Physiotherapie

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BACHELORARBEIT II

Titel der Bachelorarbeit

Influence of elbow position and forearm rotation on grip strength of the non-/dominant hand of healthy older adults

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EHRENWÖRTLICHE ERKLÄRUNG

Ich erkläre, dass ich die vorliegende Bachelorarbeit selbstständig verfasst, andere als die angegebenen Quellen und Hilfsmittel nicht benutzt und mich auch sonst keiner unerlaubten Hilfe bedient habe.

Dieses Bachelorarbeitsthema habe ich bisher weder im In- noch im Ausland in irgendeiner Form als Prüfungsarbeit vorgelegt.

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I. Abstract

Influence of elbow position and forearm rotation on grip strength of the non-/dominant hand of healthy older adults

Introduction: Handgrip strength can be a reliable parameter for total muscle strength, depression or hand rehabilitation, but concerning the method, there is no standardized procedure. Parameters like handedness, elbow and forearm position can influence the maximum grip strength.

Methods: The proband group consisted of thirty-two healthy older adults (15 left-dominant subjects and 17 right-dominant subjects). Each subject had to demonstrate maximum grip strength in four different positions with his dominant and with his non-dominant hand, eight different positions in total. The difference between these positions was elbow flexion/extension and neutral /supinated forearm, as well as non-dominant and dominant hand.

Results: Partial (in regard to 3 other positions) significant higher grip strength with the right arm in elbow flexion and forearm supination was measured for left-dominant (43,3 mean; 11,3 SD) and right-dominant (41,7 mean; 8,8 SD) subjects.

Conclusion: Although the results of the present work appear not to be in accordance with the available literature, comparable studies utilize a wide range of measurement methods as well as subjects of varying age level. As such, there is clear need to develop standards regarding handgrip strength measurements, particularly the development of reference charts for isolated age groups.

KEYWORDS: handgrip, handgrip strength, hand dominance, elbow position, forearm rotation

I. Zusammenfassung

Einfluss der Ellbogenposition und der Unterarmrotation auf die Handgriffkraft der nicht-/dominanten Hand bei gesunden, älteren Erwachsenen.

Einleitung: Die Messung der Handgriffkraft kann als reliabler Parameter dienen um die totale Muskelmasse, Depressionen oder Handrehabilitationen zu ermitteln. Eine standardisierte Durchführung ist derzeit nicht bekannt. Parameter wie Händigkeit, Ellbogen- und Unterarmposition können die maximale Griffkraft beeinflussen.

Methoden: Die Probandengruppe bestand aus zweiunddreißig gesunden, älteren (15 Linksdominante und 17 Rechtsdominante). Jeder/Jede Proband/Probandin demonstrierte die maximale Griffkraft in vier verschiedenen Positionen, mit der dominanten und der nicht-dominanten Hand, also acht Positionen insgesamt. Der Unterschied zwischen diesen Positionen war ein gebeugter/gestreckter Ellbogen, ein neutraler/supinierter Unterarm und die nicht-/dominante Hand.

Ergebnisse: Teilweise (in Bezug zu den anderen drei Positionen) signifikant höhere Griffkraftwerte wurden mit dem rechten Arm in Ellenbeugung und Unterarmsupination gemessen, bei links- (43,3 durchschnittlich; 11,3 SD) und rechts-dominanten(41,7 durchschnittlich; 8,8 SD) Personen.

Schlussfolgerung: Die Resultate dieser Arbeit scheinen nicht in Korrelation mit der verfügbaren Literatur zu stehen. Vergleichbare Studien beinhalten verschiedene Ansätze der Messmethoden, ebenso eine abweichende Altersklasse. Daher ist es notwendig, klare Standardisierungsverfahren zur Messung der Handgriffkraft zu entwickeln, insbesondere die Erstellung von Vergleichswerte für bestimmte Altersgruppen.

SCHLÜSSELWÖRTER: Handgriff, Handgriffkraft, Handdominanz, Ellbogenposition, Unterarmrotation

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MVC – Maximum Voluntary Contraction

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1 Introduction

They are used to greet, to eat, to work, to grab, for almost every activity of our daily life and for much more- our hands.

Their importance cannot be denied, both in sensoric and motoric functions. The sensoric functions include haptic perception, feeling temperature or pain. The motoric functions, such as fine and gross coordination skills or grip strength, are the key elements of manual functions. Together, sensoric and motoric functions affect the quality of daily living skills and work related functioning to a large degree. These factors that ensure manual function, are influenced by an important bias- the hand dominance (Incel, Ceceli, Durukan, Erdem, & Yorgancioglu, 2002).

There are many ways to test several hand functions, for example the Purdue Pegboard Test for dexterity or the Minnesota Manual Dexterity Test for hand-eye coordination and gross motor skills (Wiggen, Heen, Færevik, & Reinertsen, 2011). Via measuring these factors, it is possible to deduce the outcomes to the commonly called functional, psychological and social health (Taekema, Gussekloo, Maier, Westendorp, & de Craen, 2010). There are many factors on handgrip strength that can influence the outcome such as the position of the measured arm, hand dominance and the measuring device.

1.1 Handgrip Strength

In regard of the different hand functions, this thesis will mainly focus on handgrip strength.

This is the force that generates by bending the fingers so that they form a fist. According to Carmeli, Patish and Coleman (2003) handgrip complies with the power grip, one of the three main prehensions. Whereas, Prehension is described as the act of grasping.

More precisely, the maximum voluntary contraction (MVC) of grip strength will be measured. This is the same parameter used by Farooq and Ali Khan (2012). The MVC is measured at the highest peak of grip force the participant can reach when pressing the hand dynamometer up to full strength.

1.2 Measuring Device

Measuring the grip strength can be done with a hand dynamometer. Three common hand dynamometer tools are:

- The JAMAR® hydraulic hand dynamometer
- The DynEx electronic hand dynamometer

- The TKK digital hand dynamometer

España-Romero, Ortega, Vicente-Rodríguez, Artero, Rey and Ruiz (2010) compared these three dynamometers with regard to their reliability. According to this study, the precision of the JAMAR® hydraulic hand dynamometer is 2kg while the precision of the DynEx and the TKK is 0.1kg. The JAMAR® and the DynEx dynamometers have fixed grip span positions. The TKK dynamometer has an adjustable grip span, making this even more precise because the accurate grip span is related to the maximum handgrip strength (España-Romero, Artero, Santaliestra-Pasias, Gutierrez, Castillo & Ruiz, 2008). Handgrip dynamometers are inexpensive to purchase, simple in applicability and non-invasive.

1.3 Positions

A crucial element to measure the MVC represents the arm position during the testing procedure, although there are controversial opinions about possible influences. The following are various results:

Kong (2014), Farooq and Ali Khan (2012) measured no significant difference in grip strength due to elbow angles.

España-Romero et al. (2010) measured a higher grip strength with extended elbows compared to a 90° flexed elbow, but only when measured with the TKK dynamometer.

