fx.Dominant and MCS is 0.2589; the CI is -0.3407 to 0.7088; P-value = 0.393.
==
The analysis of Min.Fy.Dominant; task = Start; joint = g.
The correlation between Min.Fy.Dominant and PCS is 0.0853; the CI is -0.4887 to 0.6077; P-value = 0.7817.The correlation between Min.Fy.Dominant and MCS is 0.4376; the CI is -0.1494 to 0.7965; P-value = 0.1348.
==
The analysis of Min.Fz.Dominant; task = Start; joint = g.
The correlation between Min.Fz.Dominant and PCS is 0.1537; the CI is -0.4341 to 0.6496; P-value = 0.6162.The correlation between Min.Fz.Dominant and MCS is -0.2023; the CI is -0.6777 to 0.3924; P-value = 0.5075.
==
The analysis of Max.Mx.Dominant; task = Start; joint = g.
The correlation between Max.Mx.Dominant and PCS is 0.097; the CI is -0.4796 to 0.6151; P-value = 0.7526.The correlation between Max.Mx.Dominant and MCS is -0.1681; the CI is -0.6582 to 0.4219; P-value = 0.5829.
==
The analysis of Max.My.Dominant; task = Start; joint = g.
The correlation between Max.My.Dominant and PCS is 0.2833; the CI is -0.3172 to 0.7217; P-value = 0.3482.The correlation between Max.My.Dominant and MCS is 0.0703; the CI is -0.5001 to 0.5981; P-value = 0.8195.
==
The analysis of Max.Mz.Dominant; task = Start; joint = g.

The correlation between Max.Mz.Dominant and PCS is 0.1183; the CI is -0.4629 to 0.6283; P-value = 0.7003.The correlation between Max.Mz.Dominant and MCS is -0.4578; the CI is -0.8056 to 0.1247; P-value = 0.1157.
===
The analysis of Min.Mx.Dominant; task = Start; joint = g.
The correlation between Min.Mx.Dominant and PCS is 0.0831; the CI is -0.4904 to 0.6063; P-value = 0.7873.The correlation between Min.Mx.Dominant and MCS is 0.5084; the CI is -0.0592 to 0.8276; P-value = 0.0761.
===
The analysis of Min.My.Dominant; task = Start; joint = g.
The correlation between Min.My.Dominant and PCS is 0.441; the CI is -0.1453 to 0.7981; P-value = 0.1315.The correlation between Min.My.Dominant and MCS is 0.1537; the CI is -0.4341 to 0.6496; P-value = 0.6162.
===
The analysis of Min.Mz.Dominant; task = Start; joint = g.
The correlation between Min.Mz.Dominant and PCS is 0.297; the CI is -0.3037 to 0.7287; P-value = 0.3244.The correlation between Min.Mz.Dominant and MCS is 0.1425; the CI is -0.4433 to 0.643; P-value = 0.6424.
===
The analysis of Max.Fx.Dominant; task = Stop; joint = w.
The correlation between Max.Fx.Dominant and PCS is 0.1798; the CI is -0.3877 to 0.6485; P-value = 0.5384.The correlation between Max.Fx.Dominant and MCS is -0.4337; the CI is -0.7839 to 0.1258; P-value = 0.1213.
===
The analysis of Max.Fy.Dominant; task = Stop; joint = w.
The correlation between Max.Fy.Dominant and PCS is 0.0405; the CI is -0.5008 to 0.5591; P-value = 0.8907.The correlation between Max.Fy.Dominant and MCS is -0.0242; the CI is -0.5478 to 0.513; P-value = 0.9345.
===
The analysis of Max.Fz.Dominant; task = Stop; joint = w.
The correlation between Max.Fz.Dominant and PCS is 0.151; the CI is -0.4127 to 0.631; P-value = 0.6064.The correlation between Max.Fz.Dominant and MCS is -0.0963; the CI is -0.5964 to 0.4577; P-value = 0.7434.
===
The analysis of Min.Fx.Dominant; task = Stop; joint = w.
The correlation between Min.Fx.Dominant and PCS is 0.3233; the CI is -0.2502 to 0.7289; P-value = 0.2595.The correlation between Min.Fx.Dominant and MCS is -0.2114; the CI is -0.6672 to 0.3595; P-value = 0.468.
===
The analysis of Min.Fy.Dominant; task = Stop; joint = w.
The correlation between Min.Fy.Dominant and PCS is 0.2922; the CI is -0.2821 to 0.7124; P-value = 0.3107.The correlation between Min.Fy.Dominant and MCS is 0.1009; the CI is -0.454 to 0.5994; P-value = 0.7315.
===
The analysis of Min.Fz.Dominant; task = Stop; joint = w.

The correlation between Min.Fz.Dominant and PCS is 0.2359; the CI is -0.3368 to 0.6812; P-value = 0.4167.The correlation between Min.Fz.Dominant and MCS is -0.0145; the CI is -0.5409 to 0.5201; P-value = 0.9607.
===
The analysis of Max.Mx.Dominant; task = Stop; joint = w.
The correlation between Max.Mx.Dominant and PCS is -0.2054; the CI is -0.6637 to 0.3649; P-value = 0.4811.The correlation between Max.Mx.Dominant and MCS is -0.3757; the CI is -0.7557 to 0.1934; P-value = 0.1855.
===
The analysis of Max.My.Dominant; task = Stop; joint = w.
The correlation between Max.My.Dominant and PCS is -0.4171; the CI is -0.7759 to 0.1458; P-value = 0.1379.The correlation between Max.My.Dominant and MCS is -0.0059; the CI is -0.5348 to 0.5263; P-value = 0.9839.

===
The analysis of Max.Mz.Dominant; task = Stop; joint = w.
The correlation between Max.Mz.Dominant and PCS is -0.2262; the CI is -0.6757 to 0.3459; P-value = 0.4367.The correlation between Max.Mz.Dominant and MCS is -0.0712; the CI is -0.5799 to 0.4774; P-value = 0.8089.
===
The analysis of Min.Mx.Dominant; task = Stop; joint = w.
The correlation between Min.Mx.Dominant and PCS is -0.3412; the CI is -0.7382 to 0.2312; P-value = 0.2325.The correlation between Min.Mx.Dominant and MCS is -0.039; the CI is -0.558 to 0.502; P-value = 0.8946.
===
The analysis of Min.My.Dominant; task = Stop; joint = w.
The correlation between Min.My.Dominant and PCS is -0.2474; the CI is -0.6877 to 0.3259; P-value = 0.3937.The correlation between Min.My.Dominant and MCS is -0.0113; the CI is -0.5386 to 0.5224; P-value = 0.9694.
===
The analysis of Min.Mz.Dominant; task = Stop; joint = w.
The correlation between Min.Mz.Dominant and PCS is 0.0359; the CI is -0.5043 to 0.5559; P-value = 0.9031.The correlation between Min.Mz.Dominant and MCS is 0.2386; the CI is -0.3343 to 0.6828; P-value = 0.4113.
===
The analysis of Max.Fx.Dominant; task = Stop; joint = e.
The correlation between Max.Fx.Dominant and PCS is 0.1612; the CI is -0.4039 to 0.6373; P-value = 0.5819.The correlation between Max.Fx.Dominant and MCS is -0.3351; the CI is -0.735 to 0.2377; P-value = 0.2415.
===
The analysis of Max.Fy.Dominant; task = Stop; joint = e.
The correlation between Max.Fy.Dominant and PCS is 0.1172; the CI is -0.4408 to 0.6098; P-value = 0.6899.The correlation between Max.Fy.Dominant and MCS is 0.1359; the CI is -0.4253 to 0.6217; P-value = 0.6431.

==
The analysis of Max.Fz.Dominant; task = Stop; joint = e.
The correlation between Max.Fz.Dominant and PCS is 0.3421; the CI is -0.2303 to 0.7386; P-value = 0.2312.The correlation between Max.Fz.Dominant and MCS is -0.1363; the CI is -0.6219 to 0.425; P-value = 0.6422.
==
The analysis of Min.Fx.Dominant; task = Stop; joint = e.
The correlation between Min.Fx.Dominant and PCS is 0.4713; the CI is -0.079 to 0.8015; P-value = 0.0889.The correlation between Min.Fx.Dominant and MCS is -0.0379; the CI is -0.5573 to 0.5028; P-value = 0.8977.
==
The analysis of Min.Fy.Dominant; task = Stop; joint = e.
The correlation between Min.Fy.Dominant and PCS is 0.175; the CI is -0.392 to 0.6456; P-value = 0.5496.The correlation between Min.Fy.Dominant and MCS is 0.3122; the CI is -0.2618 to 0.723; P-value = 0.2772.

==
The analysis of Min.Fz.Dominant; task = Stop; joint = e.
The correlation between Min.Fz.Dominant and PCS is 0.4124; the CI is -0.1513 to 0.7737; P-value = 0.1429.The correlation between Min.Fz.Dominant and MCS is 0.0367; the CI is -0.5037 to 0.5565; P-value = 0.9008.
==
The analysis of Max.Mx.Dominant; task = Stop; joint = e.
The correlation between Max.Mx.Dominant and PCS is -0.2728; the CI is -0.7018 to 0.3014; P-value = 0.3454.The correlation between Max.Mx.Dominant and MCS is -0.1876; the CI is -0.6532 to 0.3809; P-value = 0.5207.
==
The analysis of Max.My.Dominant; task = Stop; joint = e.
The correlation between Max.My.Dominant and PCS is -0.3118; the CI is -0.7228 to 0.2622; P-value = 0.2778.The correlation between Max.My.Dominant and MCS is -0.1987; the CI is -0.6597 to 0.371; P-value = 0.4959.
==
The analysis of Max.Mz.Dominant; task = Stop; joint = e.
The correlation between Max.Mz.Dominant and PCS is -0.0036; the CI is -0.5332 to 0.528; P-value = 0.9902.The correlation between Max.Mz.Dominant and MCS is -0.3103; the CI is -0.722 to 0.2637; P-value = 0.2803.
==
The analysis of Min.Mx.Dominant; task = Stop; joint = e.
The correlation between Min.Mx.Dominant and PCS is -0.3312; the CI is -0.733 to 0.2419; P-value = 0.2474.The correlation between Min.Mx.Dominant and MCS is 0.0114; the CI is -0.5223 to 0.5387; P-value = 0.9691.
==
The analysis of Min.My.Dominant; task = Stop; joint = e.

