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Vichte (Anzegem), 6th of June 2017 A-S B

Zutendaal, 6th of June 2017 I N

RESEARCH CONTEXT

Today, malnutrition presents itself as a major threat to overall human health. First, there is 'undernutrition' which includes stunting, wasting, underweight and micronutrient deficiencies. Malnutrition, on the other hand, also includes 'overnutrition' which refers to both overweight and obesity. Worldwide 1.9 billion adults are overweight, while 462 million are underweight. An estimated 41 million children under the age of 5 years are overweight or obese, while 155 million are stunted and 52 million are wasted (WHO, 2017). This dualism is known as the double burden of malnutrition. In our study, malnutrition is solely used as an expression of undernutrition. Insufficient nutrition has the greatest impact on pregnant women and young children by increasing the risk of fetal and neonatal growth failure, morbidity and early death of the child (Black et al., 2013). Despite economic growth, nutritional insufficiencies continue to affect many children in low- and middle- income countries (Tzioumis & Adair, 2014). Malnutrition and related growth failure in early life have substantially negative consequences in later life for both the person itself and the society e.g. lower education, lower household per capita expenditure, and increased probability of living in poverty (Hoddinott et al., 2013).

Child mortality caused by malnutrition was an important indicator for monitoring progress towards the Millennium Development Goals (MDG). Nowadays, 12 out of 17 Sustainable Development Goals (SDG) require efficient nutrition in order to be met. Young children are most vulnerable for malnutrition because of their high nutritional requirements for growth and development (Blössner & de Onís, 2005). Nutritional deficiency can cause growth failure and developmental delay. To minimize these consequences early screening, to detect such children at risk, and intervention is necessary.

Growth assessment is the best method to assess the nutritional status of a child. As muscle function reacts early to nutritional deprivation, handgrip strength has also become a popular marker of nutritional status (Norman, Stobaus, Gonzalez, Schulzke, & Pirlich, 2011). One of the main problems with the current instruments to measure handgrip strength at young malnourished children was the lack of accuracy in the lower measuring ranges, f.i. the Martin Vigorimeter, up to three kiloPascal (kPa). To measure grip strength in such weakened populations preliminary research proposed an alternative instrument, i.e. the Greisinger manometer GDH 200-13 (Vanderaspoilden, 2013). The purpose of this study is firstly to examine the test-retest reliability of the Greisinger Manometer GDH 200-13 in children up to six years old, and next to compare the handgrip strength of malnourished and non-malnourished children and to assess how grip strength relates to several demographic and anthropometric variables. This study took place in Jaipur (Hasanpura, India) in collaboration with OPUS III (Belgium) and Draydan Social Wellfare Society (DSWS, India). The last-mentioned organisation provides four Fun and Child Schools (FCS), the Draydan Public School and a hospital. Recruitment of children occurred from two of these Fun and Child Schools. The research design was determined in consultation with our promoter Prof. Dr. Marita Granitzer. This study was achieved by full and independent recruitment, data acquisition, data processing and academic writing process.

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ABSTRACT

Background: Adequate nutrition is essential for proper development of children. Determining physical fitness is an important factor in developmental testing, because the outcome of a developmental test is the result of both neurological development and physical fitness of the child. Neurological development can be masked by the physical capacity, especially in case of weakened children (eg. undernourished).

Objectives: To determine the test-retest reliability of the Greisinger manometer, to explore if grip strength discriminates between malnourished and non-malnourished children, to assess relations between handgrip strength and several demographic (age, gender) and anthropometric (weight, height, MUAC) variables.

Participants: 199 children (100 girls; 99 boys) between 3 and 7.5 years old (mean age 67.91 $\pm$ 13.67 months) are included from two schools in Hasanpura (Jaipur). Children with neurological, cardiovascular and/or musculoskeletal disease or sensory problems of upper extremity are excluded.

Measurements: Test-retest reliability of the Greisinger manometer (GDH 200-13) is calculated with intra-class correlation (ICC), confidence interval (CI) of 95% and Cronbach's alpha (α).

Z-scores are calculated for weight/height, weight/age, height/age to make a distinction between malnourished and non-malnourished children.

Results: Test-retest reliability was very high for malnourished and non-malnourished children, gender and both hands. A significant difference in grip strength (kPa) is found between malnourished and non-malnourished children from 5 to 7.5 years old. There is a significant correlation of grip strength with age ($r = 0.67$), weight ($r = 0.79$), height ($r = 0.82$) and MUAC ($r = 0.49$). For the total group, a significant difference in grip strength is seen between right and left hand. No significant distinction is found between boys and girls ($p=0.844$).

