Title page

Title:

Functional Range of Motion of the Hand Joints in activities of the International Classification of Functioning, Disability and Health (ICF)

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ABSTRACT AND KEY TERMS

ABSTRACT

Study Design: Cross-sectional research design

Introduction: The active range of motion (AROM) is commonly used as an index of hand function recovery after injury. However, functional range of motion (FROM) data in the literature, compared with AROM, is scarce, limited to flexions, and fail to represent activities of daily living (ADL).

Purpose of the Study: To provide FROM of the dominant hand joints in ADL, including flexions, abductions and palmar arching, in order to establish a relationship between AROM and hand function in people less than 50 years.

Methods: AROM of hand joints and hand postures in 24 representative ADL according to the ICF were recorded in 24 subjects (12 men, 12 women). A thorough descriptive analysis of the hand postures and comparison with AROM values were performed.

Results: Detailed quantitative FROM data are reported globally, per activity and ICF area, and compared with AROM values. Global AROM and FROM dependency with gender and hand size is also reported.

Discussion: AROM values are consistent with those in the literature, but more complete. Median values of hand postures should serve for decision-making in clinical interventions. In general, the FROM values required to perform ADL are much lower than the AROM values, from 5º to 28º depending on the movement and joint, with the exception of palmar arch and some thumb and little finger joints.

Conclusions: The data reported are clinically relevant to assess hand functionality.

Level of Evidence: N/A

KEY WORDS

Hand joints, functional range of motion, active range of motion.

ABBREVIATIONS:

ADL: activities of daily living

ADL_FROM: specific FROM for each ADL

AROM: active range of motion

CMC: carpometacarpal

Ch_Postures: hand postures from all subjects in all ADLs of each ICF chapter

FROM: functional range of motion

G_AROM: global AROM

G_FROM: global FROM

G_Postures: hand postures from all subjects in all ADLs

ICF International Classification of Functioning, Disability and Health

IP: interphalangeal

MCP: metacarpophalangeal

PIP: proximal interphalangeal

PROM: passive range of motion

ROM: range of motion

s_AROM: subject-specific AROM

s_FROM: subject-specific FROM

WHO: World Health Organization

1. INTRODUCTION

Hand therapists use different intervention strategies to restore the range of motion (ROM) of hand joints after hand injury and surgery.[1] The ultimate goal is to reduce impairments and enhance functional performance for activities of daily living (ADL) as well as work and leisure activities. During the rehabilitation processes, therapists assess the active and passive ROM (AROM and PROM, respectively) of hand joints as general indicators of the hand function.[2,3]

More recently, the assessment of the functional range of motion (FROM) has been proposed, especially for the wrist, elbow and shoulder. The FROM is defined as the minimum ROM necessary to comfortably and effectively perform ADL.[4] The FROM in the wrist, elbow and shoulder required for ADL has been reported to be less than the AROM.[5–7] These data are relevant, as they can be used to dictate clinical care and assess outcomes. Very few works have addressed the establishment of the FROM of the thumb and finger joints:[8–11] Hume et al.[8] studied flexion of the metacarpophalangeal (MCP) and interphalangeal (IP) joints of the thumb and fingers; Hayashi et al.[9] studied flexion of the MCP joints of fingers; and the most recent work by Bain et al.[10] studied flexion of the MCP and IP joints of fingers. The results of FROM reported in these works seem to be aligned with those reported for the wrist, elbow and shoulder, with lower values of FROM than AROM. However, there is no consensus concerning the computation of the FROM. Many works have used the average of the extreme values across subjects recorded during the development of a set of activities.[8,9] This is recognized in Bain et al.[10] to provide excessive values, therefore proposing the use of the extreme values of 90% of the activities considered. In other works, the median and 5th and 95th percentiles of the postures used are provided to analyze the requirements for upper extremity motions during activities of daily living.[12,13] In addition, the available studies on FROM of hand joints present some deficiencies and limitations. The first deficiency is that none of them analyzes the palmar arching provided by the flexion of the little and ring carpometacarpal (CMC) joints nor the abduction motions of the fingers or thumb, as was also observed in a recent review work,[3] where attention was drawn to the need for further research examining the ROM and hand functions of the thumb, because of its importance in hand function.[14] Abductions of fingers are needed to assure stability when grasping objects with different sizes, as they allow for higher distances between fingertips. And thumb abduction, along with palmar arching, are fundamental in many ADL to perform thumb opposition to fingertips.

Another limitation arises from the way the FROM was measured. The works by Hume et al.[8] and Bain et al.[10] both measured only one static position for each activity, which was hypothesized to be representative of the whole activity, thus losing many joint angle data, e.g., maximum hand opening is achieved about midway through the reaching movement.[15] Only the work by Hayashi et al.[9] took into account all the postures adopted during the activities performed.

An additional limitation comes from the selection of the tasks representing the ADL: Hume et al.[8] used 11 varied activities chosen with no systematic criterion, Hayashi et al.[9] used 19 activities from the DASH test, and Bain et al.[10] used the 20 activities from the Sollerman hand grip function test. An appropriate selection of activities representing the ADL is very important to obtain clinically relevant data and to avoid misleading conclusions. Assessment tests like the DASH or Sollerman hand grip function tests were developed for specific illnesses so that their use for assessing the hand function for other pathologies is limited. In particular, the activities of the DASH test are focused on assessing the function of the arm as a whole instead of the specific hand function, and the Sollerman hand grip function test, although being focused on assessing the hand function, lacks activities representing some important ADL aspects, as doing housework. In this sense, the

International Classification of Functioning, Disability and Health (ICF)[16] is the framework of the World Health Organization (WHO) for measuring health and disability at both individual and population levels. The ICF is, therefore, a standardized and accepted reference for reporting the level of functional recovery. To this end, the ADL are systematically collected in the “Activities and Participation” component of the “Functioning and Disability” part of the ICF.

Consequently, the purpose of the current study was to analyze the FROM of the thumb and finger joints of the right hand in people under 50 years for carrying out a reduced set of representative ADL of the ICF, including abduction motion and palmar arching, unlike other approaches. Also, the goodness of assessing hand functionality directly through AROM (as hand therapists usually do) is investigated through the comparison between FROM and AROM values.

2. MATERIAL AND METHODS

The experiment was approved by the University Ethical Committee, in accordance with the Declaration of the World Medical Association. Twenty-four right-handed subjects (12 males and 12 females) participated in the experiment, whose descriptive data are shown in Table 1. All the participants, free of hand lesions or pathologies, were properly informed and gave their written consent. The age was intentionally lower than 50 years to avoid kinematic alterations due to joint degeneration caused by the process of aging.

Insert Table 1 here

2.1 AROM AND FROM ASSESSMENT

A right-hand instrumented glove (Cyberglove Systems LLC; San Jose, CA), equipped with 18 resistive bend sensors, was used to measure the hand posture. A previously validated protocol was used to obtain 16 hand joint angles from the data from the sensors, with a global precision error of 4.45º:[17] flexion at all fingers and thumb joints (thumb CMC joint, MCP joint of thumb and fingers, proximal IP (PIP) joints of fingers and IP joint of thumb); abduction between thumb and index finger due to CMC joint of the thumb; abductions at MCP joints between index and middle, middle and ring, and ring and little fingers; and finally, flexion of palmar arch. Flexion was considered as the motion in the sagittal plane of each finger or thumb, in volar direction; thumb CMC abduction, as the motion in the perpendicular plane to the palm, which separates the thumb from the palm in palmar direction; index-middle, middle-ring and ring-little abductions, as the motions in the palmar plane that separate one finger from each other; and flexion of palmar arch, as the angle described in Figure 1. The protocol uses *across-subject gains* to transform the sensor data into joint angles, and requires the recording of a reference posture for each subject (Figure 2), in which all joint angles are considered as 0º. Flexion and abduction angles from this reference posture were considered positive, while extension and adduction angles from the reference posture were considered negative.

Insert Figure 1 here

Insert Figure 2 here

The AROM of the hand joints of each subject was assessed by measuring ten actively forced static postures (Figure 3), AROM postures, selected according to the indications of Clarkson,[2] in order to have maximum values for: flexion and extension of all fingers and thumb joints, abductions of MCP joints of fingers and thumb CMC joint, and flexion of palmar arch. For adductions, and for extension of palmar arch, AROM values were considered as 0º.

The FROM of the hand joints was evaluated for each subject by recording the hand posture while performing a set of ADL selected to cover all the areas of the ICF Chapters most directly related with hand function (Table 2), although lacking from exhaustiveness for two reasons: the restriction of defining a limited, feasible set of ADL and the limitations arising from the use of an instrumented glove for specific activities, such as '*d6506 Taking care of animals*'.

Insert Figure 3 here

Insert Table 2 here

2.2 EXPERIMENTAL PROCEDURE AND ANALYSIS

For each subject, the reference posture (static trial) was recorded (Figure 2), and considered as 0º for all joints. Then, 10 AROM postures (static trials) were recorded for each subject, and the hand joint angles at the joints of interest were calculated using the glove protocol[17] (the mean value of the sensor data during each static trial was considered), thus obtaining the subject-specific AROM (s_AROM) for the different joints and movements. Statistical values across subjects of these s_AROM values were calculated, both globally and stratified by gender, and the resulting mean values were used as global AROM (G_AROM) at each joint. Statistical differences in AROM between genders were checked by means of a set of ANOVAs (27 analyses, one per each AROM measured): dependent variable 's_AROM', with factor 'gender'. Dependency of AROM values on hand size was checked through Pearson's correlation coefficients between hand length and s_AROM, for each AROM measured.

Subsequently, in order to evaluate the FROM, 24 dynamic trials were recorded for each subject, one for each of the 24 ADL selected. The objects used in these ADL were placed in the same starting position for all the subjects, and they started and finished each activity with the same hand posture: for standing up activities, with the arms and hands relaxed at their sides; for seated activities, with the palm of the hand lying relaxed on the table. All the ADL were performed in laboratory conditions, with the same instructions for all the subjects, and using real objects. Placement of objects and subjects was controlled, as well as the actions and their sequencing to accomplish each ADL. As an example, for the action of serving water, the subject was sat in front of a table, with the hands lying on the table at shoulders distance, and the position of the bottle and the glass was the same for all the subjects. At the operator's indication, the subject took the bottle, served half a glass of water, released the bottle to its original position and returned the hands to the starting position lying on the table. The glove sensor data were recorded with a sampling frequency of 75 Hz, resulting in a sequence of hand postures that could be assimilated to frames as in a video recording. For each trial and frame, the joint angles in each hand posture were obtained with the same protocol. The beginning and end of each trial was trimmed by removing the frames in which all the joint angles varied by less than 2.5% from the initial or end posture, respectively, to avoid a starting/ending hand posture bias. The remaining frames of each trial were filtered with a 2nd order, 2-way Butterworth filter with cutoff frequency of 5 Hz to avoid noise due to artifacts. The number of frames per trial after trimming varied from 259 to 2461. A total of 576 dynamic trials resulted from all the ADL (24) and subjects (24), consisting of more than 621,100 frames, with angles for 16 hand joints in each frame. These data represent the hand postures used by the subjects when performing the 24 ADL. For each subject, a subject-specific FROM (s_FROM) for each hand joint angle was calculated as the 5^{th} and 95^{th} percentiles of all his/her frames, therefore representing the range of angles covering 90% of the postures used by each subject during all the ADL. Statistical values across subjects of these s_FROM data were calculated, both globally and stratified by gender, and the resulting mean values were used as global FROM (G_FROM) at each joint. Statistical differences in FROM between genders were checked by means of a set of ANOVAs (32 analyses, two per each movement measured): dependent variable 's_FROM', with factor 'gender'. Dependency of FROM values on hand size was checked through Pearson's correlation coefficients between hand length and s_FROM, for each FROM measured.