The correlation between Min.My.Dominant and PCS is -0.1705; the CI is -0.6429 to 0.3959; P-value = 0.5601.The correlation between Min.My.Dominant and MCS is 0.0746; the CI is -0.4748 to 0.5821; P-value = 0.7999.
===
The analysis of Min.Mz.Dominant; task = Stop; joint = e.
The correlation between Min.Mz.Dominant and PCS is 0.273; the CI is -0.3012 to 0.7019; P-value = 0.345.The correlation between Min.Mz.Dominant and MCS is 0.0067; the CI is -0.5258 to 0.5354; P-value = 0.9819.
===
The analysis of Max.Fx.Dominant; task = Stop; joint = g.
The correlation between Max.Fx.Dominant and PCS is -0.3953; the CI is -0.7654 to 0.1711; P-value = 0.1618.The correlation between Max.Fx.Dominant and MCS is -0.3413; the CI is -0.7382 to 0.2311; P-value = 0.2324.
===
The analysis of Max.Fy.Dominant; task = Stop; joint = g.
The correlation between Max.Fy.Dominant and PCS is -0.1047; the CI is -0.6018 to 0.4509; P-value = 0.7217.The correlation between Max.Fy.Dominant and MCS is 0.05; the CI is -0.4937 to 0.5656; P-value = 0.8652.

===
The analysis of Max.Fz.Dominant; task = Stop; joint = g.
The correlation between Max.Fz.Dominant and PCS is 0.2993; the CI is -0.275 to 0.7161; P-value = 0.2986.The correlation between Max.Fz.Dominant and MCS is -0.1615; the CI is -0.6374 to 0.4037; P-value = 0.5813.
===
The analysis of Min.Fx.Dominant; task = Stop; joint = g.
The correlation between Min.Fx.Dominant and PCS is -0.4143; the CI is -0.7746 to 0.1491; P-value = 0.1408.The correlation between Min.Fx.Dominant and MCS is -0.3237; the CI is -0.7291 to 0.2498; P-value = 0.2589.
===
The analysis of Min.Fy.Dominant; task = Stop; joint = g.
The correlation between Min.Fy.Dominant and PCS is -0.0176; the CI is -0.5431 to 0.5178; P-value = 0.9524.The correlation between Min.Fy.Dominant and MCS is 0.0881; the CI is -0.4642 to 0.5911; P-value = 0.7645.
===
The analysis of Min.Fz.Dominant; task = Stop; joint = g.
The correlation between Min.Fz.Dominant and PCS is 0.5103; the CI is -0.0278 to 0.8191; P-value = 0.0622.The correlation between Min.Fz.Dominant and MCS is -0.2023; the CI is -0.6618 to 0.3678; P-value = 0.488.
===
The analysis of Max.Mx.Dominant; task = Stop; joint = g.
The correlation between Max.Mx.Dominant and PCS is -0.0966; the CI is -0.5966 to 0.4574; P-value = 0.7425.The correlation between Max.Mx.Dominant and MCS is -0.4836; the CI is -0.8071 to 0.0632; P-value = 0.0798.
===

The analysis of Max.My.Dominant; task = Stop; joint = g.
The correlation between Max.My.Dominant and PCS is -0.2974; the CI is -0.7151 to 0.2768; P-value = 0.3017.The correlation between Max.My.Dominant and MCS is -0.2691; the CI is -0.6998 to 0.305; P-value = 0.3522.
===
The analysis of Max.Mz.Dominant; task = Stop; joint = g.
The correlation between Max.Mz.Dominant and PCS is -0.2264; the CI is -0.6758 to 0.3457; P-value = 0.4364.The correlation between Max.Mz.Dominant and MCS is -0.1806; the CI is -0.649 to 0.387; P-value = 0.5366.
===
The analysis of Min.Mx.Dominant; task = Stop; joint = g.
The correlation between Min.Mx.Dominant and PCS is 0.1086; the CI is -0.4478 to 0.6043; P-value = 0.7118.The correlation between Min.Mx.Dominant and MCS is 0.2084; the CI is -0.3623 to 0.6654; P-value = 0.4747.
===
The analysis of Min.My.Dominant; task = Stop; joint = g.
The correlation between Min.My.Dominant and PCS is -0.2607; the CI is -0.6951 to 0.3132; P-value = 0.368.The correlation between Min.My.Dominant and MCS is 0.2942; the CI is -0.2801 to 0.7134; P-value = 0.3073.

===
The analysis of Min.Mz.Dominant; task = Stop; joint = g.
The correlation between Min.Mz.Dominant and PCS is -0.1123; the CI is -0.6068 to 0.4447; P-value = 0.7022.The correlation between Min.Mz.Dominant and MCS is 0.2955; the CI is -0.2788 to 0.7141; P-value = 0.3051.
===
The analysis of Max.Fx.Dominant; task = Wt Rel; joint = w.
The correlation between Max.Fx.Dominant and PCS is 0.1813; the CI is -0.3864 to 0.6494; P-value = 0.535.The correlation between Max.Fx.Dominant and MCS is -0.0364; the CI is -0.5563 to 0.5039; P-value = 0.9016.
===
The analysis of Max.Fy.Dominant; task = Wt Rel; joint = w.
The correlation between Max.Fy.Dominant and PCS is 0.0368; the CI is -0.5036 to 0.5565; P-value = 0.9007.The correlation between Max.Fy.Dominant and MCS is -0.1356; the CI is -0.6214 to 0.4256; P-value = 0.644.
===
The analysis of Max.Fz.Dominant; task = Wt Rel; joint = w.
The correlation between Max.Fz.Dominant and PCS is 0.1212; the CI is -0.4375 to 0.6124; P-value = 0.6799.The correlation between Max.Fz.Dominant and MCS is 0.07; the CI is -0.4784 to 0.5791; P-value = 0.8121.
===
The analysis of Min.Fx.Dominant; task = Wt Rel; joint = w.
The correlation between Min.Fx.Dominant and PCS is 0.1842; the CI is -0.3839 to 0.6511; P-value = 0.5285.The correlation between Min.Fx.Dominant and MCS is 0.0849; the CI is -0.4667 to 0.5889; P-value = 0.7729.

==
The analysis of Min.Fy.Dominant; task = Wt Rel; joint = w.
The correlation between Min.Fy.Dominant and PCS is 0.1306; the CI is -0.4298 to 0.6183; P-value = 0.6564.The correlation between Min.Fy.Dominant and MCS is -0.4529; the CI is -0.7929 to 0.1023; P-value = 0.1039.
==
The analysis of Min.Fz.Dominant; task = Wt Rel; joint = w.
The correlation between Min.Fz.Dominant and PCS is 0.0426; the CI is -0.4992 to 0.5605; P-value = 0.8849.The correlation between Min.Fz.Dominant and MCS is -0.0951; the CI is -0.5956 to 0.4586; P-value = 0.7464.
==
The analysis of Max.Mx.Dominant; task = Wt Rel; joint = w.
The correlation between Max.Mx.Dominant and PCS is 0.1917; the CI is -0.3772 to 0.6556; P-value = 0.5114.The correlation between Max.Mx.Dominant and MCS is -0.1206; the CI is -0.612 to 0.438; P-value = 0.6812.
==
The analysis of Max.My.Dominant; task = Wt Rel; joint = w.
The correlation between Max.My.Dominant and PCS is 0.0252; the CI is -0.5123 to 0.5484; P-value = 0.932.The correlation between Max.My.Dominant and MCS is -0.0606; the CI is -0.5728 to 0.4856; P-value = 0.837.

==
The analysis of Max.Mz.Dominant; task = Wt Rel; joint = w.
The correlation between Max.Mz.Dominant and PCS is -0.1048; the CI is -0.6019 to 0.4509; P-value = 0.7216.The correlation between Max.Mz.Dominant and MCS is 0.3303; the CI is -0.2429 to 0.7325; P-value = 0.2488.
==
The analysis of Min.Mx.Dominant; task = Wt Rel; joint = w.
The correlation between Min.Mx.Dominant and PCS is -0.1857; the CI is -0.652 to 0.3826; P-value = 0.525.The correlation between Min.Mx.Dominant and MCS is -0.0801; the CI is -0.5858 to 0.4705; P-value = 0.7855.
==
The analysis of Min.My.Dominant; task = Wt Rel; joint = w.
The correlation between Min.My.Dominant and PCS is -0.2427; the CI is -0.685 to 0.3305; P-value = 0.4032.The correlation between Min.My.Dominant and MCS is -0.1795; the CI is -0.6483 to 0.388; P-value = 0.5392.
==
The analysis of Min.Mz.Dominant; task = Wt Rel; joint = w.
The correlation between Min.Mz.Dominant and PCS is 0.2464; the CI is -0.3269 to 0.6872; P-value = 0.3957.The correlation between Min.Mz.Dominant and MCS is 0.025; the CI is -0.5124 to 0.5483; P-value = 0.9323.
==
The analysis of Max.Fx.Dominant; task = Wt Rel; joint = e.

The correlation between Max.Fx.Dominant and PCS is 0.1831; the CI is -0.3848 to 0.6505; P-value = 0.5309.The correlation between Max.Fx.Dominant and MCS is -0.0364; the CI is -0.5563 to 0.5039; P-value = 0.9016.
==
The analysis of Max.Fy.Dominant; task = Wt Rel; joint = e.
The correlation between Max.Fy.Dominant and PCS is 0.0058; the CI is -0.5264 to 0.5347; P-value = 0.9844.The correlation between Max.Fy.Dominant and MCS is -0.1625; the CI is -0.6381 to 0.4028; P-value = 0.5789.
==
The analysis of Max.Fz.Dominant; task = Wt Rel; joint = e.
The correlation between Max.Fz.Dominant and PCS is 0.1271; the CI is -0.4327 to 0.6161; P-value = 0.6651.The correlation between Max.Fz.Dominant and MCS is 0.0724; the CI is -0.4765 to 0.5807; P-value = 0.8057.
==
The analysis of Min.Fx.Dominant; task = Wt Rel; joint = e.
The correlation between Min.Fx.Dominant and PCS is 0.1839; the CI is -0.3842 to 0.651; P-value = 0.5291.The correlation between Min.Fx.Dominant and MCS is 0.0853; the CI is -0.4664 to 0.5892; P-value = 0.7718.
==
The analysis of Min.Fy.Dominant; task = Wt Rel; joint = e.
The correlation between Min.Fy.Dominant and PCS is 0.1302; the CI is -0.4301 to 0.6181; P-value = 0.6572.The correlation between Min.Fy.Dominant and MCS is -0.4526; the CI is -0.7928 to 0.1026; P-value = 0.1041.