Conclusion: The Greisinger manometer is a reliable instrument to measure handgrip strength in malnourished and non-malnourished boys and girls between 3 and 7.5 years old. There might be a possibility of handgrip strength to discriminate between children with and without malnutrition starting from the age of five years old and to follow these children in their growth development.

INTRODUCTION

Annually more than 200 million children under the age of five years do not reach their developmental potential. The majority of such children at risk are living in developing countries. Poverty, poor health, malnutrition and non-stimulating environments are the most important risk factors that contribute to these developmental problems (Grantham-McGregor et al., 2007). Crucial factors to anticipate these problems are early screening, early intervention and regular evaluation during rehabilitation (Engle et al., 2007).

Adequate nutrition is essential for proper development of a child (Ali, 2013). However, a high prevalence of malnutrition is still observed in India. The NFHS-4 Survey, completed in 2016, reported 38.4% of under-fives in India with stunting, with 35.7% suffering from underweight, and 28,5% have wasting (*National Family Health Survey-4*, 2015-16).

Adequate linear growth and nutritional status of a child are determined by the anthropometric measurements, weight and height, and further derived anthropometric indices (Cogill, 2003). The most important anthropometric indices for nutritional status are weight-for-age, length/height-for-age, weight-for-length/height and BMI-for-age and can be interpreted using the z-score classification system (Cogill, 2003; Mercedes de Onis & Blössner, 2003). A too low weight-for-height indicates wasting which results from acute malnutrition. Acute malnourished children can be divided in severe (SAM), z-score below -3, and moderate (MAM), z-score between -3 and -2, affected children. Chronic malnutrition manifests phenotypically mainly in "stunting" which reflects a too small height-for-age. Similarly, stunting can be subdivided into severe, z-score below -3, and moderate, z-score between -3 and -2, affected children (WHO, 2012; WHO/UNICEF/WFP, 2014; Wirth et al., 2017). ‘Underweight’ as a phenotype is determined by weight-for-age. Moderate and severe underweight are z-scores between -3 and -2 standard deviations (SD) and -3 SD, respectively, from median weight for age of the reference population.

Not only assessing nutritional status, but also determining physical fitness is an important factor in developmental testing in children. This is an aspect of great importance because the outcome of a developmental test of a child at a certain time is always the result of both the neurological development and physical fitness of the child. Neurological development can be masked by the physical capacity of the child, especially in case of weakened children (eg.

undernourished).

One of the health-related components of physical fitness is muscular strength (Caspersen, Powell, & Christenson, 1985). Handgrip strength is the most commonly used indicator to determine overall strength (Tietjen-Smith et al., 2006; Wind, Takken, Helders, & Engelbert, 2010). A single measurement of handgrip strength can make a quick estimation of the status of 35 hand- and forearm muscles. Normative values of handgrip strength therefore are an essential complement in testing the development of children, the fragile ones in particular (Engle et al., 2007; Grantham-McGregor et al., 2007).

So far there is still a lack of normative values for handgrip strength in young children. The main cause is a shortage of instruments for measuring handgrip strength in this study population. A preliminary study, in Jimma, Ethiopia, therefore presented the Greisinger manometer as an alternative tool for the measurement of voluntary handgrip strength and seemed to be a reliable instrument for healthy children from three to six years. However, the youngest age group had lower power (Vanderaspoilden, 2013). There remains a gap in the literature under the age of three years. The objectives of our study are to make a re-evaluation of the test-retest reliability of the Greisinger manometer GDH 200-13 to check if the results are reproducible. The researchers expect to find a good reliability for the older age groups and probably a lower test-retest reliability of the younger children.

The reliability needs to be verified in order to obtain normative data for the measurement of handgrip strength in children up to six years old. The focus is on the youngest age group. A second objective is to evaluate if grip strength discriminates between malnourished and non-malnourished children and finally how grip strength relates to several demographic and anthropometric variables will be further explored. Lower handgrip strength is expected to be found for the malnourished children when compared with non-malnourished children. This study takes place in Jaipur (Hasanpura, India) in collaboration with OPUS III.