In order to compare AROM with FROM, a paired t-test was performed for each of the 32 movements to check statistical differences between s_AROM and s_FROM (s_AROM was considered 0º for all those joint movements where the AROM was not measured).

Furthermore, a specific FROM for each ADL (ADL_FROM) at each joint angle was defined by the 5th and 95th percentiles of the joint angles of the frames of all the subjects for the ADL considered, therefore representing the range of angles covering 90% of the postures used during each ADL at each specific joint by all the subjects of the sample.

Additionally, the requirements for hand postures during ADL were graphically analyzed, both globally and per ICF chapter. For each hand joint angle, and considering the data from all the frames and subjects, descriptive statistics were computed (median, extreme values and 5th, 25th, 75th and 95th percentiles) as global estimates of the distribution of the hand postures used to perform all the ADL considered for all the subjects of the sample (G_Postures). The same analysis was performed stratified by ICF Chapter (Ch_Postures). These statistics of G_Postures and Ch_Postures were represented with box-plots, accompanied by the G_AROM values measured, represented with bars, for their comparison.

In order to consider a subject specific comparison between AROM and FROM, an additional analysis was performed to deepen knowledge about the goodness of the assessment of hand functionality directly with AROM. For each subject, each joint angle was linearly re-scaled so that values 0 and 100 correspond to the lower and upper bounds of the s_AROM. With this normalization, the new data is a measure of the deviation of the recorded angle with respect to each s_AROM, thereby allowing comparison between values from different subjects. Histograms of re-scaled angles from all frames (time instants) were plotted for each hand joint. Also, for each ADL, the percentages of time beneath re-scaled values of 0, 10, 20 and 30, and over 70, 80, 90 and 100 were computed.

3. RESULTS

Mean and standard deviation (SD) values of s_AROM both globally and stratified by gender are shown in Table 3. Significant differences in s_AROM values between genders from the ANOVAs are marked in this table with *, and significant correlations of s_AROM values with hand size are marked with $ (preceded by the sign of the correlation, + or –). The mean values at each joint are considered as G_AROM. As expected, the highest s_AROM values correspond to the flexion/extension of IP and PIP joints, followed by finger flexion/extension at MCP joints, while the lowest s_AROM values are found for abduction/adduction. In general, the s_AROM values are not affected by gender or hand size.

Insert Table 3 here

Mean and standard deviation (SD) values of s_FROM both globally and stratified by gender are shown in Table 4. Again, significant differences in s_FROM values between genders from the ANOVAs are marked in this table with *, and significant correlations of s_FROM values with hand size are marked with $ (preceded by the sign of the correlation, + or –). The mean values at each joint are considered as G_FROM. This table can be used to check the levels of G_FROM needed to globally perform the ADL considered. The G_FROM values are more affected by gender than the G_AROM values, seemingly due to differences in hand sizes. Especially MCP joints and palmar arch are the most dependent joints, as bigger hands need more flexed postures to grasp the same objects.

Insert Table 4 here

All measured G_AROM values are higher than G_FROM, except for flexion of the MCP joint of the little finger and the palmar arch, and the thumb-index CMC abduction, which have slightly higher values of G_FROM. These differences can be analyzed in more detail by means of the results of the paired t-test shown in Table 5, which compares differences between subject specific ROM values (s_AROM and s_FROM). No statistically significant differences have been found between measured s_AROM and s_FROM values for extension of MCP and IP joints of the thumb and for flexion of the MCP joint of the little finger and the palmar arch. Measured s_AROM values are significantly higher ($p<0.05$) than s_FROM values for most hand joint motions. Highest differences between s_AROM and s_FROM values correspond to flexion of the IP joint of the thumb and the PIP joint of the index finger, extension of MCP joints of the index and middle fingers, and to abduction between fingers. But s_AROM of many other hand joint motions exceed s_FROM in more than 10 degrees. Only for abduction at the thumb CMC joint a significantly higher value of s_FROM than s_AROM has been found, although with a very small difference.

Insert Table 5 here

ADL_FROM values obtained are presented in Table 6. This table can be used to check the level of FROM needed to perform each specific ADL, which are very different between ADLs, as it is clearly observed in the table.

Insert Table 6 here

The distributions of G_Postures and Ch_Postures for each hand joint are shown in Figure 4, along with G_AROM values. The distribution of G_Postures and Ch_Postures is represented through whiskers for extreme values (minimum and maximum), boxes for percentiles (5^{th}, 25^{th}, 75^{th} and 95^{th} percentiles) and an inner line for the median. The G_AROM values measured are represented with bars. This figure can be used to check the level of FROM required for the set of representative activities considered in each chapter. Median values and percentiles of Ch_Postures present some differences among chapters, and with those of G_Postures, especially for flexion of the thumb CMC joint, along with flexion of finger MCP and PIP joints. Note that G_AROM values are lower than the extreme G_Postures values for all hand joints, although they contain 90% of the G_Postures for most hand joint motions, as explained above. Note also that G_AROM of abduction of MCP joints of fingers do not seem to contain 90% of the G_Postures. However, maximal angles of these joints were recorded only in the sense of abducting the fingers, so that this comparison is hampered by a lack of information in the sense of adducting. The same argument applies to the palmar arching, where the maximal extension was not recorded. Furthermore, as previously noted, these comparisons have to be taken with caution, as subject-specific values are being compared with mean AROM values across subjects.

Insert Figure 4 here

Histograms of re-scaled angles from all the frames (time instants) are presented in Figure 5, along with the percentages of time beyond the s_AROM values. These histograms can be used to check the percentage of time that each re-scaled angle is used. In those cases where both s_AROM values were measured, many distributions present a bell-shaped profile more or less centered within the s_AROM values, like some histograms of thumb and index joints. Nevertheless, other joints present a bimodal profile, e.g., flexion of MCP joints of ring and little fingers. Some of the bell-shaped distributions are somewhat skewed within the measured s_AROM values, especially flexion of the thumb IP joint. Some distributions have longer tails than others, e.g., extension of the thumb CMC and MCP joints, thus providing a higher percentage of time beyond the measured s_AROM values. The highest percentage of time beyond measured s_AROM corresponds to palmar deviation of the abduction of the CMC joint (more than 12% of time), followed by flexion of the MCP of the little finger (more than 11%).

A more detailed comparison of AROM and FROM values for each ADL is presented in the appendix. For each joint movement, the percentages of time beneath re-scaled angles of 0, 10, 20 and 30, and over 70, 80, 90 and 100 are presented. These tables can be used by clinicians to estimate the loss of functionality for performing each ADL of a person who has experienced a reduction of his/her AROM because of a lesion or pathology (an example of use is provided in the next section).

Insert Figure 5 here

4. DISCUSSION

In this work, AROM values both globally and stratified by gender are provided for all hand joints of the right hand in right-handed subjects, except for DIP joints, although in some joints they are given only for the sense of flexion movement. AROM values of the palmar arching are a novelty. AROM values obtained for flexion of MCP and PIP joints and abduction of MCP joints of the fingers are in agreement with those reported in previous works.[8,10,11] Flexion ranges for MCP joints are a little smaller than reported elsewhere, probably due to the stiffness provided by the instrumented glove used for conducting the experiments. However, these comparisons have to be taken with care, because the postures used to obtain the AROM values are not reported in many cases, and may differ from ours.

AROM values of flexion of CMC, MCP and IP joints and abduction of the CMC joint of the thumb are also consistent with those reported previously.[8,11,18,19] Comparison of CMC abduction and flexion AROM values with those reported by other works is cumbersome, as they present a high degree of variability,[11,20,21] probably due to a lack of consensus on the definition of these movements. Also, the AROM values for flexion and extension of the thumb MCP joint have to be taken with care, as the thumb MCP joint is somewhat flexed in the reference posture considered, thus providing high extension and low flexion AROM values. The mean flexion AROM for palmar arching, not previously reported in the literature, is about 30º. This angle has been measured over the knuckles (Figure 1) with respect to the hand resting on a flat surface. These data are relevant. Most research is focused only on the flexion capabilities of the fingers and the thumb, as they define the gross motion of the hand.

However, a reduction in the ability of flexing the palmar arch would require a higher flexion of ring and little finger MCP joints, thus affecting the opposition between the thumb and the fingers.

The values of FROM reported when performing a representative set of ADL according to the ICF of the WHO, both globally and per ADL (G_FROM and ADL_FROM), are another relevant contribution of this work. Values of global FROM are also provided stratified by gender. Additionally, extreme and percentile values of the hand postures used for developing these ADL are provided globally and per ICF Chapter (G_Postures and Ch_Postures).

AROM is commonly used as a reference goal for assessing the level of recovery achieved for hand functionality by medical and therapist staff. The comparison of AROM and FROM values obtained in this work may help to clarify the role of the AROM in the assessment of functionality. To complete all the activities tested, participants required the FROM values (G_FROM) described in Table 4, which are smaller than the G_AROM values for most joints. However, when comparing the G_AROM values with all values of G_Postures registered (Figure 4), angles at all joints exceed G_AROM bounds at specific moments for some subjects while performing the selected set of ADL. But at least 90% (approximately) of them are contained within the limits of the G_AROM values measured, consistently with the results from the comparison between G_AROM and G_FROM values, as well as from the results of the paired t-test comparing the s_AROM and s_FROM values. It is not strange that joint angles exceed the AROM values at specific moments, as hand joints during ADL might be passively forced to reach these values. This fact reinforces the proposal of computing the FROM as the 5^{th} and 95^{th} percentiles of the hand joint angles used, instead of directly using the extreme values recorded. Additionally, these comparisons show that using AROM as an indicator of the joint angle limits for establishing hand function may be useful but excessive in some cases, because the G_FROM values required to perform ADL are, in general, much lower than the AROM values (e.g., flexion of the thumb IP joint and PIP joint of the index finger). For these situations, the data provided here might be considered. The exceptions to this rule occur for the flexion of the little MCP joint and the palmar arch, the extension of the thumb MCP and IP joints, and the abduction of the thumb CMC joint, where the differences between AROM and FROM values are not significant or are very small. All these results are provided with respect to the postures that we have used to measure the AROM data, which in some cases may not be providing the maximum joint angles achievable, probably because the extreme values occur when a combination of movements is performed (e.g., circumduction of the thumb), and efforts were made to ensure the postures used for the AROM computation (selected according to classical indications) included just one pure movement, as they are more reproducible. This is a drawback of using AROM for the hand functional assessment. In any case, the exceeding values are not so high.