Oxford (2000) gained similar results by conducting a study with 64 male and 64 female subjects. She tested 128 subjects knowing that one of the main problems of many studies measuring the handgrip strength, namely the discrepancies in the results, is based on small subject groups. In this study, Oxford used the GreenLeaf electrodynamometer and discovered that the handgrip strength is higher in fully extended elbow position compared to a position of the elbow in 90° flexion.

Although there was no significant difference in grip strength with forearm rotation, Farooq and Ali Khan (2012) experienced a decreasing grip strength from pronated to supinated forearm position.

Whereas Mogk and Keir (2003) also found a non-significant difference in grip strength with pronated forearm position to be the one with lowest grip force. The different outcomes may be the result of the small subject groups with 10 and 20 participants.

1.3.1 Biomechanical Considerations

Oxford (2000), Kuzala and Vargo (1992) explain the various results of the measured grip strength at different elbow positions on the basis of biomechanical circumstances. As shown in Figure 1, there is a part of one muscle crossing the elbow joint that affects the flexion of the fingers: the musculus flexor digitorum superficialis. One head of the m. flexor digitorum superficialis originates from the medial epicondyle of the humerus, thereby it gets progressively placed in a shortened position by flexing the elbow. Oxford (2000) also mentions the biomechanical advantage of the wrist extensors, which also stabilize the wrist joint as they get under tension at full elbow extension. These biomechanical reasons are related to the length-tension relationship, as pictured below.

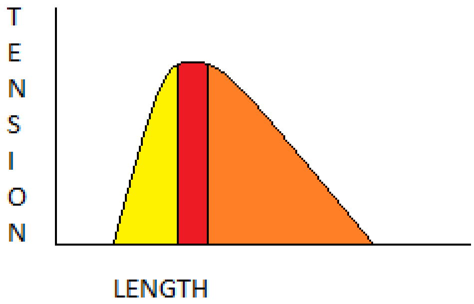

Figure 2: Length-Tension-Relationship, modified after Lieber and Ward (2011). The yellow area represents sarcomeres in a shortened position, red area in optimal overlap, and orange area in extended position.

Carmeli, Coleman and Reznick (2002) also mention the decrease of grip strength of older adults due to major reduction in muscle mass, ranging from 25% to 45%. They also refer to the intrinsic and extrinsic hand muscle which also takes part in handgrip strength, being affected by muscle mass loss as well.

1.4 Hand Dominance

When it comes to measuring the strength of the upper limbs, the hand dominance should always be taken into account, also in handgrip strength tests. Incel et al. (2002) determined that right handed subjects have a significantly stronger right handgrip but left handed subjects don’t have a significant difference in handgrip strength between the left or right side. They assumed that this equal strength may be attributed to the use of the right hand in daily activities because of the predetermined orientation to right hand dominance. Oxford (2000) also considered the hand dominance with the dominant hand to be stronger, but there was no distinction between right and left hand dominance. A very recent study from Sebastjan, Skrzek, Ignasiak & Sławińska (2017) showed that there are significant differences in fine motor performance in laterality between the dominant and non-dominant hand - except in the oldest group, which consisted of women aged >70.

A popular belief that clinicians have is the „10%“rule, which implies that the non-dominant hand is approximately 10% weaker than the dominant hand. Armstrong and Oldham (1999) measured 3 different values: maximum voluntary contraction of the first dorsal interosseous muscle, pulp-to-pulp pinch strength and power grip strength. Their findings showed no significant difference between these three testing positions for left-handed individuals, but significant differences for all three tests in right-handed subjects. The test subjects were 83 healthy participants aged between 18 and 72 years.

1.5 State of the art

On the basis of handgrip strength, it is possible to make statements about many topics such as patients suffering depression (Phillips, Biland, Costa, & Souverain, 2011) by calculating the standard deviation and visual analyses of the force curve plots, or to be more obvious-upper limb strength can be predicted by measuring grip strength (Bohannon, 1998). Handgrip strength also correlates to the quality of life of patients and to the physical ability of healthy male and female subjects (Jakobsen, Rask, & Kondrup, 2010). These conclusions are similar to the findings of Sayer, Syddall, Martin, Dennison, Roberts, & Cooper (2006) about reduced health-related quality of life for men and women aged 59-73 years with lower handgrip strength, linked to sarcopenia and frailty. Luna-Heredia, Martín-Pena and Ruiz-Galiana (2005) examined that handgrip strength correlates with age and gender, but not with height.

Wind, Takken, Helders, & Engelbert (2010) examined that handgrip strength is related to total muscle strength (measured with shoulder abduction, hip flexion and ankle dorsiflexion) in healthy children, adolescents and young adults.

The broadest spectrum of possible predictions is measured by Taekema, Gussekloo, Maier, Westendorp, & Craen (2010) by finding a correlation with lower baseline handgrip strength and accelerated dependency in activities of daily living and cognitive decline, with 555 subjects aged 85 years.

In general, conducting studies about measuring handgrip strength can be helpful in comparing a measured handgrip strength with a reference value of a healthy individual. Although, it is required to have a correlating reference chart.

1.6 Clinical Relevance

Grip strength is assumed to be clinically relevant as it has a strong correlation to total muscle strength (Wang, Leger, & Dumas, 2005; Wind et al., 2010). It can be used as evidence for accelerated dependency in activities of daily living and cognitive decline among people aged 85 years (Taekema et al., 2010). Hence a useful instrument to identify those at risk.

Grip strength is also an important tool in hand rehabilitation as a parameter of the effectiveness of the therapy. Also to monitor the development of postoperative complications after fractures of the collum femoris (Shyam Kumar, Parmar, Ahmed, Kar, & Harper, 2008). Also by testing a specific population group, for example dutch children, it is possible to create a reference chart for grip strength. Thus a feasible comparison of the measured grip strength with the already determined gender-, age-, height- and weight-specific scores can be achieved (Wind et al., 2010). Bohannon (1998) compared the dynamometry measurements of patients receiving home care with the measurements of gender- and age- matched healthy individuals, finds a correlation of the dynamometry measurements and the manual muscle test scores of the upper extremities. This supporting the validity of deducing handgrip tests for generalized upper extremity strength impairment. In order to enable a correct information about handgrip strength and its consequences, it is important to standardize a clinically relevant and reproducible methodology.

1.7 Aim of the study and hypothesis

This Bachelor thesis will show the effects of different arm positions – elbow flexion/extension and forearm supination/neutral position- and hand dominance in generating the maximum voluntary grip strength by pressing the JAMAR® hydraulic hand dynamometer.

The aim is to analyze the influence of different positions and handedness on maximum voluntary handgrip strength of older people.

Many studies investigated the influence of different body, shoulder or elbow position and came to different conclusions, making it hard to find a standardized measuring method. Oxford (2000) and Liao, Wang, Yu, Chen, & Wang (2013) had a large group of subjects in their studies, Oxford having 128 subjects and Liao et al. 249 subjects. Both measured statistic significant higher handgrip strength when measured in an extended elbow position.