METHODS

OBJECTIVES AND RESEARCH DESIGN

The objectives within this explorative study are determining the test-retest reliability of the Greisinger manometer for the measurement of grip strength for both hands, for boys and girls and malnourished and non-malnourished children. All the measurements are conducted in a standardized way and performed by the same trained researcher. The retest of grip strength takes place one hour after the first test at the same testing location.
Other objectives were to assess the relations between handgrip strength and several demographic and anthropometric variables and to explore if grip strength can discriminate between malnourished and non-malnourished. Height, weight and Mid-Upper Arm Circumference (MUAC) are measured in order to make an assessment of the nutritional status of the child. (M. de Onis & Blossner, 2003)

PARTICIPANTS

At the time of recruitment, a total of 217 children were invited to enrol in this study. The children are recruited from two schools in Hasanpura (Jaipur), namely Fun and Child School 1 (FCS1) and Fun and Child School 2 (FCS2). Boys and girls between 3 and 7.5 years old are included, for which malnutrition (underweight, stunting or wasting) was not an exclusion criterion. Children with neurological, cardiovascular, respiratory and/or musculoskeletal disease or children with dysfunctions and/or sensory problems of upper extremity are excluded. All parents are asked for their written informed consent and children are asked for their willingness to participate. Protocol was previously approved by the Ethical Commission of the UHasselt (RPGC/248/2011).

In total, parents of 210 children gave written consent to participate. Eleven of these 210 children were excluded because of neurological, orthopaedic or cardiovascular problems or because they were not able to understand the instructions. A remaining group of 199 children are included, 100 girls and 99 boys. These children are divided into nine age groups for statistical analysis. Figure 1 presents a flow-chart of the research design.

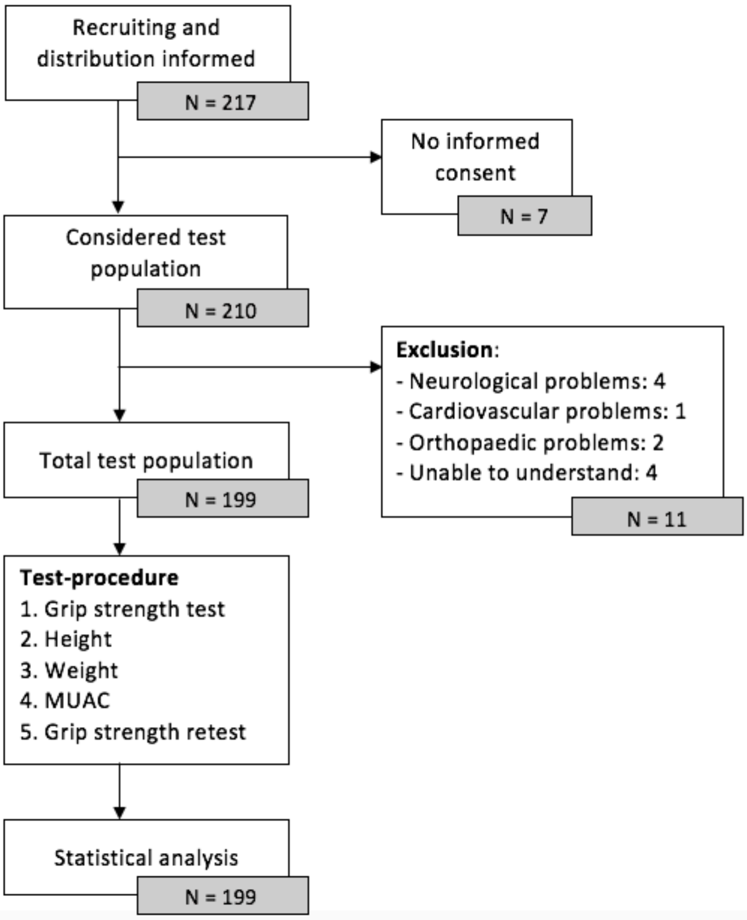

Fig 1. Flow-chart research design

OUTCOMES, MEASUREMENTS, INSTRUMENTS

Grip strength (hPa), assessed by the Greisinger manometer, type GDH 200-13 (Greisinger Electronic, Germany) connected to the second bulb of the Baseline dynamometer (Fabrication Enterprises Inc., White Plains, NY) is the primary outcome. The Greisinger manometer has a digital LCD display and measures accurately up to 0,01 hPa. Secondary outcome measures are the correlations between grip strength and age, sex, nutritional status, bodyweight and height. Nutritional status is expressed by the circumference of the upper arm, height and weight. The circumference of the upper arm (MUAC) is determined with a MUAC measuring tape (S0145620 MUAC, Child 11.5 Red/PAC-50) (WHO, 2009). Body weight (kg) is measured with a Uniscale (UNICEF Electronic Scale 890) and meets following requirements of the WHO: solidly built and durable, electronic (digital reading), measures up to 150 kg with a precision of 0.1 kg (100g) and allows tared weighing. Body height (cm) is measured with a stadiometer (Seca 213 mobile stadiometer) (WHO, 2008). Z-scores are calculated for weight/height, weight/age, height/age, MUAC/age and body mass index/age to make a distinction between malnourished and non-malnourished children. Z-scores are expressed in terms of standard deviations (SD) above or below the reference mean or median value. Cut off values for "wasting," "stunting" or "underweight" are: -2 SD (moderate) and -3 SD (severe) (M. de Onis & Blossner, 2003). To calculate these Z-scores both WHO Anthro software (version 3.2.2 January 2011) and WHO Anthro-plus software (version 1.0.4 2009) are used.