The FROM is quite dependent on the ADL, with values depending on the grasp types used for developing the activity, and with range of variation related to the required dexterity. For example, the activity 16 (Putting on a shoe and tying the shoelaces) requires a more flexed median posture than activity 21 (Drinking water), and a much higher range of joint flexion angles. Different social environments may require different ADL to be performed, so that in order to assess hand function different sets of ADL should be considered to represent the FROM. As FROM is highly dependent on the ADL, some differences among chapters are also observed in the distributions of Ch_Postures. For example, the 95th percentiles for some joints are higher in different chapters: in Chapter 3 (Communication), for the thumb IP flexion and palmar arching, which agrees with handling a pen for writing, and for abduction of all fingers, compatible with typing on a PC keyboard; in Chapter 4 (Mobility), for the CMC extension of the thumb and for MCP and PIP flexion of the index and middle fingers, which is compatible with grasping a door handle to open it; in Chapter 5 (Self-care), for thumb CMC flexion and ring and little PIP flexion, which agrees with the fine manipulation grasps required in many activities in this chapter; in Chapter 6 (Domestic life), for abduction of all fingers and for MCP extension of the ring and little fingers, which matches using a cloth for cleaning. These results have to be taken with care, as they are obviously dependent on the selection of the activities considered in each chapter. It is worth mentioning that global values per chapter presented have been obtained from a reduced set of representative activities.

Extreme values of postures used (previous AROM and FROM values) are important data to assess functionality, but also median values of hand postures (G_Postures and Ch_Postures) are relevant information as they represent the central posture of the joints required for performing ADL. This central posture should be considered for decision-making in clinical intervention. The central posture observed for the tasks considered in this work corresponds to a slightly flexed posture with neutral abduction of the fingers and the thumb, and the palm slightly arched. PIP and IP joints are more flexed than MCP joints (see relative values in Figure 4).

Another way of comparing AROM and FROM arises from using direct subject-specific values of AROM. In this work, this has been performed by calculating each FROM as the percentage of the subject-specific AROM (called s_AROM). From the histograms in Figure 5 it can be observed that, in those cases where both s_AROM bounds were measured, the distributions of FROM (measured as a percentage) present a bell-shaped profile, more or less centered within the s_AROM values, which means that the postures needed to perform ADL are mainly the central posture of each subject AROM. However, some exceptions also occur here. First, for the IP joint of the thumb, which is used mainly extended and flexed to a very small extent. This can be clinically relevant when a decision regarding an arthrodesis has to be made. Second, some joints present a bimodal or quasi bimodal distribution of FROM. This is the case of MCP and PIP flexion of the ring and little fingers. In these cases the central posture is not so relevant, but a wider range of postures should be considered for clinical purposes. Some distributions of FROM have longer tails than others and require a higher percentage of time beyond the measured AROM values. This is the case for extension and palmar deviation of the thumb CMC joint, extension of the thumb MCP joint, palmar arching, and flexion and extension of the little MCP joint. This means that this way of measuring the AROM for these particular movements and joints is not the best indicator of hand function.

The data presented in the tables of the appendix will allow clinicians to assess functionality. The loss of functionality for performing ADL of a person who has experienced a reduction of his/her AROM because of a lesion or pathology may be estimated from the values of these tables. As an example, consider the case of a worker with the middle PIP joint affected because of an accident so that his/her AROM is reduced to 20º/80º. If his/her normal values of flexion before the accident were 0º/100º (these values could be obtained from the non-affected hand), then his/her loss in AROM would be about 40% (20% in flexion, 20% in extension). From Table A2, one can infer that not being able to flex the middle PIP joint more than 80º means that the worker cannot adopt only 1% of the postures needed for handling a book and 2% of the postures required to open a door using a handle, but 40% of the postures needed for using a key to open a door. Conversely, being unable to adopt joint angles lower than 20º prevents the worker from achieving 48% of the postures needed for handling a book, but only 11% of the postures for opening a door and 6% of the postures for using a key to open a door. The use of these data to assess functionality is a novelty, but has to be used with caution. The complexity of the hand kinematics allows humans to substitute one grasp by another to perform ADL when impaired[8]. Thus, in the case of a reduction of mobility of a specific joint, functionality to perform a specific activity might not be affected if the rest of the hand manages to overcome the limitations of that specific joint to perform this activity. Some works have tried to evaluate this compensatory mechanism by using different metrics such as the functional arc[8] or the reachable space[22,23] when grasping. In addition, other works have attempted to evaluate the FROM resulting from a reduction of the ROM of a specific joint achieved by constraining the joint with an orthosis. This is the case of Hayashi et al.[24], who established, by means of an orthosis limiting the flexion of the MCP joints of all fingers, that a flexion of 70º and an extension lag of 20º was enough for normal functionality, assessed through Jebsen and O'Connor tests[25]. These findings can be compared with the estimations that may be performed using the data provided in the Appendix A. As an example, considering the G_AROM values reported in Table 4 (-25.3º/70.6º) for the MCP joint of the index finger, the constraints on the AROM considered in Hayashi et al.[24] correspond to re-scaled angles 21 and 99. From Table A3, we can observe that this constraint in the flexion of the MCP joint of the index finger would introduce a limitation of 0% in all the activities of self-care, thus in agreement with Hayashi's observation. According to Table 3, the reduction of extension would provide a higher limitation, ranging from 1% in eating with a fork or cutting with a knife, 5% in eating soup, 7% in brushing teeth or putting on pants, up to 33% or 37% in pouring or drinking water, respectively. These limitations from AROM reduction may be overcome by modifying the global hand posture, probably by demanding a greater extension of the thumb to reach the objects. In this case, these new angles required at the thumb joints may allow the action to be performed, but probably providing a less stable grasp and with more extreme angles at the thumb joints.

Finally, one limitation of these results is that the angles reported here include all the hand joints, even those corresponding to fingers that may not be participating in grasping the product, as well as reaching it; however, they are not expected to be very extreme angles. Another limitation of the work is that the number of activities selected as representatives of each chapter is limited, and a higher number of activities could be more enriching. Also worth noting as a limitation is the effect that the glove can have on the postures during the performance of the ADL. However, this is a minor disadvantage in comparison with the advantages of using an instrumented glove over the use of other less invasive systems with less precision, as visual recognition of postures, or other more accurate systems as motion capture systems with markers, where the problems of hiding do not allow measuring the hand motion during ADL. Despite these limitations, the data presented in this work could be used by clinicians to improve the current functional assessment performed, by checking the AROM of the hand joints of their patients.

5. ACKNOWLEDGMENTS

This research was funded by the Universitat Jaume I through projects P1·1B2013-33 and P1- 1B2014-10, and by the Spanish Ministry of Research and Innovation and the EU (FEDER funds) through project DPI2014-52095-P.

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7. TABLES

Table 1. Descriptive data of the subjects participating in the experiment. HL: hand length (from the proximal palmar crease to the tip of the middle finger), HW: hand width (at the metacarpal heads, including thumb)

		Age (years)	HL (mm)	HW (mm)
Men	Mean (SD)	33.3 (9.7)	194.8 (7.1)	103.8 (5.8)
	Min	20.0	178.0	92.0
	Max	46.0	205.0	110.0
Women	Mean (SD)	34.3 (8.2)	178.4 (9.2)	90.4 (4.9)
	Min	21.0	158.0	82.0
	Max	46.0	189.0	97.0

Table 2. ADL selected for defining the FROM of the hand joints, body posture used, and corresponding ICF Chapter and Area.

ICF Chapter	ICF Area	ADL selected	Body posture
3. Communication	d325. Communicating with - receiving - written messages	1. Reading	Seated
	d345. Writing messages	2. Writing	Seated
	d360. Using communication devices and techniques	3. Talking by phone	Seated
		4. Typing numbers on the phone	Seated
		5. Typing on PC keyboard	Seated
4. Mobility	d430. Lifting and carrying objects	6. Handling a book	Standing
	d440. Fine hand use	7. Using a key to open a door	Standing
	d445. Hand and arm use	8. Opening a door	Standing
5. Self-care	d520. Caring for body parts	9. Turning on and off the faucet	Standing
		10. Washing and drying hands	Standing
		11. Brushing teeth	Standing
		12. Putting toothpaste onto a toothbrush	Standing
		13. Combing hair	Standing
	d540. Dressing	14. Putting on a shirt and fastening two buttons	Standing
		15. Putting on pants, buttoning and zipping them up	Standing
		16. Putting on a shoe and tying the shoelaces	Seated
	d550. Eating	17. Eating soup	Seated
		18. Cutting with a knife	Seated
		19. Eating with a fork	Seated
	d560. Drinking	20. Pouring water	Seated
		21. Drinking water	Seated
6. Domestic life	d640. Doing housework	22. Using a spray	Standing
		23. Cleaning using a cloth	Standing
		24. Ironing	Standing

Table 3. Global AROM (G_AROM), globally and stratified by gender: mean and standard deviation (SD) values of subject specific AROM (s_AROM) values across subjects, mean values being considered as G_AROM. Note that no adduction AROM was registered at finger MCP joints and the thumb CMC joint, nor extension AROM at the palmar arch. Significant differences by gender from ANOVAs: * p <0.05, ** p<0.01. Significant Pearson's correlations with hand length: $^{\$}$ p <0.05, $^{\$\$}$ p<0.01, the signs + /– denote the sign of the correlation.