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The analysis of Min.Fz.Dominant; task = Wt Rel; joint = e.
The correlation between Min.Fz.Dominant and PCS is 0.0521; the CI is -0.4921 to 0.567; P-value = 0.8595.The correlation between Min.Fz.Dominant and MCS is -0.0862; the CI is -0.5898 to 0.4657; P-value = 0.7695.
==
The analysis of Max.Mx.Dominant; task = Wt Rel; joint = e.
The correlation between Max.Mx.Dominant and PCS is 0.1847; the CI is -0.3834 to 0.6514; P-value = 0.5273.The correlation between Max.Mx.Dominant and MCS is -0.0165; the CI is -0.5424 to 0.5186; P-value = 0.9552.
==
The analysis of Max.My.Dominant; task = Wt Rel; joint = e.
The correlation between Max.My.Dominant and PCS is 0.117; the CI is -0.4409 to 0.6097; P-value = 0.6904.The correlation between Max.My.Dominant and MCS is 0.044; the CI is -0.4982 to 0.5615; P-value = 0.8813.
==
The analysis of Max.Mz.Dominant; task = Wt Rel; joint = e.
The correlation between Max.Mz.Dominant and PCS is -0.3538; the CI is -0.7446 to 0.2176; P-value = 0.2146.The correlation between Max.Mz.Dominant and MCS is 0.1731; the CI is -0.3936 to 0.6445; P-value = 0.5539.
==

The analysis of Min.Mx.Dominant; task = Wt Rel; joint = e.
The correlation between Min.Mx.Dominant and PCS is -0.0995; the CI is -0.5985 to 0.4551; P-value = 0.7351.The correlation between Min.Mx.Dominant and MCS is -0.0827; the CI is -0.5875 to 0.4685; P-value = 0.7787.
==
The analysis of Min.My.Dominant; task = Wt Rel; joint = e.
The correlation between Min.My.Dominant and PCS is -0.1084; the CI is -0.6042 to 0.448; P-value = 0.7123.The correlation between Min.My.Dominant and MCS is 0.0478; the CI is -0.4953 to 0.5641; P-value = 0.871.
==
The analysis of Min.Mz.Dominant; task = Wt Rel; joint = e.
The correlation between Min.Mz.Dominant and PCS is -0.2293; the CI is -0.6775 to 0.343; P-value = 0.4304.The correlation between Min.Mz.Dominant and MCS is 0.3637; the CI is -0.2067 to 0.7496; P-value = 0.2011.
==
The analysis of Max.Fx.Dominant; task = Wt Rel; joint = g.
The correlation between Max.Fx.Dominant and PCS is 0.186; the CI is -0.3823 to 0.6522; P-value = 0.5244.The correlation between Max.Fx.Dominant and MCS is -0.0376; the CI is -0.557 to 0.503; P-value = 0.8985.
==
The analysis of Max.Fy.Dominant; task = Wt Rel; joint = g.
The correlation between Max.Fy.Dominant and PCS is -0.1023; the CI is -0.6003 to 0.4528; P-value = 0.7278.The correlation between Max.Fy.Dominant and MCS is -0.2213; the CI is -0.6729 to 0.3504; P-value = 0.4471.

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The analysis of Max.Fz.Dominant; task = Wt Rel; joint = g.
The correlation between Max.Fz.Dominant and PCS is 0.1342; the CI is -0.4268 to 0.6206; P-value = 0.6474.The correlation between Max.Fz.Dominant and MCS is 0.0767; the CI is -0.4731 to 0.5835; P-value = 0.7943.
==
The analysis of Min.Fx.Dominant; task = Wt Rel; joint = g.
The correlation between Min.Fx.Dominant and PCS is 0.1854; the CI is -0.3829 to 0.6518; P-value = 0.5258.The correlation between Min.Fx.Dominant and MCS is 0.0861; the CI is -0.4658 to 0.5897; P-value = 0.7699.
==
The analysis of Min.Fy.Dominant; task = Wt Rel; joint = g.
The correlation between Min.Fy.Dominant and PCS is 0.1282; the CI is -0.4318 to 0.6168; P-value = 0.6623.The correlation between Min.Fy.Dominant and MCS is -0.4514; the CI is -0.7923 to 0.1041; P-value = 0.1052.
==
The analysis of Min.Fz.Dominant; task = Wt Rel; joint = g.
The correlation between Min.Fz.Dominant and PCS is 0.0681; the CI is -0.4798 to 0.5778; P-value = 0.8172.The correlation between Min.Fz.Dominant and MCS is -0.0779; the CI is -0.5843 to 0.4722; P-value = 0.7913.

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The analysis of Max.Mx.Dominant; task = Wt Rel; joint = g.
The correlation between Max.Mx.Dominant and PCS is 0.1725; the CI is -0.3942 to 0.6441; P-value = 0.5554.The correlation between Max.Mx.Dominant and MCS is 0.2085; the CI is -0.3621 to 0.6655; P-value = 0.4744.
==
The analysis of Max.My.Dominant; task = Wt Rel; joint = g.
The correlation between Max.My.Dominant and PCS is 0.1698; the CI is -0.3965 to 0.6425; P-value = 0.5616.The correlation between Max.My.Dominant and MCS is 0.2041; the CI is -0.3661 to 0.6629; P-value = 0.4839.
==
The analysis of Max.Mz.Dominant; task = Wt Rel; joint = g.
The correlation between Max.Mz.Dominant and PCS is 0.2703; the CI is -0.3038 to 0.7004; P-value = 0.3499.The correlation between Max.Mz.Dominant and MCS is -0.214; the CI is -0.6686 to 0.3571; P-value = 0.4626.
==
The analysis of Min.Mx.Dominant; task = Wt Rel; joint = g.
The correlation between Min.Mx.Dominant and PCS is -0.0379; the CI is -0.5573 to 0.5028; P-value = 0.8977.The correlation between Min.Mx.Dominant and MCS is 0.3287; the CI is -0.2445 to 0.7317; P-value = 0.2511.
==
The analysis of Min.My.Dominant; task = Wt Rel; joint = g.
The correlation between Min.My.Dominant and PCS is 0.3001; the CI is -0.2741 to 0.7166; P-value = 0.2972.The correlation between Min.My.Dominant and MCS is 0.287; the CI is -0.2873 to 0.7095; P-value = 0.3198.

==
The analysis of Min.Mz.Dominant; task = Wt Rel; joint = g.
The correlation between Min.Mz.Dominant and PCS is 0.26; the CI is -0.3139 to 0.6947; P-value = 0.3693.The correlation between Min.Mz.Dominant and MCS is 0.1093; the CI is -0.4472 to 0.6048; P-value = 0.71.

Appendix I: Kinematic and Kinetic Analysis Results

```
=============================================================
The analysis of Max.Fx.Dominant; task = Prop.
        Estimate Std..Error t.value      P     LB     UB
b$jointw   4.6742     0.6904  6.7699 0.0000 3.3209 6.0274
b$jointe   3.1550     0.6904  4.5696 0.0003 1.8017 4.5082
b$jointg   1.9860     0.6904  2.8765 0.0820 0.6328 3.3392
Pvalue for comparing Elbow vs Wrist = 0.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
=============================================================
The analysis of Max.Fy.Dominant; task = Prop.
        Estimate Std..Error t.value P     LB     UB
b$jointe   4.0600     0.1822 22.2859 0 3.7029 4.4171
b$jointw   1.8412     0.1822 10.1066 0 1.4841 2.1983
b$jointg   6.8478     0.1822 37.5881 0 6.4907 7.2048
Pvalue for comparing Elbow vs Wrist = 0.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
=============================================================
The analysis of Max.Fz.Dominant; task = Prop.
        Estimate Std..Error t.value     P     LB     UB
b$jointe   3.8217     0.6834  5.5924 0e+00 2.4823 5.1612
b$jointw   3.1117     0.6834  4.5534 4e-04 1.7722 4.4511
b$jointg   4.7934     0.6834  7.0142 0e+00 3.4540 6.1328
Pvalue for comparing Elbow vs Wrist = 3e-04.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
=============================================================
The analysis of Min.Fx.Dominant; task = Prop.
        Estimate Std..Error  t.value     P      LB      UB
b$jointe  -3.4224     0.5032  -6.8006 0.000 -4.4088 -2.4360
b$jointw  -2.1566     0.5032  -4.2854 0.001 -3.1430 -1.1702
b$jointg  -6.6522     0.5032 -13.2186 0.000 -7.6386 -5.6659
```

Pvalue for comparing Elbow vs Wrist = 0.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
==

The analysis of Min.Fy.Dominant; task = Prop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-4.8875	0.8623	-5.6682	0.0000	-6.5775	-3.1975
b$jointw	-5.2807	0.8623	-6.1243	0.0000	-6.9707	-3.5907
b$jointg	-2.4338	0.8623	-2.8226	0.0928	-4.1238	-0.7438

Pvalue for comparing Elbow vs Wrist = 0.8254.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
==

The analysis of Min.Fz.Dominant; task = Prop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-3.3359	0.4877	-6.8401	0	-4.2918	-2.3800
b$jointw	-2.5576	0.4877	-5.2441	0	-3.5135	-1.6017
b$jointg	-2.7218	0.4877	-5.5809	0	-3.6777	-1.7659

Pvalue for comparing Elbow vs Wrist = 0.
Pvalue for comparing GH vs Wrist = 0.7405.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
==

The analysis of Max.Mx.Dominant; task = Prop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	0.7586	0.104	7.2928	0.0000	0.5548	0.9625
b$jointw	0.4291	0.104	4.1251	0.0019	0.2252	0.6330
b$jointg	0.8937	0.104	8.5912	0.0000	0.6898	1.0976

Pvalue for comparing Elbow vs Wrist = 6e-04.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.5143.

Overall P-value that at least 1 joint is different = 0
==

The analysis of Max.My.Dominant; task = Prop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	1.0749	0.4122	2.6074	0.1469	0.2669	1.8829
b$jointw	0.5069	0.4122	1.2296	0.8245	-0.3011	1.3149
b$jointg	1.4449	0.4122	3.5051	0.0153	0.6370	2.2529

Pvalue for comparing Elbow vs Wrist = 0.7313.

Pvalue for comparing GH vs Wrist = 0.2379.
Pvalue for comparing GH vs Elbow = 0.9303.

Overall P-value that at least 1 joint is different = 0.061
==

The analysis of Max.Mz.Dominant; task = Prop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	1.2246	0.1488	8.2289	0	0.9329	1.5162
b$jointw	0.9226	0.1488	6.2000	0	0.6310	1.2143
b$jointg	0.8723	0.1488	5.8619	0	0.5807	1.1640

Pvalue for comparing Elbow vs Wrist = 0.0131.
Pvalue for comparing GH vs Wrist = 0.9863.
Pvalue for comparing GH vs Elbow = 0.0018.