The findings from Oxford (2000) imply to measure greater grip strength when measured with the elbow in extended position. Furthermore, a neutral forearm position and the dominant hand are expected to generate the greatest strength (Bohannon, 2003), although the handgrip strength difference between dominant and non-dominant hand of right handed individuals is bigger than of left-handed individuals. These differences in handgrip strength of left-handed and right-handed subjects correlates with the findings of Incel et al. (2002).

1.7.1 Hypothesis

Based on a comprehensive literature research, the following hypotheses is postulated:

“Grip strength is highest with the dominant hand, the elbow in an extended position and the forearm, considering the length-tension-relationship, in a neutral position.”

This position is expected to have the highest grip strength with the dominant hand, although a higher difference between dominant and non-dominant hand for right-handed subjects compared to left-handed subjects is assumed.

1.8 Flow Chart

Task/Date	03.2017	04.2017	05.2017	06.2017	07.2017	08.2017	09.2017	10.2017	11.2017	12.2017	01.2018
Topic choice											
Literature research											
Concept											
Ethics vote											
Introduction											
Material & Methods											
Material & Methods										adapting	adapting
Recruitment											
Measurement											
Data Analysis											

Figure 3: Yellow- time table for BAC I. Green- timetable for BAC II

2 Material and methods

2.1 Study design

This non-interventional, prospective study was approved under the supervision of Dipl.-Sporting. Dr. Mario Heller and by the ethics committee of Lower Austria. All participants provided written informed consent. The research work for this present thesis started in March 2017.

Together with Thomas Kern, the implementation of the recruitment of subjects took place during November and December 2017. Thomas Kern is currently working on his thesis „Zum möglichen Einfluss der Handdominanz auf die Feinmotorik bei älteren Menschen" about the possible influence of hand dominance on dexterity of older adults under the same supervisor, Dipl.-Sporting. Dr. Mario Heller. Due to the fact, that Thomas Kern' thesis deals with a similar issue, we developed the written confirmed consent together and we also defined inclusion and exclusion criteria. Furthermore, we also decided to plan the recruitment and the measuring tests together, with the tests performed in November and December 2017. Thereby it will be possible to find correlations between handgrip strength and dexterity of healthy older adults, under consideration of hand dominance.

2.2 Participants

Thirty-three healthy participants were included in this study. For recruitment, we started calls on social media and we contacted physiotherapists from different hospitals in Lower Austria and Vienna. Furthermore, a pre-fabricated form by Thomas Kern and Marco Minic was posted in the group practice for general medicine Dr. Rudolf and Markus Kern in Hürm (Lower Austria) and in the hospitals of Melk and St.Pölten. This pre-fabricated form includes information to the studies 'scientific issue, the inclusion and exclusion criteria, a brief explanation about the procedures, the estimated duration and the contact data of the students and their supervisor, Dipl.-Sporting. Dr. Mario Heller. All participants had to be between 60 and 85 years old and sufficient cognitive and language skills capable of understanding the instructions. Subjects with the following conditions had to be excluded from this study: individuals younger than 60 or older than 85, with impaired cognitive function, insufficient german language skills, present or recent (up to three months ahead) injuries (fractures etc.) of the upper limbs, impairments which may decrease upper extremity function, sensoric or perceptual disorder of the upper limbs, neurological diseases (for example Morbus Parkinson, Multiple sclerosis or other diseases with possible impairment of hand function) or significant loss of hearing or vision. At the time of assessments and measurements, a written informed consent was signed by every subject. For facilitated data evaluation, we divided the subjects in two main groups, male and female, and two subgroups, left handed subjects and right handed subjects. This allocation is due to significant differences in hand grip strength between genders (Dodds et al., 2014; Mogk & Keir, 2003). The subjects were not paid for their participation in the study.

2.3 Instrumentation

One hydraulic JAMAR® hand dynamometer was used for measuring handgrip strength. Measurements were done in a seated position, therefore a chair without armrests but a backrest was required. The JAMAR® hand dynamometer has four features for screening and evaluating. It has a dual-scale readout in pounds and kilograms with a maximum reading of 200 pounds or 90 kilograms, a peak-hold needle which retains at the highest peak until reset to facilitate reading and measuring. Furthermore, the JAMAR® is isometric in use, so there will be almost no perceptible motion of the handle, regardless of grip strength. It consists of an adjustable handle, so it is able is customizable five different grip positions to accommodate various hand sizes. The gripping distance reaches from 1-3/8 to 3-3/8 inches, in half-inch increments. According to the user instructions of Lafayette Instrument®, the adjustable handle had to be set to the desired spacing of each test subject. The dexterity tests, which were measured at the same date but from Thomas Kern, are not described in detail in this thesis. The following focuses on the handgrip strength tests.

2.4 Procedures

After the information presentation and signing of the written informed consent, the measuring session began. It started with the Edinburgh Handedness Inventory tests which shows the laterality of the subject; and the Duruöz Hand Index which examines impairments of the upper limbs. The duration for these pre-tests was five to ten minutes. After these tests, Thomas Kern and Marco Minic carried out the Nine Hole Peg Test and the Moberg Pick Up Test, both testing dexterity and taking the handedness into account. The dexterity took five to ten minutes each. Following this, the measurements for handgrip strength were conducted. The test subject sat in an upright position and manipulated the hand dynamometer in eight different positions, four on each side. By starting with the dominant hand of each participant, the measurements were implemented under the same circumstances. Two sequences, which can be distinguished by their reversed order, had to be completed by the participants.

Sequence One starts with:

The dominant hand in extended elbow position and neutral forearm rotation, followed by the non-dominant hand in extended elbow position and neutral forearm rotation. After that, subjects will switch again to the dominant hand and manipulate the hand dynamometer with elbow in 90° flexion and a supinated forearm position, followed by the same position with the non-dominant hand. Repeating this again with an extended elbow but with forearm in supination, first on the dominant side then with the non-dominant hand. Lastly with 90° flexed elbow and neutral forearm position, again starting with the dominant hand.

Sequence Two starts in reversed order, as illustrated below:

1) Non-dominant side, elbow in 90° flexion, forearm in neutral position
2) Dominant side, elbow in 90° flexion, forearm in neutral position
3) Non-dominant side, elbow extended, forearm in supinated position
4) Dominant side, elbow extended, forearm in supinated position
5) Non-dominant side, elbow in 90° flexion, forearm in supinated position
6) Dominant side, elbow in 90° flexion, forearm in supinated position
7) Non-dominant side, elbow extended, forearm in neutral position
8) Dominant side, elbow extended, forearm in neutral position

The handgrip test took approximately fifteen minutes. The maximum voluntary contraction should be reached within three seconds. After each position, the subject had one minute time to rest for the equilateral side. During this rest period, the subject conducted the test with the opposite arm. This continued for the whole measurement session. In total, it took approximately 40 minutes per subject. Testing 33 subjects took approximately 22hours, distributed over nine days.