Digit	Joint	Motion	Mean (SD) s_AROM (º) lower bound / upper bound		
			Global	Men	Women
Thumb	CMC	Flexion	-26.2 / 42.1 (16.8) / (10.3)	-28.9 / 42.3 (15.5) / (12.4)	-23.5 / 41.9 (18.2) / (8.3)
	MCP	Flexion	-21.0 / 26.1 (11.7) / (9.1)	-23.3 / 24.6 (8.7) / (10.2)	-18.6 / 27.6 (14.1) / (7.9)
	IP	Flexion	-12.4 / 102.1 (14.6) / (19.7)	-15.7 / 108.9 (15.3) / (17.7)	-9.0 / 95.3 (13.7) / (20.0)
Thumb-Index	CMC	Abduction	0.0 / 19.7 (0.0) / (3.7)	0.0 / 20.7 (0.0) / (3.7)	0.0 / 18.8 (0.0) / (3.7)
Index	MCP	Flexion	-25.3 / 70.6$^{+\$\$}$ (14.5) / (9.1)	-30.2 / 72.2 (15.3) / (7.5)	-20.4 / 69.0 (12.4) / (10.6)
	PIP	Flexion	-3.8 / 108.8 (4.0) / (9.1)	-2.9 / 109.7 (3.1) / (9.4)	-4.7 / 107.8 (4.9) / (9.1)
Index-Middle	MCP	Abduction	0.0 / 35.2 (0.0) / (6.3)	0.0 / 37.0 (0.0) / (6.0)	0.0 / 33.4 (0.0) / (6.4)
Middle	MCP	Flexion	-27.9 / 81.9$^{+\$}$ (14.4) / (11.2)	-27.7 / 83.2 (15.9) / (9.8)	-28.2 / 80.6 (13.6) / (12.7)
	PIP	Flexion	-6.7 / 96.6 (4.9) / (9.6)	-7.2 / 97.1 (4.8) / (9.8)	-6.2 / 96.1 (5.3) / (9.7)
Middle-Ring	MCP	Abduction	0.0 / 25.7 (0.0) / (5.6)	0.0 / 28.8 (0.0) / (5.4)	0.0 / 22.6 (0.0) / (4.1)
Ring	MCP	Flexion	-23.1 / 73.6$^{+\$}$ (11.1) / (8.9)	-21.1 / 75.8* (9.6) / (6.5)	-25.1 / 71.4* (12.7) / (10.7)
	PIP	Flexion	-9.9 / 102.8 (6.5) / (7.6)	-10.9 / 102.4 (7.7) / (8.8)	-8.9 / 103.1 (5.4) / (6.4)
Ring-Little	MCP	Abduction	0.0 / 28.4 (0.0) / (3.8)	0.0 / 29.2 (0.0) / (4.3)	0.0 / 27.5 (0.0) / (3.2)
Little	MCP	Flexion	-21.9 / 68.4 (12.1) / (7.0)	-21.1 / 67.7 (10.4) / (6.0)	-22.7 / 69.2 (14.2) / (8.1)
	PIP	Flexion	-7.8 / 89.9 (8.1) / (10.1)	-8.1 / 89.3 (10.0) / (12.3)	-7.5 / 90.5 (6.3) / (7.9)
Palm	Palmar arch	Flexion	0.0 / 29.6 (0.0) / (8.6)	0.0 / 35.8** (0.0) / (5.8)	0.0 / 23.5** (0.0) / (6.1)

Table 4. Global FROM (G_FROM), globally and stratified by gender: mean and standard deviation (SD) values of subject specific FROM (s_FROM) values across subjects, mean values being considered as G_FROM. Significant differences by gender from ANOVAs: * p <0.05, ** p<0.01. Significant Pearson's correlations with hand length: $^{\$}$ p <0.05, $^{\$\$}$ p<0.01, the signs + /– denote the sign of the correlation.

Digit	Joint	Motion	Mean (SD) s_FROM (º) lower bound / upper bound		
			Global	Men	Women
Thumb	CMC	Flexion	-11.2 / 33.9 (12.8) / (10.4)	-7.4 / 34.8 (11.5) / (12.2)	-15.0 / 33.0 (13.4) / (8.7)
	MCP	Flexion	-17.1 / 14.3 (6.8) / (7.8)	-19.1 / 11.5 (4.5) / (6.8)	-15.2 / 17.1 (8.2) / (8.0)
	IP	Flexion	-7.2 / 80.6 (14.5) / (23.4)	-4.7 / 82.5 (12.8) / (21.7)	-9.7 / 78.7 (16.2) / (25.8)
Thumb-Index	CMC	Abduction	5.4 / 21.2 (2.6) / (4.0)	6.1/ 22.2 (2.7) / (4.6)	4.7 / 20.2 (2.4) / (3.2)
Index	MCP	Flexion	-1.8$^{+\$\$}$ / 51.5$^{+\$}$ (10.2) / (9.8)	2.7* / 52.5 (6.6) / (6.6)	-6.3* / 50.6 (11.4) / (12.5)
	PIP	Flexion	4.6 / 88.9$^{+\$}$ (7.1) / (13.6)	5.6 / 86.1 (7.6) / (12.3)	-3.5 / 75.6 (6.8) / (13.2)
Index-Middle	MCP	Abduction	-7.3 / 16.0$^{-\$}$ (2.8) / (3.4)	-7.6 / 14.3** (2.5) / (2.2)	-7.0 / 17.8** (3.1) / (3.6)
Middle	MCP	Flexion	-1.3$^{+\$\$}$ / 62.7$^{+\$\$}$ (10.1) / (13.5)	5.2** / 65.5 (6.3) / (9.7)	-7.8** / 59.9 (9.0) / (16.4)
	PIP	Flexion	8.3 / 78.3 (4.6) / (7.6)	9.9 / 78.1 (4.9) / (4.8)	6.7 / 78.5 (3.8) / (9.8)
Middle-Ring	MCP	Abduction	-13.7 / 2.2 (3.0) / (3.5)	-13.0 / 2.0 (2.5) / (4.2)	-14.4 / 2.4 (3.3) / (2.8)
Ring	MCP	Flexion	-5.5$^{+\$\$}$ / 60.8$^{+\$\$}$ (6.6) / (11.5)	-2.2* / 64.9 (5.1) / (7.0)	-8.7* / 56.7 (6.4) / (13.7)
	PIP	Flexion	9.3 / 91.1 (5.9) / (7.8)	11.6 / 90.3 (6.4) / (6.7)	7.0 / 92.0 (4.4) / (9.1)
Ring-Little	MCP	Abduction	-8.1 / 10.6$^{-\$}$ (3.1) / (4.4)	-7.4 / 8.8* (2.5) / (3.8)	-8.8 / 12.4* (3.6) / (4.3)
Little	MCP	Flexion	-5.4 / 71.0 (6.0) / (8.2)	-4.5 / 71.6 (4.8) / (5.8)	-6.4 / 70.4 (7.1) / (10.3)
	PIP	Flexion	6.6 / 84.5$^{-\$}$ (6.4) / (9.8)	10.4** / 81.2 (6.4) / (7.1)	2.9** / 87.8 (3.9) / (11.2)
Palm	Palmar arch	Flexion	-5.2$^{+\$\$}$ / 29.8 (8.5) / (9.7)	-0.2** / 33.9* (7.8) / (10.1)	-10.2** / 25.8* (5.9) / (7.6)

Table 5. Results of the paired t-tests: mean values of the differences s_FROM – s_AROM and p-values of the tests.

Digit	Joint	Motion	lower bound _s_FROM – lower bound _s_AROM		upper bound _s_FROM – upper bound _s_AROM	
			Mean difference	P value (2-tailed)	Mean difference	P value (2-tailed)
Thumb	CMC	Flexion	14.9	0.001	-8.2	0.000
	MCP	Flexion	3.8	0.137	-11.8	0.000
	IP	Flexion	5.2	0.181	-21.6	0.000
Thumb-Index	CMC	Abduction	5.4*	0.000	1.5	0.005
Index	MCP	Flexion	23.7	0.000	-19.0	0.000
	PIP	Flexion	8.5	0.001	-27.9	0.000
Index-Middle	MCP	Abduction	-7.3*	0.000	-18.5	0.000
Middle	MCP	Flexion	28.5	0.000	-19.2	0.000
	PIP	Flexion	15.5	0.000	-18.3	0.000
Middle-Ring	MCP	Abduction	-13.4*	0.000	-23.2	0.000
Ring	MCP	Flexion	18.7	0.000	-12.8	0.000
	PIP	Flexion	19.9	0.000	-11.6	0.000
Ring-Little	MCP	Abduction	-7.7*	0.000	-17.3	0.000
Little	MCP	Flexion	16.8	0.000	2.6	0.107
	PIP	Flexion	16.4	0.000	-5.4	0.014
Palm	Palmar arch	Flexion	-4.4*	0.059	-0.1	0.966

* AROM has not been measured for these movements

Table 6. FROM for each ADL: 5^{th} / 95^{th} percentiles of each hand joint angle from the frames of all the subjects for each ADL (ADL_FROM)

	Thumb			Thumb-Index	Index		Index-Middle	Middle		Middle-Ring	Ring		Ring-Little	Little		Palm
	CMC Flex (º)	MCP Flex (º)	IP Flex (º)	CMC Abd (º)	MCP Flex (º)	PIP Flex (º)	MCP Abd (º)	MCP Flex (º)	PIP Flex (º)	MCP Abd (º)	MCP Flex (º)	PIP Flex (º)	MCP Abd (º)	MCP Flex (º)	PIP Flex (º)	Arch Flex (º)
Activities 1	-22/32	-19/10	-17/59	2/20	-4/41	3/57	-4/11	-8/51	-1/48	-12/0	-8/40	0/53	-8/4	-8/44	0/43	-1/27
2	-13/41	-21/14	-12/118	10/25	5/57	20/103	-5/18	0/68	10/82	-18/-1	3/65	37/99	-3/14	12/82	22/90	4/44
3	-32/23	-25/9	-1/83	2/17	-29/31	-1/90	-3/32	-24/54	8/89	-18/2	-10/59	8/94	-6/13	-3/73	6/87	-8/25
4	-26/18	-18/27	7/72	1/16	-3/45	-2/41	-4/15	-11/66	3/81	-15/-1	-12/47	3/88	-11/4	-12/46	2/74	-7/30
5	-22/25	-15/10	6/61	2/17	-5/36	12/62	-2/14	-15/35	9/65	-16/-3	-20/17	10/67	-14/0	-20/16	2/40	-4/31
6	-21/35	-14/17	0/61	7/21	-10/49	3/57	-8/13	-5/66	-1/59	-11/7	-3/67	-2/63	-5/10	3/72	-14/44	2/37
7	-36/20	-19/31	9/98	5/22	3/78	18/108	-12/9	0/85	15/90	-11/3	-3/69	15/92	-9/7	-7/65	6/76	-18/29
8	-13/38	-13/14	-8/69	4/24	3/62	7/84	-13/7	9/79	11/71	-10/5	2/66	11/75	-6/10	1/72	12/65	-3/34
9	-22/23	-27/13	11/90	4/24	-16/48	7/88	-15/16	1/74	17/75	-9/12	5/76	21/96	-3/14	7/81	15/88	-7/35
10	-32/32	-17/14	5/61	0/18	-10/52	-1/72	-9/12	-14/59	3/71	-13/5	-10/53	4/78	-8/10	-7/63	-2/66	-3/29
11	-18/41	-10/20	-25/51	5/20	1/59	6/74	-10/14	-2/66	17/86	-13/2	-2/62	22/100	-9/14	-10/78	17/97	-16/27
12	-15/43	-15/13	-25/57	4/21	2/53	7/83	-9/13	-3/59	16/78	-13/2	-4/58	22/87	-7/12	-3/70	15/89	-9/32
13	-17/46	-13/17	-25/51	3/20	-13/48	3/81	-4/19	-8/66	18/79	-14/3	-3/64	18/87	-5/14	3/74	11/77	-9/32
14	-8/45	-13/15	-18/59	6/23	1/55	13/73	-7/13	-1/62	13/74	-12/2	-1/56	17/79	-8/9	-1/65	6/73	-7/29
15	-13/41	-16/20	-30/80	5/22	-1/59	12/90	-12/16	-2/65	15/89	-13/7	1/61	15/93	-8/11	2/68	7/84	-9/31
16	-13/45	-14/17	-24/70	5/22	-1/54	5/78	-12/13	-7/59	8/84	-13/6	-4/56	12/95	-8/11	-3/63	8/84	-6/33
17	-14/40	-10/21	4/86	5/18	0/55	14/80	-11/11	1/72	21/71	-10/4	7/64	27/94	-3/13	6/75	22/85	-7/43
18	-2/45	-6/24	0/77	6/19	11/57	-9/58	-6/15	6/74	39/79	-15/1	8/73	48/100	-2/16	11/79	33/101	-14/25
19	-10/38	-7/26	-12/58	4/18	15/57	-5/81	-8/11	2/69	27/79	-15/3	6/61	35/99	-3/17	7/76	27/102	-19/27
20	-9/40	-29/3	8/84	5/26	-20/25	12/64	2/24	-14/46	8/54	-15/-1	-8/44	6/59	-11/6	-6/50	-3/47	-2/36
21	-12/38	-24/4	8/94	6/26	-28/27	13/68	-1/17	-12/44	9/48	-20/-2	-13/36	5/55	-13/8	-5/56	-3/51	-3/35
22	-25/41	-19/14	1/70	7/22	-7/45	11/76	-5/13	-10/57	13/66	-13/5	-5/61	15/79	-7/10	-1/70	9/66	-5/29
23	-16/39	-14/16	-3/57	1/17	-7/41	-3/65	-5/21	-18/38	-1/79	-21/-2	-27/35	0/92	-18/4	-28/41	-3/94	-12/26
24	-26/32	-25/14	-11/63	7/23	-1/60	21/89	-2/23	5/77	23/75	-14/2	3/75	24/74	-5/16	4/80	16/62	-14/27