Overall P-value that at least 1 joint is different = 1e-04
==

The analysis of Min.Mx.Dominant; task = Prop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.6140	0.1071	-5.7338	0.000	-0.8239	-0.4041
b$jointw	-0.2905	0.1071	-2.7129	0.118	-0.5004	-0.0806
b$jointg	-0.9910	0.1071	-9.2541	0.000	-1.2009	-0.7811

Pvalue for comparing Elbow vs Wrist = 0.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
==

The analysis of Min.My.Dominant; task = Prop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.8443	0.3297	-2.5605	0.1613	-1.4905	-0.1980
b$jointw	-0.1998	0.3297	-0.6060	0.9851	-0.8460	0.4465
b$jointg	-1.0823	0.3297	-3.2826	0.0292	-1.7286	-0.4361

Pvalue for comparing Elbow vs Wrist = 0.5985.
Pvalue for comparing GH vs Wrist = 0.2695.
Pvalue for comparing GH vs Elbow = 0.9843.

Overall P-value that at least 1 joint is different = 0.0628
==

The analysis of Min.Mz.Dominant; task = Prop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.4465	0.0752	-5.9396	0.0000	-0.5938	-0.2991
b$jointw	-0.1993	0.0752	-2.6520	0.1341	-0.3467	-0.0520
b$jointg	-1.1992	0.0752	-15.9542	0.0000	-1.3466	-1.0519

Pvalue for comparing Elbow vs Wrist = 1e-04.
Pvalue for comparing GH vs Wrist = 0.

Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0

==

The analysis of Max.Fx.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointw	5.5592	0.9143	6.0803	0.0000	3.7672	7.3513
b$jointe	3.7054	0.9143	4.0528	0.0025	1.9134	5.4975
b$jointg	3.0703	0.9143	3.3581	0.0236	1.2783	4.8624

Pvalue for comparing Elbow vs Wrist = 0.0449.
Pvalue for comparing GH vs Wrist = 0.0015.
Pvalue for comparing GH vs Elbow = 0.8872.

Overall P-value that at least 1 joint is different = 1e-04

==

The analysis of Max.Fy.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	4.4851	0.2453	18.2859	0	4.0043	4.9658
b$jointw	2.0406	0.2453	8.3198	0	1.5599	2.5214
b$jointg	6.7407	0.2453	27.4823	0	6.2600	7.2214

Pvalue for comparing Elbow vs Wrist = 0.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0

==

The analysis of Max.Fz.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	5.2467	1.2132	4.3246	9e-04	2.8688	7.6246
b$jointw	4.9970	1.2132	4.1187	2e-03	2.6190	7.3749
b$jointg	6.5940	1.2132	5.4351	0e+00	4.2161	8.9719

Pvalue for comparing Elbow vs Wrist = 0.9903.
Pvalue for comparing GH vs Wrist = 0.0175.
Pvalue for comparing GH vs Elbow = 0.0741.

Overall P-value that at least 1 joint is different = 0.0013

==

The analysis of Min.Fx.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-4.9996	1.0524	-4.7507	0.0002	-7.0622	-2.9369
b$jointw	-3.4920	1.0524	-3.3182	0.0264	-5.5547	-1.4293
b$jointg	-8.2148	1.0524	-7.8059	0.0000	-10.2775	-6.1522

Pvalue for comparing Elbow vs Wrist = 0.0014.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0

===

The analysis of Min.Fy.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-7.8965	1.3949	-5.6609	0.0000	-10.6305	-5.1625
b$jointw	-8.2954	1.3949	-5.9469	0.0000	-11.0294	-5.5613
b$jointg	-4.5917	1.3949	-3.2917	0.0285	-7.3257	-1.8576

Pvalue for comparing Elbow vs Wrist = 0.9845.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0

===

The analysis of Min.Fz.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-3.1697	0.486	-6.5223	0e+00	-4.1222	-2.2172
b$jointw	-2.3285	0.486	-4.7915	1e-04	-3.2811	-1.3760
b$jointg	-2.2058	0.486	-4.5388	4e-04	-3.1583	-1.2533

Pvalue for comparing Elbow vs Wrist = 0.0629.
Pvalue for comparing GH vs Wrist = 0.9958.
Pvalue for comparing GH vs Elbow = 0.0195.

Overall P-value that at least 1 joint is different = 0.0013

===

The analysis of Max.Mx.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	0.9112	0.1589	5.7329	0.0000	0.5997	1.2227
b$jointw	0.6447	0.1589	4.0562	0.0025	0.3332	0.9562
b$jointg	1.0673	0.1589	6.7152	0.0000	0.7558	1.3789

Pvalue for comparing Elbow vs Wrist = 0.0761.
Pvalue for comparing GH vs Wrist = 3e-04.
Pvalue for comparing GH vs Elbow = 0.574.

Overall P-value that at least 1 joint is different = 0

===

The analysis of Max.My.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	0.4967	0.1675	2.9653	0.0665	0.1684	0.8249
b$jointw	0.7973	0.1675	4.7602	0.0001	0.4690	1.1256
b$jointg	1.1603	0.1675	6.9277	0.0000	0.8320	1.4886

Pvalue for comparing Elbow vs Wrist = 0.1912.
Pvalue for comparing GH vs Wrist = 0.0634.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
==

The analysis of Max.Mz.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	1.8039	0.2451	7.3591	0.0000	1.3234	2.2843
b$jointw	1.5730	0.2451	6.4172	0.0000	1.0925	2.0534
b$jointg	0.9927	0.2451	4.0499	0.0025	0.5123	1.4732

Pvalue for comparing Elbow vs Wrist = 0.9022.
Pvalue for comparing GH vs Wrist = 0.1569.
Pvalue for comparing GH vs Elbow = 0.0115.

Overall P-value that at least 1 joint is different = 0.0014
==

The analysis of Min.Mx.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.7293	0.1648	-4.4257	0.0006	-1.0523	-0.4063
b$jointw	-0.3524	0.1648	-2.1383	0.3341	-0.6754	-0.0294
b$jointg	-1.3100	0.1648	-7.9492	0.0000	-1.6329	-0.9870

Pvalue for comparing Elbow vs Wrist = 0.0092.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
==

The analysis of Min.My.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.2567	0.1546	-1.6602	0.5994	-0.5598	0.0464
b$jointw	-0.2797	0.1546	-1.8092	0.5132	-0.5828	0.0233
b$jointg	-0.7722	0.1546	-4.9944	0.0001	-1.0753	-0.4692

Pvalue for comparing Elbow vs Wrist = 0.9997.
Pvalue for comparing GH vs Wrist = 1e-04.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
==

The analysis of Min.Mz.Dominant; task = Start.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.4434	0.063	-7.0362	0.000	-0.5669	-0.3199
b$jointw	-0.1582	0.063	-2.5095	0.178	-0.2817	-0.0346
b$jointg	-1.1307	0.063	-17.9417	0.000	-1.2542	-1.0072

Pvalue for comparing Elbow vs Wrist = 0.0047.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0

```
==================================================================
The analysis of Max.Fx.Dominant; task = Stop.
        Estimate Std..Error t.value      P      LB     UB
b$jointw   2.3253     0.8065  2.8834 0.0807  0.7447 3.9060
b$jointe   1.4325     0.8065  1.7763 0.5322 -0.1481 3.0132
b$jointg   0.1407     0.8065  0.1745 0.9999 -1.4400 1.7213
Pvalue for comparing Elbow vs Wrist = 0.4799.
Pvalue for comparing GH vs Wrist = 3e-04.
Pvalue for comparing GH vs Elbow = 0.1208.

Overall P-value that at least 1 joint is different = 1e-04
==================================================================
The analysis of Max.Fy.Dominant; task = Stop.
        Estimate Std..Error t.value P     LB      UB
b$jointe   6.8757     1.1713  5.8704 0 4.5801  9.1714
b$jointw   6.0385     1.1713  5.1555 0 3.7428  8.3341
b$jointg   9.6771     1.1713  8.2621 0 7.3814 11.9727
Pvalue for comparing Elbow vs Wrist = 0.866.
Pvalue for comparing GH vs Wrist = 1e-04.
Pvalue for comparing GH vs Elbow = 0.0066.

Overall P-value that at least 1 joint is different = 0
==================================================================
The analysis of Max.Fz.Dominant; task = Stop.
        Estimate Std..Error t.value      P     LB     UB
b$jointe   2.4774     0.5117  4.8420 0.0001 1.4746 3.4803
b$jointw   1.5738     0.5117  3.0759 0.0506 0.5710 2.5766
b$jointg   2.4464     0.5117  4.7814 0.0001 1.4436 3.4492
Pvalue for comparing Elbow vs Wrist = 0.0214.
Pvalue for comparing GH vs Wrist = 0.0298.
Pvalue for comparing GH vs Elbow = 1.

Overall P-value that at least 1 joint is different = 8e-04
==================================================================
The analysis of Min.Fx.Dominant; task = Stop.
        Estimate Std..Error t.value      P      LB      UB
b$jointe  -2.9470     0.4952 -5.9506 0.0000 -3.9176 -1.9763
b$jointw  -1.9555     0.4952 -3.9486 0.0036 -2.9262 -0.9848
b$jointg  -4.4799     0.4952 -9.0460 0.0000 -5.4506 -3.5092
Pvalue for comparing Elbow vs Wrist = 0.2856.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.0174.

Overall P-value that at least 1 joint is different = 0
==================================================================
```

The analysis of Min.Fy.Dominant; task = Stop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	0.7484	0.5284	1.4164	0.7346	-0.2872	1.7841
b$jointw	0.2476	0.5284	0.4685	0.9944	-0.7881	1.2832
b$jointg	3.6980	0.5284	6.9986	0.0000	2.6624	4.7337

Pvalue for comparing Elbow vs Wrist = 0.7716.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0

==

The analysis of Min.Fz.Dominant; task = Stop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.9726	0.4152	-2.3423	0.2409	-1.7864	-0.1587
b$jointw	-1.4648	0.4152	-3.5277	0.0143	-2.2786	-0.6510
b$jointg	-1.1179	0.4152	-2.6922	0.1234	-1.9317	-0.3040

Pvalue for comparing Elbow vs Wrist = 0.3387.
Pvalue for comparing GH vs Wrist = 0.6896.
Pvalue for comparing GH vs Elbow = 0.9829.

Overall P-value that at least 1 joint is different = 0.0921

==

The analysis of Max.Mx.Dominant; task = Stop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	0.1895	0.1301	1.4567	0.7133	-0.0655	0.4444
b$jointw	0.2092	0.1301	1.6084	0.6291	-0.0457	0.4642
b$jointg	0.3321	0.1301	2.5532	0.1636	0.0772	0.5871

Pvalue for comparing Elbow vs Wrist = 0.9998.
Pvalue for comparing GH vs Wrist = 0.8441.
Pvalue for comparing GH vs Elbow = 0.7567.