2.5 Dominance

Due to reasons of standardization an appropriate test had to be applied. Oldfield (1971) designed the so called Edinburgh Handedness Inventory which was utilized in this study. Although Oldfield himself suggest in his conclusions, that the Edinburgh Inventory is not to be seen as a sufficient measure of manual or cerebral laterality as main issues. For purposes of screening large populations and in order to build a standard of comparison in neuropsychological work, this inventory should be of adequate extent. Subsequently, the inventory proved to be useful in another aspect- some subjects assessed their handedness contrary to the results of the Edinburgh Handedness Inventory. The reason therefore was not a lack of self-reflection, but rather because many of the older people got retrained from left-handed to using the right-hand when they were kids, the decisive criterion being writing. Since their self-assessment was divergent, the author decided to use the data of the Edinburgh Handedness Inventory.

In this Inventory, subjects have to fill out a standardized questionnaire by themselves. In this survey, subjects are being questioned whether they use their left or their right hand for different tasks. Answers could be given as numbers on a scale, reaching from -2 to 2. Zero means that the subjects can fulfil the task with both hands. One means the subject is not sure if he uses primarily his right hand. Two means that the subject always uses his right hand. In order to make calculation easier, the author decided to apply the same meaning to the left hand, solely adding a "-" in front of the number, for example "-2" means that the subject fulfills the task always with his left hand. If the testing subject has no experience in a task, the subject is asked to write no number in the empty space.

Since there are different versions of the Edinburgh Handedness Inventory existing, the author decided together with Thomas Kern, who also used the Inventory for is bachelor thesis „Zum möglichen Einfluss der Handdominanz auf die Feinmotorik bei älteren Menschen", to use the Inventory with ten items, as prescribed in the study's Appendix II (Oldfield, 1971)

These items are: 1. Writing, 2. Drawing, 3. Throwing, 4. Scissors, 5. Toothbrush, 6. Knife (without fork), 7. Spoon, 8. Broom (upper hand), 9. Striking Match (match), 10. Opening box (lid).

To calculate the projected handedness, following formula is used to generate the Laterality Quotient value (Oldfield, 1971):

$$\frac{(\text{Sum of points given to right hand} - \text{Sum of points given to left hand})}{\text{Sum of every point}} * 100$$

Thereby, the provision of the handedness is calculable. The quotient provides a score which ranges from "-100" (left handed for all items) to "+100" (right handed for all items). In between, the ranges are interpreted that less than "-40" complies with "left-handed", "-40" to "+40" complies with ambidexterity and more than "+40" complies with "right-handed".

2.6 Data collection and analysis

Data were collected after every position. On the JAMAR® hand dynamometer there is a peak-hold needle, facilitating it for the therapist to collect the peak score of the maximum voluntary grip strength. For statistical analysis, Data were entered and evaluated with IBM‘s Software Statistical Package for the Social Sciences (SPSS). Because of the study design, the simple analysis of variance (ANOVA) with repeated measures was used in case of normal distribution, otherwise the Friedman - Test. The level of significance was set to 0,05 (p-value). There are four different groups: right handed subjects testing their dominant hand, right handed subjects testing their non-dominant hand,, left handed subjects testing their dominant hand and left handed subjects testing their non-dominant hand. Handedness was determined by the Edinburgh Handedness Inventory and not on the basis of the subjects' statements, due to contradictions between these two. Measurements from all four groups include the eight different positions. The four groups of subjects are the independent variable and the eight different positions for measuring the handgrip strength are the dependent variable.

Re-tests in handgrip strength seem to have higher grip strength. This fact can be explained by the learning effect of the subjects on how to squeeze the JAMAR® hand dynamometer stronger. This effect can be reached within two measurements (Savva, Karagiannis, & Rushton, 2012). The subjects in this present study performed handgrip strength tests in each measured position twice, conducting sequence one and two (retest). In order to obtain the values of maximum grip strength, the higher value from these repetitions was taken into account, in consideration of an eventual learning effect.

Table 1 Overview of used statistical tests

Variable	Statistical Test
Mean grip strength of right-handed men/ women with their right hand	Simple ANOVA with repeated measures, LSD-Test for pairwise comparisons
Mean grip strength of right-handed men/ women with their left hand	Simple ANOVA with repeated measures, LSD-Test for pairwise comparisons
Mean grip strength of left-handed men/ women with their right hand	Simple ANOVA with repeated measures, LSD-Test for pairwise comparisons

Mean grip strength of left-handed men/ women with their left hand	Simple ANOVA with repeated measures, LSD-Test for pairwise comparisons

SPSS allows to present the graphics with standard deviation and an observed grand mean for each tested group. Also pairwise comparisons between the testing positions are possible. If there is a statistically significant difference shown in the testing groups, pairwise comparisons are necessary to evaluate which group differs from the others. These pairwise comparisons are made with Post-hoc tests.

Before applying Post-hoc tests, it is mandatory to test normal distribution. For normal distribution, there are three parameters to check. Skewness and Kurtosis should be within the range of “-2” to “+2”, the histogram is inspected and the Kolmogorov-Smirnov-Test gets applied. Inspecting the histogram can be incorrect in a small proband group, this mangle needs to be considered. If the data is normal distributed, sphericity needs to be checked. This can be done with the Mauchly-Test, or in case the Mauchly-Test is significant, stating that there is no sphericity given, the Greenhouse-Geisser Scale will be used. If the greenhouse-Geisser-Scale as a significance below 0,05 it means that there is a significant difference and Post-hoc tests should be applied. In case of no normal distribution, proband group below ten or ordinal-scale data, the Friedman-Test has to be applied.

As Post-hoc Test, the author first used the Bonferroni Correction, also called Bonferroni type adjustment. The Bonferroni Correction is a conservative test that protects from Type 1 errors (rejecting the null hypothesis when you should not), but is vulnerable to Type 2 errors (failing to reject the null hypothesis when you should reject the null hypothesis). According to his formula, the Bonferroni type adjustment is more likely to reject the null hypothesis at a lower level of significance. The formula is: $\alpha \times 2 / k (k-1)$, where “α” stands for the agreed chance of a falsely positive result (0.05) and “k” for the number of comparisons. Because the Bonferroni Correction is conservative, it loses power and thereby raises the risk of a falsely negative result. In this present study, it means that due to the small proband group, the Bonferroni correction overlooks the power of the results, showing that there is no significant difference between the four grip positions in for each group. To be still explorative while having significant measurements, the LSD-Test was used instead of the Bonferroni Correction. The LSD-Test is the Least Significant Difference Test and can be seen as an alternative to the Bonferroni Correction. Differences found with the LSD- Test are still significant, but not highly significant as resulting from the Bonferroni Correction (Cleophas & Zwinderman, 2006).

3 Results

In the course of the measurements, 32 test subjects were able to complete the study without constrains. One participant of the initial 33 subjects could not perform the handgrip strength measurements due to an operation after a carpal tunnel syndrome four months ago, therefore this proband was excluded from the study. Gender-specific differences in grip strength, also the relation of fine motor skills to grip strength can be looked up in Thomas Kern's bachelor thesis “Zum möglichen Einfluss der Handdominanz auf die Feinmotorik älterer Menschen”.