8. Figure Captions List

Figure 1 Definition of the palmar arching measured by the glove protocol, and examples of postures with different palmar arching values.

Figure 2 Reference posture in which all joint angles are considered as zero: the hand is resting flat on a table, with the fingers and thumb close together.

Figure 3 Static postures used to determine the AROM of the hand joints: (a) Thumb CMC maximal flexion; (b) Thumb CMC, MCP and IP maximal extension; (c) Thumb CMC maximal abduction; (d) Fingers PIP and thumb IP and MCP maximal flexion; (e) Fingers MCP maximal flexion, achieved when trying to touch the base of the palm with the fingertips; (f) Fingers, except thumb, PIP and MCP maximal extension; (g1) to (g3) Index, ring and little fingers maximal abduction, respectively; (h) Maximal palmar arching.

Figure 4 Comparison between G_AROM and hand postures used, globally and stratified by chapter (G_Postures and Ch_Postures): representation of the descriptive statistics of the distributions of G_Postures, Ch_Postures and G_AROM values obtained for each hand joint angle for the representative activities considered. The whiskers represent extreme values; the thinnest boxes represent the 5th and 95th percentiles; the thickest boxes represent the 25th and 75th percentiles; and the inner line represents the median. G_AROM values represented with bars. (*) Note that no adduction AROM was registered at finger MCP joints and the thumb CMC joint, nor extension AROM at the palmar arch. Nomenclature: CMC (carpometacarpal), IP (interphalangeal), MCP (metacarpophalangeal), PIP (proximal interphalangeal), Flex (flexion), Abd (abduction).

Figure 5 Comparison between subject-specific AROM (s_AROM) and percentage of time that each joint angle is used to perform the selected ADL: histograms represent the frequency of use of re-scaled angles from all the frames (time instants) for each the joint motion. Vertical lines have been drawn at 0 and 100, representing minimum and maximum s_AROM values. Dashed lines correspond to non-measured AROM values, so that a re-scaled angle of 0 corresponds to the angle obtained in the reference posture and not to the maximal achievable angle. The percentage of time beneath re-scaled angle 0 and over re-scaled angle 100 are also presented, while values between parentheses indicate that s_AROM was not measured and was substituted by the corresponding angle in the reference posture. Nomenclature: CMC (carpometacarpal), IP (interphalangeal), MCP (metacarpophalangeal), PIP (proximal interphalangeal), Flex (flexion), Abd (abduction).

9. APPENDIX A

Detailed data of the ADL of each ICF chapter are presented in Tables A1 to A4, describing the percentages of time beneath re-scaled angles 0, 10, 20 and 30, and over 70, 80, 90 and 100. Values between parentheses indicate that the s_AROM was measured in only one of the motion senses, so that a re-scaled angle 0 corresponds to the angle in the reference posture and not to the maximal achievable angle. Nomenclature: CMC (carpometacarpal), IP (interphalangeal), MCP (metacarpophalangeal), PIP (proximal interphalangeal), Flex (flexion), Abd (abduction).

Table A1. Percentages of time requiring non achievable postures of ADL from chapter 3 Communication, for different reductions of subject-specific AROM (s_AROM): percentages of time beneath re-scaled angles of 0, 10, 20 and 30, and over 70, 80, 90 and 100, for chapter 3, classified per activity.

			1. Reading								**2.Writing**							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**	**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	3	5	10	17	13	8	4	1	5	7	8	10	31	16	6	1
	MCP	Flex	5	15	30	50	2	0	0	0	8	15	26	35	9	3	0	0
	IP	Flex	2	16	41	66	0	0	0	0	0	2	7	15	58	44	20	6
Thumb-Index		Abd	(3)	(4)	(7)	(13)	(35)	(20)	(10)	5	(0)	(0)	(1)	(2)	(84)	(75)	(68)	36
Index	MCP	Flex	2	9	19	33	4	0	0	0	0	1	2	10	41	10	0	0
	PIP	Flex	1	15	57	82	1	0	0	0	0	2	5	7	33	14	6	0
Index-Middle		Abd	(15)	(47)	(78)	(92)	(0)	(0)	(0)	0	(25)	(41)	(73)	(86)	(1)	(0)	(0)	0
Middle	MCP	Flex	5	10	19	32	4	1	0	0	0	1	5	7	57	29	0	0
	PIP	Flex	3	29	55	78	1	1	0	0	0	5	7	8	18	6	4	3
Middle-Ring		Abd	(4)	(14)	(39)	(68)	(0)	(0)	(0)	0	(3)	(13)	(32)	(51)	(12)	(6)	(4)	3
Ring	MCP	Flex	9	19	35	59	3	1	0	0	0	2	5	12	57	27	1	0
	PIP	Flex	1	15	47	75	2	0	0	0	0	1	2	3	35	18	5	1
Ring-Little		Abd	(6)	(13)	(31)	(56)	(1)	(0)	(0)	0	(41)	(52)	(73)	(89)	(0)	(0)	(0)	0
Little	MCP	Flex	13	24	43	62	4	2	1	0	1	2	3	5	79	67	58	34
	PIP	Flex	2	24	50	71	2	1	0	0	0	1	3	5	33	16	6	2
Palmar Arch		Flex	(9)	(13)	(19)	(26)	(25)	(15)	(9)	6	(4)	(5)	(7)	(8)	(74)	(60)	(46)	43

			3.Talking by phone								**4. Typing numbers on the phone**							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**	**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	12	15	20	32	6	1	1	0	12	16	22	35	7	1	0	0
	MCP	Flex	13	16	27	40	3	2	0	0	6	14	20	34	14	8	3	0
	IP	Flex	1	7	19	32	6	3	2	0	0	3	16	32	4	1	0	0
Thumb-Index		Abd	(1)	(4)	(12)	(19)	(10)	(5)	(3)	3	(3)	(7)	(14)	(22)	(6)	(3)	(3)	3
Index	MCP	Flex	20	27	35	51	0	0	0	0	2	9	17	31	8	3	1	0
	PIP	Flex	5	18	49	63	14	2	0	0	4	20	61	84	3	2	1	0
Index-Middle		Abd	(6)	(18)	(30)	(44)	(30)	(25)	(16)	4	(11)	(31)	(57)	(77)	(0)	(0)	(0)	0
Middle	MCP	Flex	12	17	26	41	9	2	0	0	8	15	26	42	14	8	0	0
	PIP	Flex	0	4	9	15	61	34	5	0	0	14	33	64	13	7	3	0
Middle-Ring		Abd	(11)	(16)	(27)	(49)	(12)	(8)	(4)	2	(4)	(8)	(19)	(47)	(3)	(1)	(1)	0
Ring	MCP	Flex	8	15	24	31	16	5	2	0	13	26	43	64	1	0	0	0
	PIP	Flex	0	3	9	13	68	44	9	0	0	12	30	61	19	12	4	0
Ring-Little		Abd	(36)	(49)	(66)	(81)	(0)	(0)	(0)	0	(6)	(10)	(23)	(34)	(5)	(2)	(1)	1
Little	MCP	Flex	5	8	13	19	47	41	29	9	14	28	43	62	9	2	1	0
	PIP	Flex	0	5	10	13	36	25	16	4	1	16	44	59	15	5	3	3
Palmar Arch		Flex	(23)	(28)	(38)	(50)	(14)	(9)	(3)	1	(26)	(31)	(36)	(44)	(22)	(10)	(5)	2

			5. Typing on PC							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	6	9	14	26	5	3	1	0
	MCP	Flex	3	5	13	32	4	1	0	0
	IP	Flex	0	5	23	40	0	0	0	0
Thumb-Index		Abd	(1)	(3)	(6)	(11)	(18)	(5)	(3)	1
Index	MCP	Flex	4	9	17	32	2	0	0	0
	PIP	Flex	0	2	11	37	0	0	0	0
Index-Middle		Abd	(8)	(36)	(67)	(85)	(0)	(0)	(0)	0
Middle	MCP	Flex	11	19	33	54	1	0	0	0
	PIP	Flex	0	3	13	23	4	1	0	0
Middle-Ring		Abd	(2)	(6)	(20)	(50)	(3)	(1)	(0)	0
Ring	MCP	Flex	22	39	58	74	0	0	0	0
	PIP	Flex	0	2	9	35	3	0	0	0
Ring-Little		Abd	(2)	(7)	(11)	(31)	(9)	(4)	(2)	1
Little	MCP	Flex	27	44	62	81	0	0	0	0
	PIP	Flex	0	11	41	65	0	0	0	0
Palmar Arch		Flex	(11)	(16)	(20)	(25)	(33)	(22)	(14)	9

Table A2. Percentages of time requiring non achievable postures of ADL from chapter 4 Mobility, for different reductions of subject-specific AROM (s_AROM): percentages of time beneath re-scaled angles of 0, 10, 20 and 30, and over 70, 80, 90 and 100, for chapter 4, classified per activity.