Overall P-value that at least 1 joint is different = 0.3274

==

The analysis of Max.My.Dominant; task = Stop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	0.3361	0.1027	3.2718	0.0301	0.1347	0.5374
b$jointw	0.2497	0.1027	2.4305	0.2062	0.0483	0.4510
b$jointg	0.3631	0.1027	3.5353	0.0140	0.1618	0.5645

Pvalue for comparing Elbow vs Wrist = 0.7467.
Pvalue for comparing GH vs Wrist = 0.5017.
Pvalue for comparing GH vs Elbow = 0.9957.

Overall P-value that at least 1 joint is different = 0.1606

==

The analysis of Max.Mz.Dominant; task = Stop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	0.2051	0.1143	1.7941	0.5219	-0.0190	0.4292
b$jointw	0.0663	0.1143	0.5796	0.9874	-0.1578	0.2904
b$jointg	0.6877	0.1143	6.0143	0.0000	0.4636	0.9118

Pvalue for comparing Elbow vs Wrist = 0.7821.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 3e-04.

Overall P-value that at least 1 joint is different = 0

==

The analysis of Min.Mx.Dominant; task = Stop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.7459	0.1233	-6.0498	0.0000	-0.9875	-0.5042
b$jointw	-0.4805	0.1233	-3.8972	0.0043	-0.7222	-0.2388
b$jointg	-0.5187	0.1233	-4.2068	0.0014	-0.7603	-0.2770

Pvalue for comparing Elbow vs Wrist = 0.045.
Pvalue for comparing GH vs Wrist = 0.9953.
Pvalue for comparing GH vs Elbow = 0.1286.

Overall P-value that at least 1 joint is different = 0.004

==

The analysis of Min.My.Dominant; task = Stop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.1857	0.0746	-2.4893	0.1850	-0.3319	-0.0395
b$jointw	-0.2753	0.0746	-3.6905	0.0086	-0.4214	-0.1291
b$jointg	-0.3327	0.0746	-4.4606	0.0005	-0.4789	-0.1865

Pvalue for comparing Elbow vs Wrist = 0.2095.
Pvalue for comparing GH vs Wrist = 0.6608.
Pvalue for comparing GH vs Elbow = 0.0033.

Overall P-value that at least 1 joint is different = 5e-04

==

The analysis of Min.Mz.Dominant; task = Stop.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-1.1057	0.1716	-6.4448	0.000	-1.4419	-0.7694
b$jointw	-1.0689	0.1716	-6.2304	0.000	-1.4051	-0.7326
b$jointg	-0.4270	0.1716	-2.4892	0.185	-0.7633	-0.0908

Pvalue for comparing Elbow vs Wrist = 0.9997.
Pvalue for comparing GH vs Wrist = 0.0049.
Pvalue for comparing GH vs Elbow = 0.0022.

Overall P-value that at least 1 joint is different = 1e-04

==

The analysis of Max.Fx.Dominant; task = Wt Rel.

Estimate Std..Error t.value P LB UB

```
b$jointw  11.7514     3.4872  3.3699 0.0228 4.9165 18.5862
b$jointe  11.7503     3.4872  3.3696 0.0229 4.9155 18.5852
b$jointg  11.7300     3.4872  3.3638 0.0232 4.8952 18.5649
Pvalue for comparing Elbow vs Wrist = 1.
Pvalue for comparing GH vs Wrist = 1.
Pvalue for comparing GH vs Elbow = 1.

Overall P-value that at least 1 joint is different = 0.9997
================================================================
The analysis of Max.Fy.Dominant; task = Wt Rel.
        Estimate Std..Error t.value P     LB     UB
b$jointe   4.0471     0.3098 13.0616 0 3.4398 4.6544
b$jointw   2.2475     0.3098  7.2537 0 1.6402 2.8548
b$jointg   7.4333     0.3098 23.9903 0 6.8260 8.0406
Pvalue for comparing Elbow vs Wrist = 0.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.

Overall P-value that at least 1 joint is different = 0
================================================================
The analysis of Max.Fz.Dominant; task = Wt Rel.
        Estimate Std..Error t.value P     LB      UB
b$jointe  10.0535     1.3609  7.3874 0 7.3862 12.7209
b$jointw  10.0723     1.3609  7.4013 0 7.4050 12.7397
b$jointg  10.0469     1.3609  7.3825 0 7.3795 12.7142
Pvalue for comparing Elbow vs Wrist = 1.
Pvalue for comparing GH vs Wrist = 1.
Pvalue for comparing GH vs Elbow = 1.

Overall P-value that at least 1 joint is different = 0.9987
================================================================
The analysis of Min.Fx.Dominant; task = Wt Rel.
        Estimate Std..Error t.value      P       LB      UB
b$jointe  -7.7991     3.3302 -2.3419 0.2411 -14.3263 -1.2719
b$jointw  -7.7541     3.3302 -2.3284 0.2467 -14.2813 -1.2270
b$jointg  -7.8965     3.3302 -2.3712 0.2292 -14.4237 -1.3693
Pvalue for comparing Elbow vs Wrist = 1.
Pvalue for comparing GH vs Wrist = 0.9999.
Pvalue for comparing GH vs Elbow = 1.

Overall P-value that at least 1 joint is different = 0.9862
================================================================
The analysis of Min.Fy.Dominant; task = Wt Rel.
        Estimate Std..Error t.value P       LB       UB
b$jointe -24.4176     3.8388 -6.3608 0 -31.9417 -16.8936
```

b$jointw -26.1811 3.8388 -6.8201 0 -33.7051 -18.6571
b$jointg -21.1127 3.8388 -5.4999 0 -28.6367 -13.5887
Pvalue for comparing Elbow vs Wrist = 0.6773.
Pvalue for comparing GH vs Wrist = 7e-04.
Pvalue for comparing GH vs Elbow = 0.0864.

Overall P-value that at least 1 joint is different = 1e-04
==

The analysis of Min.Fz.Dominant; task = Wt Rel.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-1.1824	0.3176	-3.7233	0.0077	-1.8048	-0.5600
b$jointw	-1.1961	0.3176	-3.7665	0.0067	-1.8186	-0.5737
b$jointg	-1.1973	0.3176	-3.7701	0.0066	-1.8197	-0.5748

Pvalue for comparing Elbow vs Wrist = 1.
Pvalue for comparing GH vs Wrist = 1.
Pvalue for comparing GH vs Elbow = 1.

Overall P-value that at least 1 joint is different = 0.997
==

The analysis of Max.Mx.Dominant; task = Wt Rel.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	1.4666	0.4082	3.5925	0.0117	0.6664	2.2667
b$jointw	0.8418	0.4082	2.0622	0.3729	0.0417	1.6420
b$jointg	2.1981	0.4082	5.3845	0.0000	1.3980	2.9983

Pvalue for comparing Elbow vs Wrist = 0.2738.
Pvalue for comparing GH vs Wrist = 1e-04.
Pvalue for comparing GH vs Elbow = 0.1338.

Overall P-value that at least 1 joint is different = 0
==

The analysis of Max.My.Dominant; task = Wt Rel.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	1.3555	0.3559	3.8092	0.0058	0.6580	2.0530
b$jointw	0.7411	0.3559	2.0825	0.3623	0.0436	1.4386
b$jointg	2.1411	0.3559	6.0168	0.0000	1.4436	2.8386

Pvalue for comparing Elbow vs Wrist = 0.119.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.0174.

Overall P-value that at least 1 joint is different = 0
==

The analysis of Max.Mz.Dominant; task = Wt Rel.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	3.2985	0.4364	7.5591	0	2.4432	4.1538
b$jointw	3.1949	0.4364	7.3215	0	2.3396	4.0501

b$jointg   2.5747   0.4364 5.9003 0 1.7194 3.4299
Pvalue for comparing Elbow vs Wrist = 0.9999.
Pvalue for comparing GH vs Wrist = 0.9083.
Pvalue for comparing GH vs Elbow = 0.8484.

Overall P-value that at least 1 joint is different = 0.438
==
The analysis of Min.Mx.Dominant; task = Wt Rel.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-2.3393	0.4775	-4.8996	0.0001	-3.2751	-1.4035
b$jointw	-1.3282	0.4775	-2.7819	0.1016	-2.2640	-0.3924
b$jointg	-1.7671	0.4775	-3.7010	0.0083	-2.7029	-0.8312

Pvalue for comparing Elbow vs Wrist = 0.0286.
Pvalue for comparing GH vs Wrist = 0.7285.
Pvalue for comparing GH vs Elbow = 0.4827.

Overall P-value that at least 1 joint is different = 0.0055
==
The analysis of Min.My.Dominant; task = Wt Rel.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.7593	0.1994	-3.8083	0.0059	-1.1501	-0.3685
b$jointw	-0.6100	0.1994	-3.0596	0.0527	-1.0008	-0.2192
b$jointg	-0.8837	0.1994	-4.4324	0.0006	-1.2745	-0.4930

Pvalue for comparing Elbow vs Wrist = 0.9585.
Pvalue for comparing GH vs Wrist = 0.708.
Pvalue for comparing GH vs Elbow = 0.9787.

Overall P-value that at least 1 joint is different = 0.3354
==
The analysis of Min.Mz.Dominant; task = Wt Rel.

	Estimate	Std..Error	t.value	P	LB	UB
b$jointe	-0.7551	0.2356	-3.2056	0.0360	-1.2168	-0.2934
b$jointw	-0.1332	0.2356	-0.5653	0.9885	-0.5949	0.3285
b$jointg	-1.8775	0.2356	-7.9702	0.0000	-2.3392	-1.4158

Pvalue for comparing Elbow vs Wrist = 0.4454.
Pvalue for comparing GH vs Wrist = 0.
Pvalue for comparing GH vs Elbow = 0.0166.