Calculating the ANOVA with repeated measures, only one group showed significant differences: left-dominant subjects with their right hand. But when applying the LSD-Test, significance was also shown in the group of right dominant subjects when measuring their right hand.

The following shows the mean grip strength with standard deviation (heading “Statistics”), pairwise comparisons (LSD-Test) and a bar chart.

The bar chart show on the x- axis the numbers 1, 2, 3 and 4. These are the four different positions when measuring maximum grip strength.

The number “1” stands for the position: extended elbow and neutral forearm rotation.

The number “2” stands for the position: flexed elbow and supinated forearm rotation.

The number “3” stands for the position: extended elbow and supinated forearm rotation.

The number “4” stands for the position: flexed elbow and neutral forearm rotation.

The y- coordinate describes the grip strength, measured in kilogram.

The pairwise comparisons show the differences from each group the other three groups.

“(I) Faktor1“ describes the group that stands in relation to the others.

“(J) Faktor1“ describes the other groups that are being related to the main group.

“Sig.[b]“ describes the significance. This value has to be below 0.05 in order to be statistically significant.

3.1 Mean grip strength of right-handed men/ women with their right hand

Table 2 Mean grip strength of right-dominant subjects with their dominant hand

Statistics

		DomExtNeu	DomFleSup	DomExtSup	DomFleNeu
N	Valid	17	17	17	17
	Missing	0	0	0	0
Mean		40,5588	41,7471	40,9176	41,6118
Std. Deviation		8,86405	8,80207	9,83655	9,25715

Table 3 Pairwise Comparison of right handed subjects with their dominant hand

Pairwise Comparisons

Measure: MEASURE_1

(I) Faktor1	(J) Faktor1	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	-1,188*	,541	,043	-2,335	-,041
	3	-,359	,632	,578	-1,698	,981
	4	-1,053	,674	,138	-2,483	,377
2	1	1,188*	,541	,043	,041	2,335
	3	,829	,648	,219	-,544	2,203
	4	,135	,488	,785	-,899	1,169
3	1	,359	,632	,578	-,981	1,698
	2	-,829	,648	,219	-2,203	,544
	4	-,694	,608	,271	-1,984	,596
4	1	1,053	,674	,138	-,377	2,483
	2	-,135	,488	,785	-1,169	,899
	3	,694	,608	,271	-,596	1,984

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

These pairwise comparisons show that there is a significant difference between the first testing position (extended elbow and neutral forearm rotation) and the second testing position (flexed elbow and supinated forearm rotation).

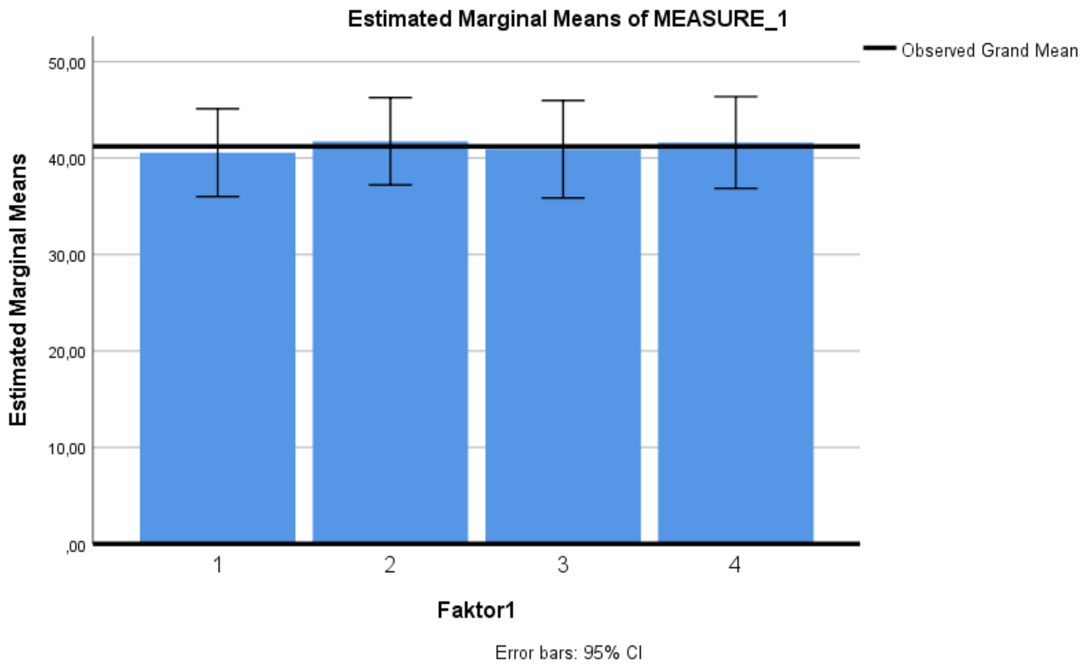

Figure 4 Bar chart of right handed subjects with their dominant hand

In the bar chart above it is possible to see the mean grip strength of each position and the grand mean, showing that the second position (flexed elbow and supinated forearm) is stronger than the first position (extended elbow and neutral forearm rotation).

3.2 Mean grip strength of right-handed men/ women with their left hand

Table 4 Mean grip strength of right-dominant subjects with their non-dominant hand

Statistics

		NonExtNeu	NonFleSup	NonExtSup	NonFleNeu
N	Valid	17	17	17	17
	Missing	0	0	0	0
Mean		38,4235	37,4882	38,0353	37,7118
Std. Deviation		9,15884	10,52597	9,83654	9,88818

Table 5 Pairwise Comparison of right handed subjects with their non-dominant hand

Pairwise Comparisons

Measure: MEASURE_1

					95% Confidence Interval for Difference[a]	
(I) Faktor1	(J) Faktor1	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	,935	,897	,313	-,967	2,837
	3	,388	1,127	,735	-2,001	2,777
	4	,712	1,010	,491	-1,429	2,852
2	1	-,935	,897	,313	-2,837	,967
	3	-,547	1,108	,628	-2,895	1,801
	4	-,224	,903	,808	-2,138	1,691
3	1	-,388	1,127	,735	-2,777	2,001
	2	,547	1,108	,628	-1,801	2,895
	4	,324	,775	,682	-1,320	1,967
4	1	-,712	1,010	,491	-2,852	1,429
	2	,224	,903	,808	-1,691	2,138
	3	-,324	,775	,682	-1,967	1,320

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

These pairwise comparisons show that there is no significant difference between any of the four tested groups.