			6. Handling a book								**7. Using a key to open a door**							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**	**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	9	12	16	23	21	11	4	2	23	31	43	57	6	3	2	1
	MCP	Flex	2	6	12	28	10	4	2	0	2	5	13	26	24	14	10	4
	IP	Flex	2	9	19	40	1	0	0	0	1	3	12	21	19	12	3	1
Thumb-Index		Abd	(0)	(0)	(1)	(2)	(62)	(44)	(27)	13	(1)	(2)	(3)	(5)	(58)	(44)	(27)	15
Index	MCP	Flex	7	11	19	32	11	4	0	0	1	2	6	14	52	38	23	5
	PIP	Flex	1	10	35	71	1	0	0	0	0	2	6	13	54	32	10	4
Index-Middle		Abd	(23)	(55)	(83)	(93)	(1)	(1)	(1)	0	(46)	(70)	(89)	(94)	(1)	(1)	(0)	0
Middle	MCP	Flex	4	7	11	22	22	8	0	0	1	3	7	15	44	28	14	1
	PIP	Flex	4	21	48	65	3	1	0	0	0	1	6	15	52	40	8	0
Middle-Ring		Abd	(26)	(38)	(63)	(80)	(0)	(0)	(0)	0	(17)	(36)	(62)	(79)	(0)	(0)	(0)	0
Ring	MCP	Flex	3	8	14	28	25	16	7	0	3	7	15	28	25	15	5	0
	PIP	Flex	1	13	42	64	3	1	0	0	0	1	5	16	46	28	3	0
Ring-Little		Abd	(41)	(54)	(70)	(85)	(0)	(0)	(0)	0	(22)	(36)	(54)	(69)	(3)	(2)	(1)	1
Little	MCP	Flex	1	4	12	23	40	31	21	9	4	13	25	39	21	16	8	4
	PIP	Flex	18	34	48	66	1	1	0	0	1	4	12	25	23	12	3	1
Palmar Arch		Flex	(3)	(6)	(9)	(14)	(36)	(29)	(22)	15	(30)	(36)	(41)	(46)	(19)	(13)	(8)	6

			8. Opening a door							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	4	7	11	18	33	20	9	4
	MCP	Flex	3	6	12	25	6	3	0	0
	IP	Flex	4	14	31	49	3	1	0	0
Thumb-Index		Abd	(0)	(1)	(3)	(8)	(48)	(38)	(26)	14
Index	MCP	Flex	0	2	5	12	36	15	3	0
	PIP	Flex	1	6	20	36	14	2	0	0
Index-Middle		Abd	(47)	(72)	(93)	(98)	(0)	(0)	(0)	0
Middle	MCP	Flex	0	1	3	7	41	24	5	0
	PIP	Flex	0	2	11	25	9	2	0	0
Middle-Ring		Abd	(30)	(47)	(67)	(82)	(0)	(0)	(0)	0
Ring	MCP	Flex	1	3	9	17	33	17	2	0
	PIP	Flex	0	2	8	18	8	2	1	0
Ring-Little		Abd	(41)	(55)	(69)	(83)	(0)	(0)	(0)	0
Little	MCP	Flex	1	5	12	21	40	27	14	3
	PIP	Flex	0	2	8	19	7	1	0	0
Palmar Arch		Flex	(12)	(18)	(25)	(34)	(31)	(21)	(14)	10

Table A3. Percentages of time requiring non achievable postures of ADL from chapter 5 Self Care, for different reductions of subject-specific AROM (s_AROM): percentages of time beneath re-scaled angles of 0, 10, 20 and 30, and over 70, 80, 90 and 100, for chapter 5, classified per activity.

			9. Turning on and off the faucet								10. Washing and drying hands							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**	**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	10	19	25	33	6	3	1	0	13	16	22	29	14	8	5	3
	MCP	Flex	14	23	41	62	4	2	1	0	3	7	15	34	4	1	0	0
	IP	Flex	0	1	7	18	18	10	1	0	1	5	19	40	1	0	0	0
Thumb-Index		Abd	(0)	(1)	(2)	(5)	(55)	(46)	(27)	18	(5)	(9)	(14)	(22)	(24)	(13)	(7)	3
Index	MCP	Flex	6	8	14	21	14	2	0	0	7	12	20	34	11	4	1	0
	PIP	Flex	0	5	9	17	21	3	0	0	2	11	28	53	4	1	0	0
Index-Middle		Abd	(38)	(54)	(73)	(81)	(6)	(6)	(4)	3	(31)	(59)	(81)	(92)	(1)	(1)	(0)	0
Middle	MCP	Flex	0	1	2	10	46	28	8	0	5	10	19	33	11	3	0	0
	PIP	Flex	0	2	5	11	12	4	3	0	1	12	28	49	8	3	0	0
Middle-Ring		Abd	(47)	(67)	(81)	(90)	(0)	(0)	(0)	0	(15)	(32)	(57)	(74)	(2)	(1)	(0)	0
Ring	MCP	Flex	0	1	3	10	57	46	23	3	6	12	26	40	9	3	1	0
	PIP	Flex	0	1	3	8	38	21	5	0	1	6	23	43	9	3	1	0
Ring-Little		Abd	(69)	(81)	(88)	(94)	(0)	(0)	(0)	0	(25)	(42)	(62)	(77)	(1)	(1)	(1)	0
Little	MCP	Flex	0	1	6	9	67	61	54	33	6	12	23	35	15	10	6	3
	PIP	Flex	0	2	5	13	40	26	15	6	4	14	31	49	7	3	2	1
Palmar Arch		Flex	(14)	(21)	(30)	(37)	(25)	(17)	(13)	9	(12)	(18)	(25)	(35)	(20)	(14)	(10)	7

			11. Brushing teeth								12. Putting toothpaste onto a toothbrush							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**	**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	5	7	10	14	39	21	10	5	3	7	10	14	47	27	13	6
	MCP	Flex	0	2	7	19	16	6	2	0	2	8	19	34	7	2	0	0
	IP	Flex	11	28	47	65	0	0	0	0	6	24	50	66	1	1	0	0
Thumb-Index		Abd	(1)	(2)	(4)	(7)	(47)	(28)	(14)	5	(0)	(1)	(2)	(7)	(50)	(32)	(16)	6
Index	MCP	Flex	2	4	7	11	29	7	1	0	1	3	6	13	18	4	1	0
	PIP	Flex	0	7	20	41	3	0	0	0	0	5	18	39	8	3	1	0
Index-Middle		Abd	(44)	(64)	(80)	(88)	(0)	(0)	(0)	0	(37)	(60)	(80)	(90)	(0)	(0)	(0)	0
Middle	MCP	Flex	1	2	5	15	21	6	1	0	1	2	7	16	14	2	0	0
	PIP	Flex	0	1	5	9	42	23	8	2	0	2	6	10	23	8	2	1
Middle-Ring		Abd	(11)	(29)	(46)	(63)	(2)	(0)	(0)	0	(12)	(27)	(48)	(66)	(1)	(1)	(0)	0
Ring	MCP	Flex	2	4	11	25	26	8	2	0	3	6	12	24	17	6	1	0
	PIP	Flex	0	0	3	7	63	46	20	5	0	0	4	6	38	15	3	0
Ring-Little		Abd	(42)	(53)	(66)	(77)	(2)	(2)	(1)	1	(34)	(45)	(62)	(75)	(2)	(0)	(0)	0
Little	MCP	Flex	6	9	14	21	48	40	29	17	3	6	13	20	36	28	18	5
	PIP	Flex	0	1	4	8	65	50	33	12	0	1	5	9	40	23	9	4
Palmar Arch		Flex	(36)	(42)	(50)	(58)	(11)	(8)	(5)	3	(19)	(23)	(27)	(33)	(24)	(14)	(9)	6

			13. Combing hair								14. Putting on a shirt & fastening 2 buttons							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**	**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	5	7	11	16	44	28	16	8	2	3	5	8	55	34	19	10
	MCP	Flex	2	5	11	23	19	6	1	0	1	4	10	22	10	2	0	0
	IP	Flex	8	25	46	62	1	0	0	0	9	22	39	59	3	2	1	0
Thumb-Index		Abd	(2)	(3)	(6)	(11)	(44)	(25)	(9)	3	(1)	(1)	(2)	(5)	(67)	(49)	(28)	11
Index	MCP	Flex	7	11	19	30	10	3	0	0	2	5	9	16	21	5	0	0
	PIP	Flex	2	11	19	29	10	2	0	0	0	3	13	31	3	0	0	0
Index-Middle		Abd	(14)	(34)	(55)	(71)	(2)	(1)	(1)	1	(29)	(54)	(76)	(90)	(0)	(0)	(0)	0
Middle	MCP	Flex	2	4	12	23	14	3	0	0	1	2	7	15	20	4	0	0
	PIP	Flex	0	2	4	11	30	15	6	1	1	3	7	19	14	4	1	0
Middle-Ring		Abd	(13)	(23)	(41)	(56)	(3)	(1)	(0)	0	(14)	(25)	(49)	(71)	(1)	(0)	(0)	0
Ring	MCP	Flex	3	6	11	20	22	8	1	0	2	5	12	23	14	5	1	0
	PIP	Flex	0	1	5	11	37	15	3	0	1	1	5	13	14	3	1	0
Ring-Little		Abd	(40)	(59)	(73)	(83)	(1)	(0)	(0)	0	(21)	(34)	(50)	(65)	(1)	(1)	(0)	0
Little	MCP	Flex	2	4	9	14	45	37	25	12	5	9	17	26	20	14	7	3
	PIP	Flex	1	4	9	19	26	13	2	0	1	4	11	22	12	6	2	1
Palmar Arch		Flex	(19)	(23)	(28)	(37)	(24)	(18)	(13)	9	(18)	(23)	(30)	(37)	(19)	(13)	(7)	5