Overall P-value that at least 1 joint is different = 0
==
The analysis of Max.Wrist.Fx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	4.6742	0.6188	7.5532	0.0000	3.4613	5.8871
tasksStart	0.8851	0.9449	0.9367	0.9278	-0.9669	2.7371
tasksStop	-2.3489	0.9449	-2.4858	0.1861	-4.2008	-0.4969

```
tasksWt Rel   7.3893     1.0962  6.7406 0.0000  5.2406  9.5379

Overall P-value that at least 1 group is different = 0
==================================================================
The analysis of Max.Wrist.Fy.Dominant
           Estimate Std..Error t.value      P      LB     UB
(Intercept)   1.8412     0.2477  7.4328 0.0000  1.3557 2.3267
tasksStart    0.1994     0.3892  0.5124 0.9921 -0.5634 0.9623
tasksStop     4.1973     0.3892 10.7840 0.0000  3.4344 4.9601
tasksWt Rel   0.3835     0.4515  0.8493 0.9487 -0.5015 1.2685

Overall P-value that at least 1 group is different = 0
==================================================================
The analysis of Max.Wrist.Fz.Dominant
           Estimate Std..Error t.value      P      LB      UB
(Intercept)   3.1117     0.6925  4.4936 0.0005  1.7544  4.4689
tasksStart    1.8853     0.4245  4.4408 0.0006  1.0532  2.7174
tasksStop    -1.5379     0.4245 -3.6224 0.0107 -2.3700 -0.7058
tasksWt Rel   7.0967     0.4927 14.4049 0.0000  6.1311  8.0623

Overall P-value that at least 1 group is different = 0
==================================================================
The analysis of Min.Wrist.Fx.Dominant
           Estimate Std..Error t.value      P      LB      UB
(Intercept)  -2.1566     0.5203 -4.1447 0.0018 -3.1765 -1.1367
tasksStart   -1.3354     0.7970 -1.6754 0.5906 -2.8976  0.2268
tasksStop     0.2011     0.7970  0.2523 0.9995 -1.3611  1.7633
tasksWt Rel  -5.3739     0.9247 -5.8115 0.0000 -7.1864 -3.5615

Overall P-value that at least 1 group is different = 0
==================================================================
The analysis of Min.Wrist.Fy.Dominant
           Estimate Std..Error  t.value      P       LB       UB
(Intercept)  -5.2807     1.0444  -5.0564 0.0000  -7.3276  -3.2338
tasksStart   -3.0147     0.9132  -3.3012 0.0277  -4.8045  -1.2248
tasksStop     5.5283     0.9132   6.0538 0.0000   3.7384   7.3181
tasksWt Rel -21.0736     1.0597 -19.8870 0.0000 -23.1506 -18.9967

Overall P-value that at least 1 group is different = 0
==================================================================
The analysis of Min.Wrist.Fz.Dominant
           Estimate Std..Error t.value      P      LB      UB
(Intercept)  -2.5576     0.3573 -7.1584 0.0000 -3.2578 -1.8573
tasksStart    0.2290     0.2905  0.7884 0.9606 -0.3403  0.7983
tasksStop     1.0928     0.2905  3.7619 0.0068  0.5234  1.6621
```

tasksWt Rel	1.4572	0.3371	4.3232	0.0009	0.7966	2.1179

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.Wrist.Mx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	0.4291	0.0782	5.4844	0.0000	0.2758	0.5825
tasksStart	0.2156	0.0841	2.5639	0.1602	0.0508	0.3804
tasksStop	-0.2199	0.0841	-2.6156	0.1445	-0.3847	-0.0551
tasksWt Rel	0.3852	0.0976	3.9479	0.0036	0.1939	0.5764

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.Wrist.My.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	0.5069	0.0911	5.5627	0.0000	0.3283	0.6855
tasksStart	0.2904	0.0836	3.4722	0.0169	0.1265	0.4543
tasksStop	-0.2572	0.0836	-3.0758	0.0506	-0.4212	-0.0933
tasksWt Rel	0.2448	0.0970	2.5226	0.1736	0.0546	0.4350

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.Wrist.Mz.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	0.9226	0.1567	5.8862	0	0.6154	1.2299
tasksStart	0.6503	0.1200	5.4183	0	0.4151	0.8856
tasksStop	-0.8564	0.1200	-7.1347	0	-1.0916	-0.6211
tasksWt Rel	2.2910	0.1393	16.4485	0	2.0180	2.5640

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Wrist.Mx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-0.2905	0.0842	-3.4491	0.0181	-0.4556	-0.1254
tasksStart	-0.0618	0.0941	-0.6571	0.9798	-0.2463	0.1226
tasksStop	-0.1900	0.0941	-2.0183	0.3961	-0.3745	-0.0055
tasksWt Rel	-1.0546	0.1092	-9.6557	0.0000	-1.2687	-0.8405

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Wrist.My.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-0.1998	0.0491	-4.0656	0.0024	-0.2961	-0.1035
tasksStart	-0.0799	0.0465	-1.7175	0.5663	-0.1712	0.0113
tasksStop	-0.0755	0.0465	-1.6213	0.6218	-0.1667	0.0158

tasksWt Rel	-0.4006	0.0540	-7.4167	0.0000	-0.5064	-0.2947

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Wrist.Mz.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-0.1993	0.0548	-3.6371	0.0102	-0.3068	-0.0919
tasksStart	0.0412	0.0673	0.6123	0.9845	-0.0907	0.1731
tasksStop	-0.8695	0.0673	-12.9235	0.0000	-1.0014	-0.7377
tasksWt Rel	0.0663	0.0781	0.8497	0.9486	-0.0867	0.2193

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.Wrist.angle.in.x.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	16.5796	2.5394	6.5289	0.0000	11.6023	21.5568
tasksStart	5.0098	1.0463	4.7883	0.0001	2.9591	7.0604
tasksStop	-0.7280	1.0463	-0.6958	0.9750	-2.7786	1.3227
tasksWt Rel	-6.0849	1.2141	-5.0117	0.0000	-8.4646	-3.7052

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.Wrist.angle.in.y.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	2.0360	0.5827	3.4938	0.0159	0.8938	3.1781
tasksStart	0.9801	0.3641	2.6921	0.1234	0.2665	1.6937
tasksStop	-0.9493	0.3641	-2.6073	0.1470	-1.6629	-0.2357
tasksWt Rel	-0.1328	0.4225	-0.3143	0.9988	-0.9609	0.6953

Overall P-value that at least 1 group is different = 5e-04

==

The analysis of Max.Wrist.angle.in.z.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-2.7091	3.8881	-0.6968	0.9749	-10.3298	4.9116
tasksStart	3.8519	1.7793	2.1648	0.3210	0.3644	7.3393
tasksStop	7.4768	1.7793	4.2021	0.0014	3.9894	10.9643
tasksWt Rel	-17.8718	2.0648	-8.6553	0.0000	-21.9189	-13.8248

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Wrist.angle.in.x.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-13.2169	2.6257	-5.0336	0.0000	-18.3633	-8.0705
tasksStart	1.4486	1.0866	1.3331	0.7767	-0.6812	3.5784
tasksStop	17.8870	1.0866	16.4610	0.0000	15.7572	20.0168

```
tasksWt Rel   2.8488     1.2610  2.2592 0.2768   0.3772  5.3203

Overall P-value that at least 1 group is different = 0
============================================================
The analysis of Min.Wrist.angle.in.y.Dominant
            Estimate Std..Error t.value      P      LB      UB
(Intercept)  -7.9017     0.8430 -9.3730 0.0000 -9.5541 -6.2494
tasksStart    1.4491     0.5086  2.8494 0.0873  0.4523  2.4459
tasksStop     6.8363     0.5086 13.4423 0.0000  5.8395  7.8331
tasksWt Rel  -1.9726     0.5902 -3.3425 0.0247 -3.1293 -0.8159

Overall P-value that at least 1 group is different = 0
============================================================
The analysis of Min.Wrist.angle.in.z.Dominant
            Estimate Std..Error  t.value      P       LB       UB
(Intercept) -43.4360     2.8967 -14.9949 0.0000 -49.1136 -37.7585
tasksStart    0.6731     1.7006   0.3958 0.9971  -2.6600   4.0062
tasksStop    30.4404     1.7006  17.9000 0.0000  27.1073  33.7735
tasksWt Rel  -3.4618     1.9734  -1.7542 0.5450  -7.3297   0.4062

Overall P-value that at least 1 group is different = 0
============================================================
The analysis of Max.Wrist.angle.in.x.Non.Dominant
            Estimate Std..Error t.value      P       LB      UB
(Intercept)  16.8453     2.3297  7.2306 0.0000  12.2791 21.4116
tasksStart    3.2338     1.0672  3.0302 0.0567   1.1421  5.3256
tasksStop    -0.0926     1.0672 -0.0868 1.0000  -2.1844  1.9991
tasksWt Rel  -8.0563     1.2385 -6.5051 0.0000 -10.4837 -5.6290

Overall P-value that at least 1 group is different = 0
============================================================
The analysis of Max.Wrist.angle.in.y.Non.Dominant
            Estimate Std..Error t.value      P      LB      UB
(Intercept)   2.2215     0.5738  3.8714 0.0047  1.0968  3.3462
tasksStart    0.3612     0.2775  1.3015 0.7918 -0.1828  0.9051
tasksStop    -1.0500     0.2775 -3.7833 0.0064 -1.5939 -0.5060
tasksWt Rel  -1.4496     0.3221 -4.5012 0.0004 -2.0809 -0.8184

Overall P-value that at least 1 group is different = 0
============================================================
The analysis of Max.Wrist.angle.in.z.Non.Dominant
            Estimate Std..Error t.value      P       LB      UB
(Intercept)  -5.4800     3.4753 -1.5769 0.6471 -12.2916  1.3316
tasksStart    5.5298     1.9973  2.7686 0.1047   1.6150  9.4446
tasksStop     9.8551     1.9973  4.9341 0.0001   5.9403 13.7699
```

tasksWt Rel	-12.0054	2.3178	-5.1796	0.0000	-16.5483	-7.4625

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Wrist.angle.in.x.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-10.5033	2.8959	-3.6269	0.0105	-16.1794	-4.8272
tasksStart	1.0632	1.1659	0.9119	0.9342	-1.2219	3.3483
tasksStop	16.9300	1.1659	14.5213	0.0000	14.6449	19.2151
tasksWt Rel	-1.5959	1.3530	-1.1795	0.8457	-4.2477	1.0559

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Wrist.angle.in.y.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-6.7599	0.7855	-8.6055	0.0000	-8.2996	-5.2203
tasksStart	0.0794	0.5365	0.1479	0.9999	-0.9722	1.1309
tasksStop	5.4532	0.5365	10.1643	0.0000	4.4017	6.5048
tasksWt Rel	-3.6712	0.6226	-5.8967	0.0000	-4.8915	-2.4509

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Wrist.angle.in.z.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-42.9758	2.6273	-16.3575	0.0000	-48.1253	-37.8263
tasksStart	-0.8175	1.8809	-0.4346	0.9958	-4.5041	2.8691
tasksStop	28.7551	1.8809	15.2879	0.0000	25.0685	32.4417
tasksWt Rel	-4.7902	2.1827	-2.1947	0.3066	-9.0682	-0.5123

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.Elbow.Fx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	3.1550	0.6147	5.1328	0.0000	1.9502	4.3597
tasksStart	0.5505	0.8380	0.6569	0.9798	-1.0920	2.1930
tasksStop	-1.7224	0.8380	-2.0554	0.3765	-3.3649	-0.0799
tasksWt Rel	8.8643	0.9723	9.1168	0.0000	6.9586	10.7700