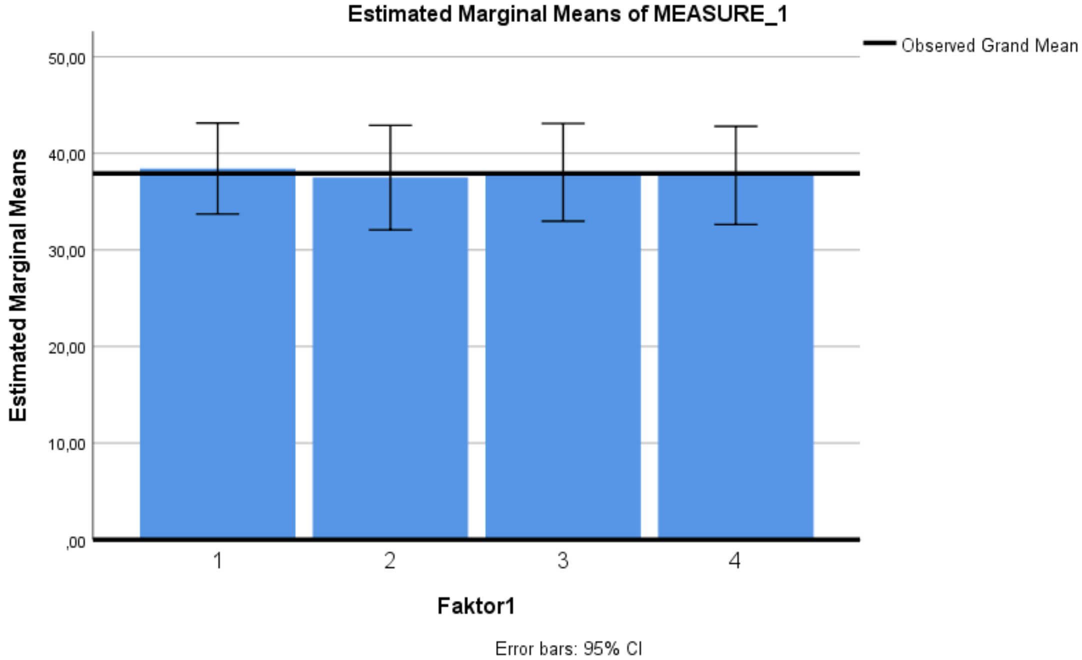

Figure 5: Bar chart of right handed subjects with their non-dominant hand

The bar chart shows that the first position (extended elbow, neutral forearm rotation) is stronger than the other tested positions, but on the basis of the pairwise comparisons, this difference is not statistically significant.

3.3 Mean grip strength of left-handed men/ women with their right hand

Table 6 Mean grip strength of left-handed subjects with their right hand

Statistics

		NonExtNeu	NonFleSup	NonExtSup	NonFleNeu
N	Valid	15	15	15	15
	Missing	0	0	0	0
Mean		41,0333	43,3733	41,6533	41,0533
Std. Deviation		9,40248	11,30104	9,96636	10,12725

Table 5: Pairwise Comparison of left handed subjects with their non-dominant hand

Pairwise Comparisons

Measure: MEASURE_1

(I) Faktor1	(J) Faktor1	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	-2,340*	,944	,027	-4,365	-,315
	3	-,620	,428	,169	-1,538	,298
	4	-,020	,499	,969	-1,090	1,050
2	1	2,340*	,944	,027	,315	4,365
	3	1,720	1,037	,119	-,504	3,944
	4	2,320*	,917	,024	,353	4,287
3	1	,620	,428	,169	-,298	1,538
	2	-1,720	1,037	,119	-3,944	,504
	4	,600	,585	,322	-,654	1,854
4	1	,020	,499	,969	-1,050	1,090
	2	-2,320*	,917	,024	-4,287	-,353
	3	-,600	,585	,322	-1,854	,654

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

On the basis of these pairwise comparisons it is demonstrated that there is a significant difference between the tested groups 2 and 1 and also 2 and 4.

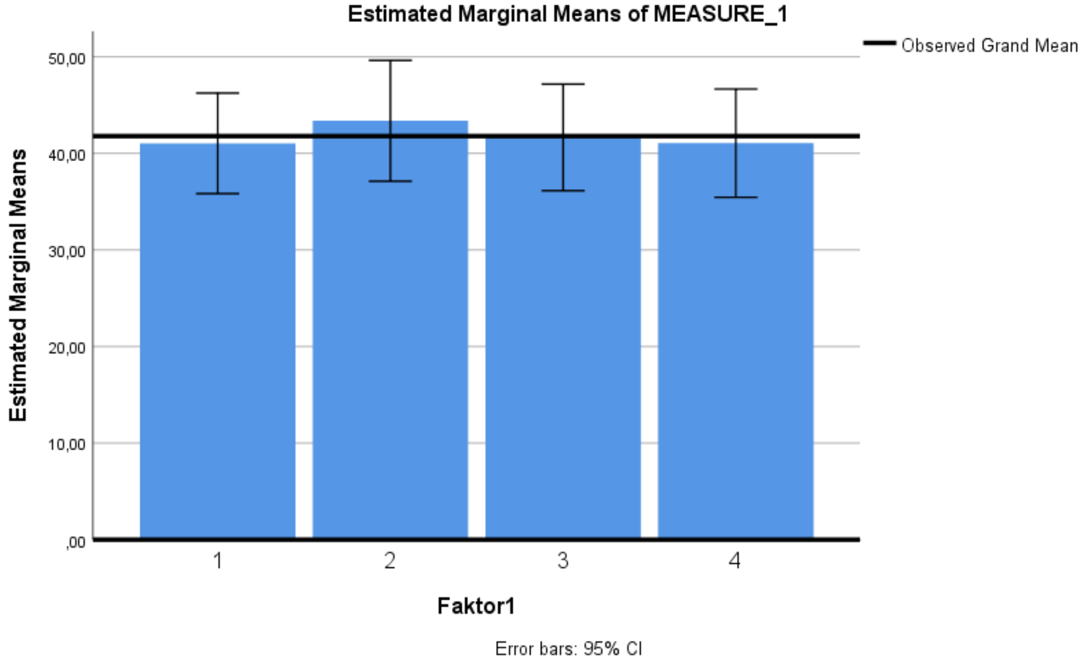

Figure 4: Bar chart of left handed subjects with their non-dominant hand

This bar chart illustrates the significant difference of the second testing position (flexed elbow, supinated forearm rotation) to the first testing position (extended elbow, neutral forearm rotation) and also to the fourth testing position (flexed elbow, neutral forearm position).

3.4 Mean grip strength of left-handed men/ women with their left hand

Table 7 Mean grip strength of left-handed subjects with their left hand

Statistics

		DomExtNeu	DomFleSup	DomExtSup	DomFleNeu
N	Valid	15	15	15	15
	Missing	0	0	0	0
Mean		41,8267	43,0200	42,5733	42,3667
Std. Deviation		10,89026	11,32842	11,52609	11,56804

Table 6: Pairwise Comparison of left handed subjects with their dominant hand

Pairwise Comparisons

Measure: MEASURE_1

(I) Faktor1	(J) Faktor1	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	-1,193	,717	,118	-2,731	,344
	3	-,747	,532	,182	-1,888	,394
	4	-,540	,562	,353	-1,746	,666
2	1	1,193	,717	,118	-,344	2,731
	3	,447	,681	,522	-1,013	1,906
	4	,653	,675	,350	-,795	2,101
3	1	,747	,532	,182	-,394	1,888
	2	-,447	,681	,522	-1,906	1,013
	4	,207	,359	,574	-,563	,976
4	1	,540	,562	,353	-,666	1,746
	2	-,653	,675	,350	-2,101	,795
	3	-,207	,359	,574	-,976	,563

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

In the group of left-handed subjects, testing their dominant hand, there is no statistical difference in any testing group quantifiable.