Table A3 Cont. I: Chapter 5. Self-care

			15. Putting on pants, buttoning and zipping them up								**16. Putting on a shoe & tying the shoelaces**							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**	**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	5	7	11	16	39	24	13	6	4	7	10	14	44	29	15	7
	MCP	Flex	3	7	15	29	16	8	3	1	3	6	13	23	16	8	3	0
	IP	Flex	15	31	47	60	7	3	2	1	11	27	43	62	3	2	0	0
Thumb-Index		Abd	(0)	(1)	(2)	(5)	(59)	(46)	(30)	15	(0)	(1)	(3)	(5)	(46)	(31)	(19)	10
Index	MCP	Flex	2	4	7	12	28	12	1	0	1	4	8	15	21	5	0	0
	PIP	Flex	0	3	12	26	13	5	2	0	2	7	18	37	7	2	1	0
Index-Middle		Abd	(36)	(54)	(71)	(83)	(1)	(0)	(0)	0	(45)	(66)	(82)	(91)	(0)	(0)	(0)	0
Middle	MCP	Flex	1	2	5	11	26	8	1	0	2	4	10	19	13	4	0	0
	PIP	Flex	0	1	6	12	32	16	6	1	1	5	11	20	24	12	3	1
Middle-Ring		Abd	(22)	(35)	(52)	(70)	(1)	(1)	(0)	0	(21)	(33)	(50)	(66)	(1)	(1)	(0)	0
Ring	MCP	Flex	1	3	8	16	23	10	2	0	2	6	13	27	11	4	1	0
	PIP	Flex	0	1	5	11	36	18	5	1	0	1	7	16	31	16	6	2
Ring-Little		Abd	(36)	(49)	(61)	(74)	(2)	(1)	(1)	1	(31)	(41)	(54)	(65)	(3)	(2)	(1)	1
Little	MCP	Flex	2	4	8	15	35	23	13	5	2	6	12	25	21	14	6	3
	PIP	Flex	1	4	10	20	28	15	6	2	1	4	11	21	27	16	8	3
Palmar Arch		Flex	(21)	(27)	(33)	(40)	(23)	(15)	(10)	6	(15)	(20)	(25)	(32)	(27)	(19)	(12)	9

			17. Eating soup								**18. Cutting with a knife**							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**	**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	7	9	13	19	34	15	4	1	2	4	7	10	50	33	14	4
	MCP	Flex	1	4	9	18	17	7	0	0	1	2	3	7	32	17	5	0
	IP	Flex	0	4	14	31	8	4	1	0	3	9	27	40	2	2	1	1
Thumb-Index		Abd	(1)	(1)	(3)	(6)	(23)	(13)	(6)	3	(0)	(0)	(1)	(3)	(46)	(12)	(5)	2
Index	MCP	Flex	1	4	5	8	23	5	0	0	0	0	1	4	46	18	2	0
	PIP	Flex	0	1	7	13	9	0	0	0	21	51	77	85	1	0	0	0
Index-Middle		Abd	(39)	(63)	(80)	(89)	(0)	(0)	(0)	0	(19)	(43)	(67)	(81)	(0)	(0)	(0)	0
Middle	MCP	Flex	0	1	2	7	61	27	3	0	1	1	3	5	44	22	3	0
	PIP	Flex	0	2	4	9	17	1	0	0	0	1	2	3	41	10	0	0
Middle-Ring		Abd	(27)	(47)	(68)	(85)	(0)	(0)	(0)	0	(9)	(23)	(43)	(59)	(5)	(2)	(1)	0
Ring	MCP	Flex	1	2	3	6	52	20	4	0	1	2	3	6	67	45	17	0
	PIP	Flex	0	2	4	5	52	14	5	0	0	1	2	3	78	60	20	0
Ring-Little		Abd	(66)	(82)	(91)	(95)	(0)	(0)	(0)	0	(55)	(72)	(84)	(90)	(1)	(0)	(0)	0
Little	MCP	Flex	1	2	4	5	76	61	39	19	1	2	3	4	85	78	66	35
	PIP	Flex	0	2	4	5	58	32	10	2	0	1	3	4	82	61	36	13
Palmar Arch		Flex	(13)	(16)	(21)	(26)	(45)	(35)	(27)	22	(38)	(48)	(58)	(66)	(9)	(7)	(4)	3

Table A3 Cont. II: Chapter 5. Self-care

			19. Eating with a fork								20. Pouring water							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**	**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	4	4	5	8	43	24	9	4	1	2	3	6	38	18	12	4
	MCP	Flex	0	1	3	7	34	23	12	1	27	39	60	80	0	0	0	0
	IP	Flex	3	12	39	64	2	0	0	0	0	3	8	15	12	4	0	0
Thumb-Index		Abd	(0)	(1)	(3)	(11)	(45)	(24)	(9)	2	(1)	(2)	(4)	(6)	(86)	(84)	(79)	67
Index	MCP	Flex	0	0	1	5	40	14	3	0	13	19	33	60	0	0	0	0
	PIP	Flex	8	28	50	60	7	5	0	0	0	3	11	29	0	0	0	0
Index-Middle		Abd	(39)	(68)	(82)	(91)	(0)	(0)	(0)	0	(0)	(6)	(32)	(49)	(6)	(2)	(0)	0
Middle	MCP	Flex	0	1	2	4	32	9	0	0	2	10	17	23	8	0	0	0
	PIP	Flex	0	1	3	5	28	11	2	0	0	4	15	23	0	0	0	0
Middle-Ring		Abd	(12)	(21)	(41)	(59)	(7)	(5)	(2)	0	(6)	(11)	(23)	(40)	(5)	(0)	(0)	0
Ring	MCP	Flex	0	1	3	6	30	8	3	1	4	10	21	35	8	0	0	0
	PIP	Flex	0	1	3	4	72	54	30	5	0	4	15	31	0	0	0	0
Ring-Little		Abd	(57)	(65)	(83)	(91)	(1)	(0)	(0)	0	(12)	(17)	(30)	(45)	(10)	(7)	(5)	4
Little	MCP	Flex	1	2	3	5	72	60	39	11	9	18	22	34	8	4	1	0
	PIP	Flex	0	1	3	4	75	68	51	19	6	18	32	60	0	0	0	0
Palmar Arch		Flex	(51)	(61)	(66)	(72)	(10)	(6)	(4)	2	(8)	(10)	(15)	(23)	(40)	(36)	(19)	13

			21. Drinking water							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	1	2	5	6	33	12	5	0
	MCP	Flex	29	42	58	78	1	0	0	0
	IP	Flex	0	3	9	17	28	8	2	0
Thumb-Index		Abd	(1)	(2)	(4)	(5)	(86)	(83)	(80)	66
Index	MCP	Flex	15	22	37	64	0	0	0	0
	PIP	Flex	0	2	9	20	0	0	0	0
Index-Middle		Abd	(3)	(15)	(36)	(57)	(0)	(0)	(0)	0
Middle	MCP	Flex	5	12	22	35	2	0	0	0
	PIP	Flex	0	3	12	25	0	0	0	0
Middle-Ring		Abd	(2)	(7)	(23)	(36)	(16)	(9)	(3)	0
Ring	MCP	Flex	11	20	28	40	0	0	0	0
	PIP	Flex	1	6	18	42	0	0	0	0
Ring-Little		Abd	(10)	(17)	(36)	(48)	(9)	(5)	(3)	2
Little	MCP	Flex	10	17	24	33	21	10	2	0
	PIP	Flex	4	18	46	67	3	0	0	0
Palmar Arch		Flex	(10)	(17)	(25)	(33)	(25)	(19)	(11)	7

Table A4. Percentages of time requiring non achievable postures of ADL from chapter 6 Domestic life, for different reductions of subject-specific AROM (s_AROM): percentages of time beneath re-scaled angles of 0, 10, 20 and 30, and over 70, 80, 90 and 100, for chapter 6, classified per activity.

			22. Using a spray								**23. Cleaning using a cloth**							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**	**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	8	11	15	21	26	13	7	4	4	7	10	15	29	18	9	4
	MCP	Flex	7	15	27	40	5	2	0	0	1	5	15	25	16	8	2	0
	IP	Flex	2	6	20	37	5	1	0	0	1	10	32	46	1	0	0	0
Thumb-Index		Abd	(0)	(1)	(1)	(3)	(67)	(47)	(31)	15	(2)	(8)	(13)	(25)	(13)	(6)	(2)	0
Index	MCP	Flex	4	8	15	26	5	1	0	0	6	12	17	31	3	0	0	0
	PIP	Flex	2	5	12	34	5	1	0	0	6	25	58	76	1	0	0	0
Index-Middle		Abd	(18)	(50)	(74)	(90)	(0)	(0)	(0)	0	(16)	(33)	(53)	(71)	(1)	(0)	(0)	0
Middle	MCP	Flex	3	7	13	25	9	1	0	0	12	22	40	59	1	0	0	0
	PIP	Flex	0	3	9	25	5	1	0	0	5	19	36	55	16	6	2	1
Middle-Ring		Abd	(14)	(22)	(47)	(71)	(1)	(0)	(0)	0	(2)	(8)	(21)	(35)	(17)	(11)	(7)	4
Ring	MCP	Flex	3	8	16	29	17	7	1	0	18	33	55	72	1	0	0	0
	PIP	Flex	0	0	6	21	14	3	0	0	2	15	31	42	31	19	7	2
Ring-Little		Abd	(26)	(38)	(56)	(73)	(0)	(0)	(0)	0	(2)	(7)	(19)	(35)	(27)	(19)	(12)	8
Little	MCP	Flex	4	9	16	27	32	23	13	4	20	34	49	60	4	1	0	0
	PIP	Flex	1	4	15	35	6	2	0	0	6	18	30	40	37	29	15	3
Palmar Arch		Flex	(16)	(21)	(27)	(35)	(19)	(12)	(8)	4	(23)	(29)	(34)	(42)	(12)	(7)	(4)	3

			24. Ironing							
% of AROM reduction			**0**	**10**	**20**	**30**	**70**	**80**	**90**	**100**
Thumb	CMC	Flex	12	17	21	25	18	8	2	1
	MCP	Flex	22	31	38	52	5	3	2	0
	IP	Flex	7	17	33	46	3	0	0	0
Thumb-Index		Abd	(0)	(1)	(1)	(2)	(75)	(57)	(43)	26
Index	MCP	Flex	1	2	7	13	23	8	2	0
	PIP	Flex	0	1	4	11	36	8	0	0
Index-Middle		Abd	(8)	(25)	(42)	(55)	(5)	(3)	(2)	1
Middle	MCP	Flex	1	2	4	8	54	32	6	0
	PIP	Flex	0	1	3	7	31	6	0	0
Middle-Ring		Abd	(15)	(28)	(42)	(55)	(3)	(0)	(2)	0
Ring	MCP	Flex	1	3	6	12	67	49	16	0
	PIP	Flex	0	0	2	7	13	0	3	0
Ring-Little		Abd	(37)	(52)	(72)	(88)	(1)	(1)	(1)	1
Little	MCP	Flex	1	3	7	11	74	72	58	33
	PIP	Flex	0	1	5	11	3	0	0	0
Palmar Arch		Flex	(38)	(46)	(56)	(66)	(5)	(2)	(0)	1