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.Elbow.Fy.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	4.0600	0.2492	16.2940	0.0000	3.5716	4.5484
tasksStart	0.4251	0.4065	1.0457	0.8953	-0.3716	1.2217
tasksStop	2.8157	0.4065	6.9271	0.0000	2.0190	3.6124

tasksWt Rel -0.0563 0.4716 -0.1193 1.0000 -0.9805 0.8680

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.Elbow.Fz.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	3.8217	0.7052	5.4192	0.0000	2.4395	5.2040
tasksStart	1.4249	0.4362	3.2666	0.0305	0.5700	2.2799
tasksStop	-1.3443	0.4362	-3.0818	0.0498	-2.1993	-0.4893
tasksWt Rel	6.3445	0.5062	12.5334	0.0000	5.3523	7.3366

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Elbow.Fx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-3.4224	0.6402	-5.3454	0.0000	-4.6773	-2.1675
tasksStart	-1.5772	0.8113	-1.9439	0.4368	-3.1674	0.0130
tasksStop	0.4754	0.8113	0.5860	0.9868	-1.1148	2.0656
tasksWt Rel	-4.1792	0.9414	-4.4394	0.0006	-6.0242	-2.3341

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Elbow.Fy.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-4.8875	1.0414	-4.6933	0.0002	-6.9286	-2.8464
tasksStart	-3.0090	0.9158	-3.2855	0.0290	-4.8041	-1.2139
tasksStop	5.6359	0.9158	6.1538	0.0000	3.8409	7.4310
tasksWt Rel	-19.6951	1.0627	-18.5322	0.0000	-21.7781	-17.6121

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Elbow.Fz.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-3.3359	0.3273	-10.1932	0.0000	-3.9774	-2.6945
tasksStart	0.1662	0.2673	0.6217	0.9836	-0.3578	0.6902
tasksStop	2.3633	0.2673	8.8402	0.0000	1.8394	2.8873
tasksWt Rel	2.2249	0.3102	7.1720	0.0000	1.6169	2.8330

Overall P-value that at least 1 group is different = 0

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The analysis of Max.Elbow.Mx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	0.7586	0.1451	5.2271	0.0000	0.4742	1.0431
tasksStart	0.1526	0.1418	1.0756	0.8851	-0.1254	0.4305
tasksStop	-0.5692	0.1418	-4.0129	0.0029	-0.8472	-0.2912

tasksWt Rel 0.6698 0.1646 4.0696 0.0024 0.3472 0.9923

Overall P-value that at least 1 group is different = 0

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The analysis of Max.Elbow.My.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	1.0749	0.3409	3.1527	0.0415	0.4066	1.7431
tasksStart	-0.5782	0.5828	-0.9921	0.9122	-1.7205	0.5641
tasksStop	-0.7388	0.5828	-1.2676	0.8076	-1.8811	0.4035
tasksWt Rel	0.2994	0.6761	0.4428	0.9955	-1.0258	1.6245

Overall P-value that at least 1 group is different = 0.4172

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The analysis of Max.Elbow.Mz.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	1.2246	0.2314	5.2911	0.0000	0.7709	1.6782
tasksStart	0.5793	0.1580	3.6669	0.0093	0.2697	0.8890
tasksStop	-1.0194	0.1580	-6.4527	0.0000	-1.3291	-0.7098
tasksWt Rel	2.1021	0.1833	11.4661	0.0000	1.7428	2.4614

Overall P-value that at least 1 group is different = 0

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The analysis of Min.Elbow.Mx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-0.6140	0.1380	-4.4485	0.0005	-0.8845	-0.3435
tasksStart	-0.1153	0.1446	-0.7973	0.9590	-0.3987	0.1681
tasksStop	-0.1319	0.1446	-0.9119	0.9342	-0.4153	0.1516
tasksWt Rel	-1.7419	0.1678	-10.3805	0.0000	-2.0708	-1.4130

Overall P-value that at least 1 group is different = 0

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The analysis of Min.Elbow.My.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-0.8443	0.2731	-3.0917	0.0486	-1.3795	-0.3090
tasksStart	0.5875	0.5632	1.0432	0.8961	-0.5164	1.6915
tasksStop	0.6586	0.5632	1.1693	0.8499	-0.4453	1.7625
tasksWt Rel	0.0967	0.6532	0.1481	0.9999	-1.1835	1.3770

Overall P-value that at least 1 group is different = 0.5587

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The analysis of Min.Elbow.Mz.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-0.4465	0.0872	-5.1188	0.0000	-0.6174	-0.2755
tasksStart	0.0030	0.1027	0.0296	1.0000	-0.1983	0.2044
tasksStop	-0.6592	0.1027	-6.4170	0.0000	-0.8605	-0.4578

	Estimate	Std..Error	t.value	P	LB	UB
tasksWt Rel	-0.3119	0.1192	-2.6171	0.1441	-0.5456	-0.0783

Overall P-value that at least 1 group is different = 0

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The analysis of Max.Elbow.angle.in.x.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	0	0	7.8010	0.0000	0	0
tasksStart	0	0	-1.6305	0.6165	0	0
tasksStop	0	0	-1.9847	0.4143	0	0
tasksWt Rel	0	0	7.3883	0.0000	0	0

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.Elbow.angle.in.y.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	129.7609	6.3619	20.3965	0.0000	117.2916	142.2303
tasksStart	-0.0012	3.0280	-0.0004	1.0000	-5.9360	5.9337
tasksStop	3.9698	3.0280	1.3110	0.7873	-1.9651	9.9046
tasksWt Rel	35.6480	3.5139	10.1450	0.0000	28.7609	42.5352

Overall P-value that at least 1 group is different = 0

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The analysis of Max.Elbow.angle.in.z.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	76.3104	2.4243	31.4776	0.0000	71.5588	81.0619
tasksStart	4.2429	1.2088	3.5099	0.0151	1.8736	6.6122
tasksStop	-6.2602	1.2088	-5.1787	0.0000	-8.6295	-3.8909
tasksWt Rel	1.0914	1.4028	0.7780	0.9625	-1.6581	3.8408

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Elbow.angle.in.x.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	0	0	-9.4575	0.0000	0	0
tasksStart	0	0	1.4236	0.7308	0	0
tasksStop	0	0	2.0098	0.4007	0	0
tasksWt Rel	0	0	-9.0902	0.0000	0	0

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Elbow.angle.in.y.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	89.7363	5.2328	17.1489	0.0000	79.4801	99.9925
tasksStart	-1.3123	2.1944	-0.5980	0.9858	-5.6134	2.9887
tasksStop	22.0215	2.1944	10.0353	0.0000	17.7205	26.3226

	Estimate	Std..Error	t.value	P	LB	UB
tasksWt Rel	-0.7817	2.5465	-0.3070	0.9989	-5.7729	4.2095

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.Elbow.angle.in.z.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	50.7816	1.4909	34.0608	0.0000	47.8594	53.7038
tasksStart	2.2703	0.8450	2.6866	0.1248	0.6140	3.9265
tasksStop	6.9488	0.8450	8.2232	0.0000	5.2925	8.6050
tasksWt Rel	-4.1522	0.9806	-4.2343	0.0013	-6.0742	-2.2302

Overall P-value that at least 1 group is different = 0

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The analysis of Max.Elbow.angle.in.x.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	0	0	12.0676	0.0000	0	0
tasksStart	0	0	-1.0321	0.8998	0	0
tasksStop	0	0	-2.5397	0.1680	0	0
tasksWt Rel	0	0	11.0035	0.0000	0	0

Overall P-value that at least 1 group is different = 0

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The analysis of Max.Elbow.angle.in.y.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	132.3282	6.1672	21.4568	0.0000	120.2405	144.4159
tasksStart	-4.2394	2.9931	-1.4164	0.7346	-10.1059	1.6270
tasksStop	-5.0369	2.9931	-1.6828	0.5863	-10.9033	0.8296
tasksWt Rel	36.6608	3.4734	10.5549	0.0000	29.8530	43.4686

Overall P-value that at least 1 group is different = 0

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The analysis of Max.Elbow.angle.in.z.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	81.0675	3.0001	27.0212	0.0000	75.1872	86.9478
tasksStart	1.6025	1.1660	1.3744	0.7562	-0.6828	3.8878
tasksStop	-6.3263	1.1660	-5.4257	0.0000	-8.6116	-4.0409
tasksWt Rel	-1.9812	1.3531	-1.4642	0.7093	-4.6332	0.6709

Overall P-value that at least 1 group is different = 0

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The analysis of Min.Elbow.angle.in.x.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	0	0	-11.2833	0.0000	0	0
tasksStart	0	0	1.6089	0.6288	0	0
tasksStop	0	0	2.7067	0.1196	0	0

	Estimate	Std..Error	t.value	P	LB	UB
tasksWt Rel	0	0	-9.2305	0.0000	0	0

Overall P-value that at least 1 group is different = 0

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The analysis of Min.Elbow.angle.in.y.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	91.8030	6.7712	13.5578	0.0000	78.5314	105.0746
tasksStart	-2.5983	1.9278	-1.3478	0.7695	-6.3769	1.1802
tasksStop	11.2428	1.9278	5.8318	0.0000	7.4642	15.0214
tasksWt Rel	-3.3307	2.2372	-1.4888	0.6960	-7.7156	1.0542

Overall P-value that at least 1 group is different = 0

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The analysis of Min.Elbow.angle.in.z.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	51.8040	1.7015	30.4454	0.0000	48.4690	55.1390
tasksStart	1.9629	0.9496	2.0670	0.3704	0.1016	3.8242
tasksStop	8.7487	0.9496	9.2126	0.0000	6.8874	10.6100
tasksWt Rel	-4.6823	1.1020	-4.2489	0.0012	-6.8423	-2.5224

Overall P-value that at least 1 group is different = 0

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The analysis of Max.GH.Fx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	1.9860	0.5923	3.3532	0.0240	0.8252	3.1468
tasksStart	1.0843	0.9309	1.1649	0.8517	-0.7402	2.9088
tasksStop	-1.8453	0.9309	-1.9824	0.4156	-3.6698	-0.0208
tasksWt Rel	10.0476	1.0799	9.3038	0.0000	7.9309	12.1643

Overall P-value that at least 1 group is different = 0

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The analysis of Max.GH.Fy.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	6.8478	0.2716	25.2165	0.0000	6.3155	7.3800
tasksStart	-0.1070	0.4065	-0.2634	0.9994	-0.9037	0.6896
tasksStop	2.8293	0.4065	6.9606	0.0000	2.0326	3.6260
tasksWt Rel	0.5932	0.4716	1.2578	0.8120	-0.3312	1.5175