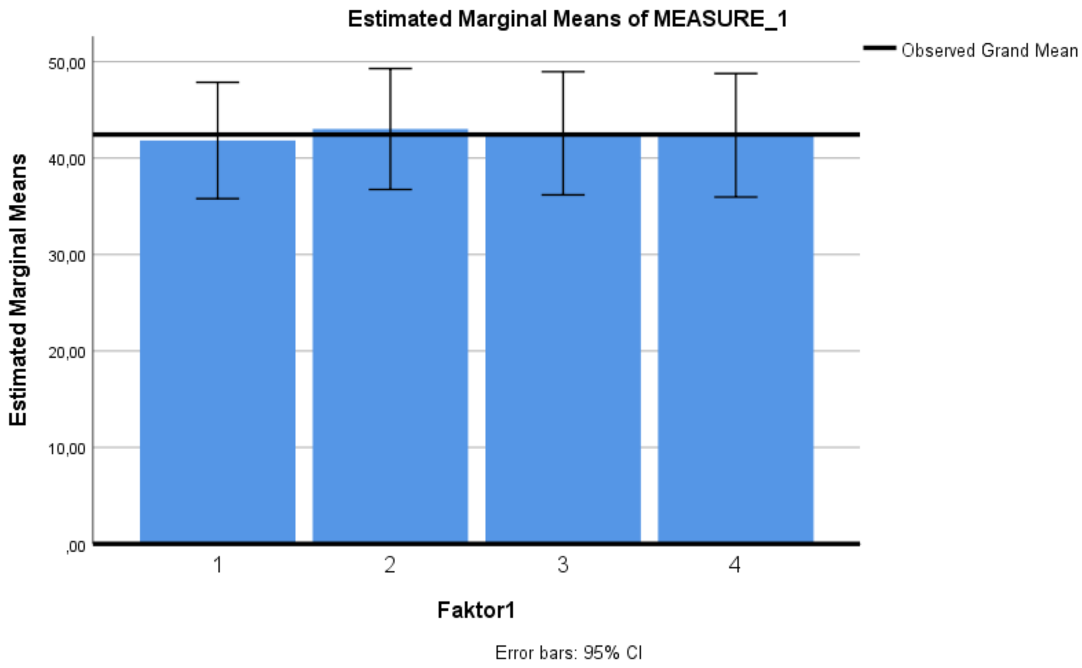

Figure 6 Bar chart of left handed subjects with their dominant hand

Although the second testing position (flexed elbow, supinated forearm rotation) is stronger than the other three positions, there is no statistical relevant difference.

4 Discussion

The aim of the study was to show the effect of different elbow and forearm positions on the grip strength of healthy older adults. The postulated hypothesis “Grip strength is highest with the dominant hand, the elbow in an extended position and the forearm, considering the length-tension-relationship, in a neutral position” has been tested. The results (grip strength being highest with the right hand in a flexed elbow and supinated forearm position) differ from that hypothesis, the eventual reasons are discussed below.

4.1 Elbow Angles

With regard to the elbow position for the maximum grip strength, this study’s findings indicate that the elbow flexion in 90° to be the position with the highest measured grip strength when measuring the dominant side of right-handed subjects and the non-dominant hand of left-handed subjects. Simplified it means, that maximum grip strength is higher with elbow flexion, but only when measuring the right arm.

The significant difference is measurable at right-dominant subjects between extended elbow with neutral forearm (the weakest position) and flexed elbow with supinated forearm (strongest position). At left-dominant subjects, the strongest position (also elbow flexion and forearm supination) was significant stronger when measuring with an extended elbow with a neutral forearm. Furthermore, it was also stronger than in elbow flexion and neutral forearm position.

However, this does not correlate with the findings from Oxford (2000). In this study, Oxford reports significant greater grip strength for both sides, dominant and non-dominant, when measuring subjects in an extended elbow position. She also mentioned the discrepancies from her study to other studies, explaining them to be conceivably caused by the different size of the subject group and the average age of the subjects. The mean age of the female subjects in her study was 30.9 years and the mean age of the male subjects was 31.5 years. In this present study a different situation is appearing, the average age of the male subjects in this present study is 67.1 and of the female subjects 66.4 years. In other words, the average age is twice as high compared to the study of Oxford.

Furthermore, Kong (2014)- measuring 39 male subjects with an average age of 25.1 did not find any statistically relevant differences in grip strength when changing elbow angles.

Farooq & Ali Khan (2012) – measuring 20 right-handed male subjects with a mean age of 26.5 years- did not find statistical relevant differences in grip strength when changing elbow angles, although they measured an increase of MVC grip strength from an extended elbow position to a 90° flexed elbow.

Kuzala & Vargo (1992) measured actually higher grip strength with an extension of the elbow, testing sixteen male and 30 female subjects, aged 21 to 46 years.

Based on the received results and comparison with the literature it is concluded that the divergent outcomes are influenced by the age difference, the sample size and the unnoticed factor of work and hobbies.

4.2 Forearm Rotation

The study's statistical analysis shows, that a supinated forearm has, at least partial, significant influence on grip strength when measuring the right hand of left-dominant and right-dominant subjects. The supinated position was indicated as the strongest position, although the significance exists between three positions altogether. Left-handed subjects showed a significant higher grip strength with a supinated forearm and flexed elbow compared with neutral forearm and extended elbow or neutral forearm and flexed elbow. Right-dominant subjects showed this significance only between the strongest position – flexed elbow and supinated forearm- and the weakest position, namely extended elbow and neutral forearm position.

These findings do not correlate with the findings from Farooq & Ali Khan (2012) which measured a decrease of MVC grip strength from a pronated to a supinated forearm position, although it was not significant.

4.3 Right-dominant versus Left-dominant

The received results for the hand dominance showed a stronger right hand for right-handed subjects as well as for left-handed subjects. This was also mentioned by Bohannon (2003) in her summary, noting that the dominant hand is more likely to be stronger. However, this applies mainly to right-handed individuals. In her summary, she compared the difference in many studies between greater grip strength with the dominant and non-dominant side. In these studies, greater grip strength could be found with the non-dominant hand of the subjects, regarding the measurements of left-dominant subjects (Crosby & Wehbé, 1994; Petersen, Petrick, Connor, & Conklin, 1989).

In conclusion, this means that the 10 % rule (it states that the dominant hand has a 10% greater grip strength than the non-dominant hand) only applies to right- handed subjects.

This adopted rule stood in the past for many years and was used by the predominant part of therapists.

Petersen et al. (1989) measured that 48% of the left handed subjects, with a proband group of 48, was stronger with their non-dominant hand. In the group of the right-dominant subjects with 262 participants, 6,9% were stronger with the non-dominant hand.