10. FIGURES

Figure 1

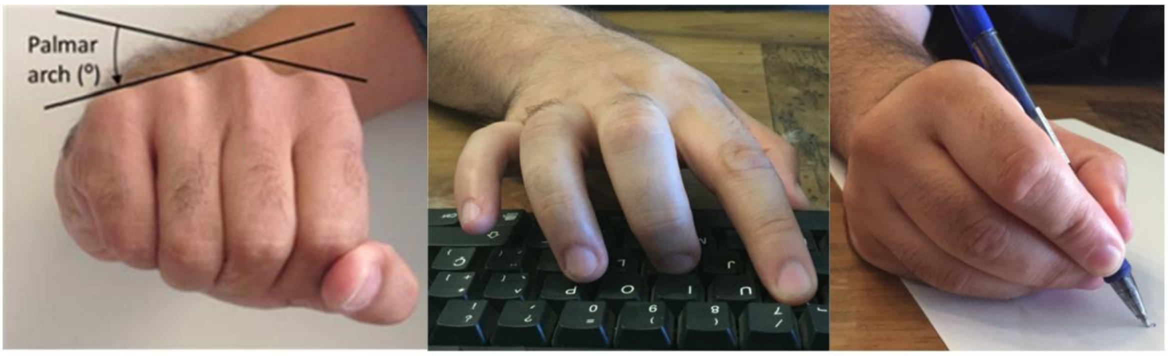


Figure 2

Figure 3

Figure 4

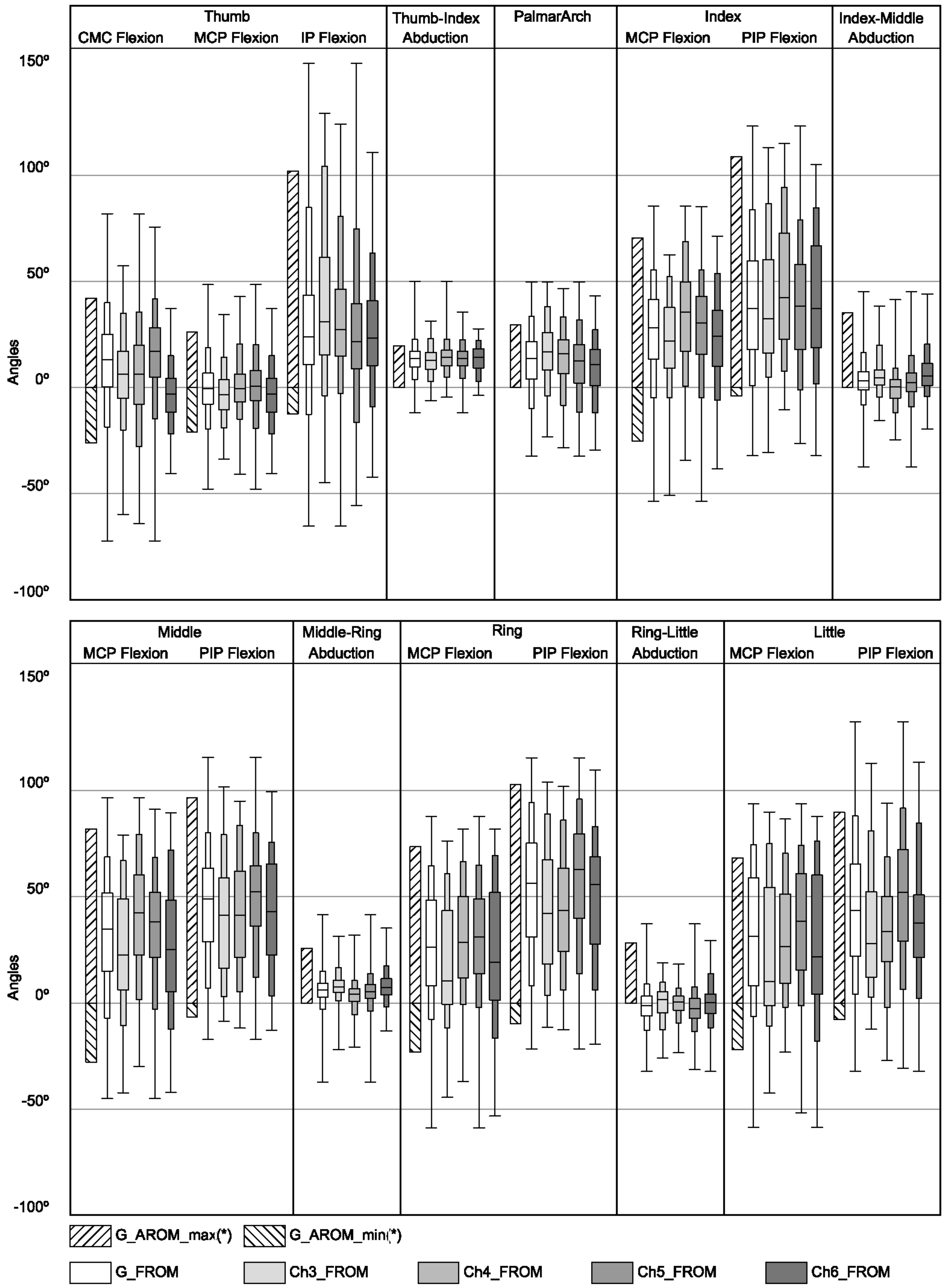
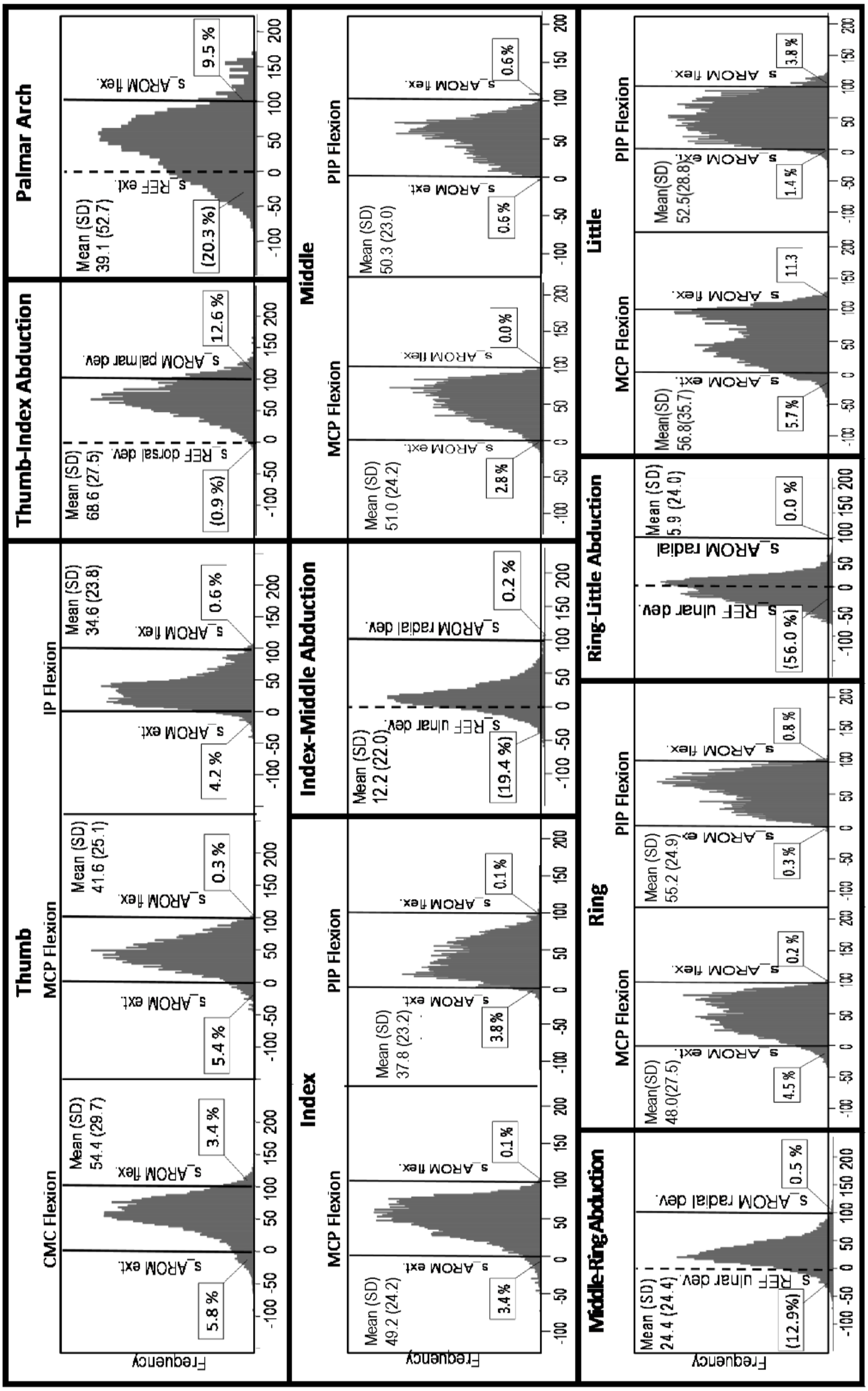

Thumb
CMC Flexion
MCP Flexion
IP Flexion
Thumb-Index Abduction
PalmarArch
Index
MCP Flexion
PIP Flexion
Index-Middle Abduction
150º
100º
50º
0º
-50º
-100º
Angles
Middle
MCP Flexion
PIP Flexion
Middle-Ring Abduction
Ring
MCP Flexion
PIP Flexion
Ring-Little Abduction
Little
MCP Flexion
PIP Flexion
G_AROM_max(*)
G_AROM_min(*)
G_FROM
Ch3_FROM
Ch4_FROM
Ch5_FROM
Ch6_FROM

Figure 5


Thumb
CMC Flexion
Mean (SD) 54.4 (29.7)
MCP Flexion
Mean (SD) 41.6 (25.1)
IP Flexion
Mean (SD) 34.6 (23.8)
Thumb-Index Abduction
Mean (SD) 68.6 (27.5)
Palmar Arch
Mean (SD) 39.1 (52.7)
Index
MCP Flexion
Mean (SD) 49.2 (24.2)
PIP Flexion
Mean (SD) 37.8 (23.2)
Index-Middle Abduction
Mean (SD) 12.2 (22.0)
Middle
MCP Flexion
Mean (SD) 51.0 (24.2)
PIP Flexion
Mean (SD) 50.3 (23.0)
Middle-Ring Abduction
Mean (SD) 24.4 (24.4)
Ring
MCP Flexion
Mean(SD) 48.0(27.5)
PIP Flexion
Mean (SD) 55.2 (24.9)
Ring-Little Abduction
Mean (SD) 5.9 (24.0)
Little
MCP Flexion
Mean(SD) 56.8(35.7)
PIP Flexion
Mean(SD) 52.5(28.8)
Frequency