Overall P-value that at least 1 group is different = 0

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The analysis of Max.GH.Fz.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	4.7934	0.7004	6.8438	0e+00	3.4206	6.1662
tasksStart	1.8006	0.4140	4.3498	8e-04	0.9893	2.6120
tasksStop	-2.3470	0.4140	-5.6696	0e+00	-3.1583	-1.5356

tasksWt Rel	5.3220	0.4804	11.0789	0e+00	4.3805	6.2635

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.GH.Fx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-6.6522	0.5413	-12.2900	0.0000	-7.7131	-5.5913
tasksStart	-1.5626	0.8049	-1.9413	0.4382	-3.1403	0.0150
tasksStop	2.1723	0.8049	2.6988	0.1216	0.5947	3.7500
tasksWt Rel	-0.9959	0.9339	-1.0665	0.8883	-2.8263	0.8344

Overall P-value that at least 1 group is different = 0.0015

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The analysis of Min.GH.Fy.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-2.4338	0.9170	-2.6542	0.1336	-4.2310	-0.6365
tasksStart	-2.1579	0.9324	-2.3143	0.2527	-3.9854	-0.3304
tasksStop	6.1318	0.9324	6.5763	0.0000	4.3043	7.9594
tasksWt Rel	-18.7582	1.0819	-17.3376	0.0000	-20.8788	-16.6376

Overall P-value that at least 1 group is different = 0

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The analysis of Min.GH.Fz.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-2.7218	0.3184	-8.5492	0.0000	-3.3458	-2.0978
tasksStart	0.5160	0.2501	2.0631	0.3724	0.0258	1.0063
tasksStop	1.6039	0.2501	6.4126	0.0000	1.1137	2.0942
tasksWt Rel	1.5904	0.2902	5.4793	0.0000	1.0215	2.1592

Overall P-value that at least 1 group is different = 0

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The analysis of Max.GH.Mx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	0.8937	0.1218	7.3385	0.0000	0.6550	1.1324
tasksStart	0.1736	0.1692	1.0261	0.9017	-0.1580	0.5053
tasksStop	-0.5616	0.1692	-3.3190	0.0264	-0.8933	-0.2300
tasksWt Rel	1.2880	0.1963	6.5604	0.0000	0.9032	1.6728

Overall P-value that at least 1 group is different = 0

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The analysis of Max.GH.My.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	1.4449	0.3378	4.2779	0.0011	0.7829	2.1070
tasksStart	-0.2846	0.5374	-0.5296	0.9910	-1.3379	0.7687
tasksStop	-1.0818	0.5374	-2.0130	0.3990	-2.1351	-0.0285

	Estimate	Std..Error	t.value	P	LB	UB
tasksWt Rel	0.7199	0.6235	1.1547	0.8557	-0.5021	1.9419

Overall P-value that at least 1 group is different = 0.0835

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The analysis of Max.GH.Mz.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	0.8723	0.2402	3.6309	0.0104	0.4014	1.3432
tasksStart	0.1204	0.1929	0.6240	0.9833	-0.2577	0.4985
tasksStop	-0.1847	0.1929	-0.9571	0.9222	-0.5628	0.1935
tasksWt Rel	1.7130	0.2239	7.6516	0.0000	1.2742	2.1518

Overall P-value that at least 1 group is different = 0

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The analysis of Min.GH.Mx.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-0.9910	0.1762	-5.6232	0.0000	-1.3364	-0.6456
tasksStart	-0.3190	0.1512	-2.1097	0.3484	-0.6153	-0.0226
tasksStop	0.4723	0.1512	3.1242	0.0447	0.1760	0.7687
tasksWt Rel	-0.8088	0.1754	-4.6104	0.0003	-1.1527	-0.4650

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.GH.My.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-1.0823	0.2799	-3.8675	0.0048	-1.6309	-0.5338
tasksStart	0.3101	0.5068	0.6119	0.9845	-0.6833	1.3035
tasksStop	0.7496	0.5068	1.4791	0.7013	-0.2438	1.7430
tasksWt Rel	0.2030	0.5879	0.3452	0.9983	-0.9493	1.3553

Overall P-value that at least 1 group is different = 0.5158

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The analysis of Min.GH.Mz.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-1.1992	0.1388	-8.6395	0.0000	-1.4713	-0.9272
tasksStart	0.0685	0.1347	0.5089	0.9923	-0.1955	0.3325
tasksStop	0.7722	0.1347	5.7331	0.0000	0.5082	1.0362
tasksWt Rel	-0.6487	0.1563	-4.1503	0.0017	-0.9550	-0.3423

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.GH.angle.in.x.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	3.7118	3.5400	1.0485	0.8944	-3.2267	10.6503
tasksStart	-1.2896	1.5819	-0.8152	0.9556	-4.3901	1.8109
tasksStop	-7.3907	1.5819	-4.6720	0.0002	-10.4912	-4.2902

```
        tasksWt Rel   3.9315     1.8357  2.1416 0.3324   0.3334  7.5295

        Overall P-value that at least 1 group is different = 0
==================================================================
        The analysis of Max.GH.angle.in.y.Dominant
                Estimate Std..Error t.value      P       LB       UB
        (Intercept)   3.0203     5.3601  0.5635 0.9887  -7.4855  13.5262
        tasksStart   -3.6517     2.9726 -1.2285 0.8250  -9.4780   2.1746
        tasksStop   -20.7260     2.9726 -6.9724 0.0000 -26.5523 -14.8997
        tasksWt Rel   2.1852     3.4495  0.6335 0.9824  -4.5760   8.9463

        Overall P-value that at least 1 group is different = 0
==================================================================
        The analysis of Max.GH.angle.in.z.Dominant
                Estimate Std..Error t.value      P       LB       UB
        (Intercept)  21.9655     6.9717  3.1507 0.0417   8.3011  35.6300
        tasksStart  -14.2727     3.8086 -3.7475 0.0072 -21.7375  -6.8079
        tasksStop   -18.5538     3.8086 -4.8716 0.0001 -26.0186 -11.0889
        tasksWt Rel -17.5940     4.4197 -3.9808 0.0032 -26.2565  -8.9314

        Overall P-value that at least 1 group is different = 0
==================================================================
        The analysis of Min.GH.angle.in.x.Dominant
                Estimate Std..Error t.value      P       LB       UB
        (Intercept) -19.9439     4.3545 -4.5801 0.0003 -28.4787 -11.4091
        tasksStart    1.1575     1.8969  0.6102 0.9847  -2.5603   4.8753
        tasksStop     8.3016     1.8969  4.3765 0.0007   4.5838  12.0195
        tasksWt Rel  12.9569     2.2012  5.8862 0.0000   8.6425  17.2713

        Overall P-value that at least 1 group is different = 0
==================================================================
        The analysis of Min.GH.angle.in.y.Dominant
                Estimate Std..Error t.value      P       LB       UB
        (Intercept) -34.1514     5.8823 -5.8058 0.0000 -45.6806 -22.6221
        tasksStart    0.0438     3.1452  0.0139 1.0000  -6.1208   6.2084
        tasksStop     1.6944     3.1452  0.5387 0.9904  -4.4703   7.8590
        tasksWt Rel -34.2568     3.6499 -9.3858 0.0000 -41.4105 -27.1030

        Overall P-value that at least 1 group is different = 0
==================================================================
        The analysis of Min.GH.angle.in.z.Dominant
                Estimate Std..Error t.value      P       LB       UB
        (Intercept) -26.4680     5.0960 -5.1939 0.0000 -36.4561 -16.4799
        tasksStart  -10.3268     3.3268 -3.1042 0.0470 -16.8473  -3.8064
        tasksStop    13.9057     3.3268  4.1799 0.0016   7.3853  20.4262
```

	Estimate	Std..Error	t.value	P	LB	UB
tasksWt Rel	-2.2057	3.8605	-0.5713	0.9880	-9.7723	5.3609

Overall P-value that at least 1 group is different = 0

==

The analysis of Max.GH.angle.in.x.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-0.2630	2.4701	-0.1065	1.0000	-5.1044	4.5784
tasksStart	4.6977	1.1471	4.0954	0.0021	2.4494	6.9460
tasksStop	-2.7589	1.1471	-2.4052	0.2158	-5.0072	-0.5107
tasksWt Rel	9.2478	1.3311	6.9472	0.0000	6.6387	11.8568

Overall P-value that at least 1 group is different = 0

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The analysis of Max.GH.angle.in.y.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	1.3036	3.8521	0.3384	0.9984	-6.2465	8.8537
tasksStart	-4.8422	2.8053	-1.7261	0.5613	-10.3406	0.6562
tasksStop	-17.9824	2.8053	-6.4102	0.0000	-23.4808	-12.4840
tasksWt Rel	4.4740	3.2553	1.3744	0.7562	-1.9064	10.8545

Overall P-value that at least 1 group is different = 0

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The analysis of Max.GH.angle.in.z.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	10.3858	4.3634	2.3802	0.2256	1.8334	18.9381
tasksStart	-9.9734	2.7583	-3.6157	0.0109	-15.3797	-4.5670
tasksStop	-12.6052	2.7583	-4.5698	0.0003	-18.0115	-7.1988
tasksWt Rel	-5.8801	3.2009	-1.8370	0.4972	-12.1539	0.3936

Overall P-value that at least 1 group is different = 0

==

The analysis of Min.GH.angle.in.x.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-22.0191	2.6444	-8.3268	0.0000	-27.2020	-16.8361
tasksStart	4.4079	1.2356	3.5674	0.0127	1.9861	6.8296
tasksStop	9.1144	1.2356	7.3767	0.0000	6.6927	11.5362
tasksWt Rel	13.3553	1.4338	9.3144	0.0000	10.5450	16.1657

Overall P-value that at least 1 group is different = 0

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The analysis of Min.GH.angle.in.y.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-33.3461	5.9220	-5.6309	0.0000	-44.9533	-21.7390
tasksStart	-2.2135	3.5705	-0.6200	0.9837	-9.2117	4.7846
tasksStop	1.9164	3.5705	0.5367	0.9906	-5.0818	8.9145

tasksWt Rel -41.1364 4.1433 -9.9283 0.0000 -49.2573 -33.0154

Overall P-value that at least 1 group is different = 0

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The analysis of Min.GH.angle.in.z.Non.Dominant

	Estimate	Std..Error	t.value	P	LB	UB
(Intercept)	-38.1281	3.9340	-9.6919	0.0000	-45.8388	-30.4174
tasksStart	-5.9345	2.5188	-2.3561	0.2353	-10.8715	-0.9976
tasksStop	19.3843	2.5188	7.6957	0.0000	14.4474	24.3213
tasksWt Rel	8.4926	2.9230	2.9055	0.0767	2.7636	14.2216

Overall P-value that at least 1 group is different = 0