TEST PROCEDURE

First of all, handgrip strength is measured using the standardised measurement protocol of the American Society of Hand Therapist (ASHT) (MacDermid, Solomon, Fedorczyk, & Valdes, 2015).The retest takes place one hour after the first test under similar test conditions: same testing location, same trained researcher and same measurement instrument. Before testing, the researcher gives the child a short demonstration and instructions to squeeze the bulb as hard as possible for three seconds. Each child has one practice trial (fig. 2). Thereafter, three measurements are taken for each hand and the average of these three measurements is used in statistical processing. The right hand is tested first, for three times with a rest interval of 30 seconds; this is repeated for the left hand. The starting position according to the ASHT is the following: the child sits on a chair, feet on the floor, both arms rest on a table, shoulders adducted and neutrally rotated, elbow in 90° flexion, forearm and wrist in a neutral position. Height, weight and MUAC are measured during the interval (I.e. one hour) between test and retest by the second researcher. First, height is measured in a standing position in accordance with the guidelines of the WHO (WHO, 2008). Then, body weight is measured with an electronic scale and MUAC is measured in a sitting position. Thereafter, the retest takes place following the same instructions as the first test with one practice trial. During both test and retest, verbal encouragement is given in a standardised way by the same person. The translator gives the instruction “as hard as you can” three times in Hindi during each trial.

Fig. 2: Position of the child during handgrip strength testing

DATA-ANALYSIS

Statistical analysis is conducted by using the IBM SPSS 24 (SPSS inc., Chicago IL, USA). The significance level was set on 0.05. To describe the main features of the participants, descriptive statistics are used. The mean age of the subgroups varies between 3 and 7.5 years old (y/o), divided into nine age subgroups: group 1= [3-3.5 y/o]; group 2= [3.5-4 y/o]; group 3= [4-4.5 y/o]; group 4= [4.5-5 y/o]; group 5= [5-5.5 y/o]; group 6= [5.5-6 y/o]; group 7= [6-6.5 y/o]; group 8= [6.5-7 y/o]; group 9= [7-7.5 y/o]. For statistical analysis of grip strength, the mean of three trials for both hands and for test and retest are calculated. This was conducted for the total group, age subgroups, gender and malnourished and non-malnourished children. To answer the first research question about the test-retest reliability of the Greisinger Manometer GDH 200-13, the intra-class correlation (ICC), the confidence interval (CI) of 95% and Cronbach's alpha (α) are calculated. There are four different ICC value categories to describe the degree of reliability namely >0.80 (very high), 0.60-0.79 (moderately high), 0.40-0.59 (moderate) and 0.40 (low). Cronbach's alpha (α) is calculated to investigate the internal consistency of the test scores. A value of $\alpha > 0.9$ is determined as 'excellent', $0.9 > \alpha > 0.8$ as 'good', $0.8 > \alpha > 0.7$ as 'acceptable', $0.7 > \alpha > 0.6$ as 'questionable', $0.6 > \alpha > 0.5$ as 'poor' and $0.5 > \alpha$ as 'unacceptable'. To represent the error of an individual test score, further calculations as the standard error of measurement (SEM= $SD*\sqrt{(1-ICC)}$) and the smallest detectable difference (SDD= $SEM*1.96*\sqrt{2}$) were done. Preferable outcomes are low values of SEM and SDD.

To answer the second and third research question whether handgrip strength can discriminate between children with and without malnutrition and how it relates to several demographic and anthropometric variables, parametric tests were used. Normality in distribution of the outcome grip strength was evaluated by the Kolmogorov-Smirnov test. There is normality seen among the participants for age ($p<0.001$), gender ($p<0.001$) and children with and without malnutrition ($p<0.001$). To investigate the significant differences in grip strength for the variable 'malnutrition' and 'gender', independent samples t-tests are used.