Crosby & Wehbé (1994) examined similar findings. Their measurements showed, that the mean grip of left-handed subjects is higher with their non-dominant hand, although not significant. However, grip strength of left handed subjects should be regarded equivalent in both hands.

4.4 Limitations

Several limitations influenced the outcomes of this study. One major limitation is the number of subjects. The total number of 32 probands participated within this study - twenty-three men and ten women. Due to this amount of probands, exploratory evaluation was difficult. This limitated number of participants required to the LSD- Test instead of the Bonferroni Correction in case of the statistical analysis. Otherwise an error of type 2 could have not been avoided. In comparison, Wind et al. (2010) examined 384 healthy children, adolescents and young adults in her study. This allowed her not only to gain more conclusive results, but also to develop a reference chart for her proband groups, aged eight to twenty years. Having a higher number of probands not only allows to make powerful and exploratory statistics. Additionally, the number also affects the p-value.

In consideration of this proband group, further investigation needs to be done. A much larger group of participants would provide a possibility to conduct exploratory analysis more efficiently. Moreover, reference charts or even standardized measurement methods could be developed.

The proband group can also be divided into different age- groups. Not only the factor of general muscle loss in progressive aging (Curtis, Litwic, Cooper, & Dennison, 2015) influences the hand grip strength, but also the daily activities differ. Wind et al. (2010) concentrated on a different subject group, namely healthy children, adolescents and young adults aged eight to twenty years with 384 participants. Having a reference chart for people at different age-levels appears to be useful. Additionally, the factor age refers to other limitations, such as work or leisure time. People in retirement are usually not as active as children and adolescents or young adults.

Another limitation is the factor work. Some of the subjects were already retired while others were still working. The strength difference itself is not important, as it should be measurable equally in every position. But the eventual position of their arms at the working place could influence the handgrip strength in a specific position. This factor may change the maximum voluntary grip strength and therefore the influence of the occupation needs to be further investigated as well as taken into consideration during evaluation. A possible solution could be the development of a chart that provides information about the occupations which could be assigned to numbers and combined with either left or right side dominant stress.

Test- Retest reliability can also be a limitating factor. In this present study, subjects got measured twice, with an estimated time interval of ten minutes. The findings from Savva et al. (2012) showed significant higher values in case of the retest, which was performed after seven days, then of the initial test. This study's results could be used to measure maximum grip strength, although the subjects were ten healthy male, aged 21 to 26 years and nine healthy female, aged 21 to 23 years. Due to that discrepancy in age, the results cannot be considered in this present study. Also, the time interval in this present study was restricted to ten minutes. To assess the retest as an outcome measure in clinical practice, further investigations in subjects with specific age groups are required.

Another limitating factor is leisure activities. In particular, hobbies that require a lot of physical activity like sport, can play a significant role if the generation of maximum grip strength in a certain position is required. Due to organizational reasons and shortage of probands, it was not possible to implement occupation and leisure time into considered factors while still having a representative number of probands. Furthermore, to the author's knowledge no approaches to integrate the hobbies correctly in hand grip strength measurements are known. For example, hobbies with a one-sided physical strain like racket sports as Tennis or Squash, have for sure an influence of the strength distribution within sides. A possible approach to this problem could be the classification of leisure time activities, categorizing them into different levels of physical exertion. Activities could be numbered in ascending order from high to low level activities. Classified due to their level of activity numbered in ascending, e.g. sports, knitting and watching television could be classified into categories. Within these categories, even further classification could be useful, for example to detect imbalance (important at sports).

As España-Romero et al. (2008) reported, hand span also influences the grip strength. In this present study, the optimal grip span was decided by the subjects themselves, according to the user instructions of Lafayette Instrument®. By asking the subject if the adjustable handle is set in a desired and comfortable spacing, the handle was set accordingly. España-Romero et al. (2008) investigated the influence of an optimal grip span on hand grip strength in boys and girls aged six to twelve years. The grip span was set in relation to hand span, calculated with the formula:

$y = x/4 + 0.44$ for boys

and

$y = 0.3x - 0.52$ for girls.

"X" stands for the maximal width between first and fifth fingers, namely hand span.

"Y" stands for the optimal grip span the handle should be adjusted to.

However, these formulas are only applicable for boys and girls aged six to twelve years. Because of that und also because of the organizational aspects, grip span was chosen by the subject's desire.

Another limitating factor is the relearning of left-handers to right-handers. Because of working tools designed for right- handers, an environment that is designed for right- handers and probably because of the wish of integration, many older people god retrained from right-dominant to left- dominant. In this study, subjects stated first that they are now right-dominant, mainly because they write with their right hand- that's the main goal when being retrained. But the Edinburgh Handedness Inventory showed, that these subjects are actually left-dominant, using the left hand for the activities they weren't trained for. This enforced use of both hands might influence the outcomes of hand grip strength.

Furthermore, the chosen position in this study also might be a limitating factor. In the literature (PubMed search 2018; keywords "grip strength" and "stand" and "sit" and "influence", no appropriate study could be found. The author decided to choose a seating position in a chair with backrests. This made standardization possible while still being in an active position. Since some individuals are not able to sit or stand, this can be a limitating factor for them.

Further, also the possible influence on handgrip strength should be further investigated.

5 Conclusion

This study's findings have a common feature with other studies regarding hand grip strength- the result differs from other studies. It is certain, that hand grip strength can be used to predict many outcomes, but still further investigation about a standardized measuring method needs to be done. With the position of a flexed elbow and supinated forearm rotation, this study's findings differ from others (Bohannon, 2003; Farooq & Ali Khan, 2012; Kattel, Fredericks, Fernandez, & Lee, 1996; Kong, 2014; Kuzala & Vargo, 1992; Oxford, 2000). Mean age of subjects that participated in this study lies at 66, 8 years and thereby higher than in most of the other studies. The factor age can be influencing the outcome as there is a general strength decrease appearing in progressive aging. Also, this factor correlates with another limitating aspect, namely leisure time. It is assumed that the organization of one's leisure time has an influence on the grip strength, and this factor could not be considered in this study due to organizational aspects.

One finding that correlates with other studies, is the fact that the 10% rule (the dominant hand is said to be stronger than the non- dominant hand) only applies to the right-handed population (Armstrong & Oldham, 1999; Petersen et al., 1989). The strength difference of left-handed subjects between the dominant and non- dominant side was not significant, so it can be considered as equal.

Until further investigations are conducted on the effects of retests, considering laterality, age group, a standardized position of the whole body and of the upper extremity, optimum grip span and consideration of occupation and leisure time, gaining a standardized handgrip strength seems to be impossible. However, in a clinical setting, standardization of positioning, retests, age group and laterality should be easy to implement. Although there is no specifically, statistical relevant data, the findings from similar studies can be taken into consideration.

The hypothesis has to be rejected on the basis of the present study's findings. However, the findings of Incel et al (2002), stating that the handgrip strength difference between dominant and non- dominant individuals is significant with right-dominant subjects, but not with left-dominant subjects, can be supported by the findings of this present study which is also in accordance with Crosby & Wehbé (1994) and Petersen et al.(1989).

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