One-way ANOVA and paired samples t-test calculated the differences in the age subgroups and for right versus left hand. The participants and the relations with the anthropometric variables and handgrip strength are investigated by multiple regression analysis. Correlations between grip strength and age, sex, nutritional status, bodyweight and height are examined by Pearson's product. A value of >0.70 is determined as 'high', 0.50-0.70 as 'good', 0.30-0.50 as 'fair' and <0.30 as 'weak' or 'no association'.

RESULTS

CHARACTERISTICS OF THE STUDY POPULATION

The mean age (±SD) of the total group (n=199) is 67.91 months (±13.67). The mean age of the malnourished and the non-malnourished group is 68.25 months (±13,50) and 67,76 months (±13.49) respectively. Table 1 visualizes the anthropometric measurements and the mean values for grip strength for the total group and the subgroups malnourished and non-malnourished children. Malnutrition is found in 64 (32.2%) children of which 50 are classified as stunted, 2 as wasted, 12 as underweight solely. 40 children showed underweight related to stunting, 2 showed underweight related to wasting. Stunting was the largest group within the malnourished group, it accounts for 78,1% of all malnourished children followed by underweight (18,8%) and wasting (3,1%). Table 2 shows the distribution of the malnourished children into stunting, wasting or underweight and the classification of moderate (Z-score between -2SD and -3SD) and severe (Z-score below -3SD). Table 3 appendix provides a more detailed view of the data for each age group.

Table 1: Main characteristics and mean values of total group, malnourished and non-malnourished children

	TOTAL GROUP	MALNOURISHED CHILDREN	NON-MALNOURISHED CHILDREN
	N= 199	**N= 64**	**N= 135**
Male participants	99	32	67
Female participants	100	32	68
Age (months)	67.91 ± 13.67	68,25 ± 13,50	67,76 ± 13.49
Length (cm)	108.50 ± 9.31	101.57 ± 6.74	111.12 ± 8,78
Weight (kg)	16.62 ± 3.12	14.28 ± 1.78	17.73 ± 3.00
MUAC (cm)	16.29 ± 1.16	15.60 ± 0.91	16.61 ± 1,23
Grip strength* (hPa)	197.64 ± 93.01	153.36 ± 70,07	218.63 ± 95.37
Grip strength right° (hPa)	207.72 ± 97.31	162.17 ± 76.49	229.32 ± 98.89
Grip strength right test (hPa)	207.49 ± 98.17	162.37 ± 81.12	228.88 ± 98.56
Grip strength right retest (hPa)	207.96 ± 99.24	161.97 ± 74.18	229.77 ± 102.36
Grip strength left° (hPa)	187.56 ± 92.00	144.56 ± 68.41	207.94 ± 94.89
Grip strength left test (hPa)	184.58 ± 92.46	141.72 ± 71.49	204.90 ± 94.52
Grip strength left retest (hPa)	190.53 ± 94.87	147.40 ± 68.70	210.98 ± 98.85

* Mean left and right combined
° Mean test and retest

Table 2: Distribution of children with stunting, wasting, underweight

	TOTAL MALNOURISHED	STUNTING N= 50		WASTING N= 2		UNDERWEIGHT N= 12 + 42*	
		Moderate	Severe	Moderate	Severe	Moderate	Severe
Total group (N=199)	64 (32.2%)	39	11	2	-	11 + 30*	1 + 12*
3-3.5 years (N= 7)	2 (28.6%)	1	1	-	-	-	-
3.5-4 years (N= 9)	3 (37.5%)	2	-	1	-	2*	-
4-4.5 years (N= 25)	7 (28.0%)	5	1	1	-	5*	1*
4.5-5 years (N= 15)	5 (33.3%)	5	-	-	-	3*	-
5-5.5 years (N= 29)	11 (37.9%)	7	1			3 + 6*	2*
5.5-6 years (N= 24)	8 (33.3%)	4	2			2 + 4*	1*
6-6.5 years (N= 33)	8 (24.2%)	3	4			1 + 3*	4*
6.5-7 years (N= 35)	12 (34.3%)	7	1			3 + 4*	1 + 2*
7-7.5 years (N= 22)	8 (36.4%)	5	1			2 + 3*	2*

*Underweight related with stunting/wasting

TEST-RETEST RELIABILITY

The test-retest reliability is estimated by using ICC, CI and Cronbach's Alpha (α) values. There is a very high test-retest reliability for the total group between mean grip strength of the right and the left hand (ICC = 0.96; CI = 0.89-0.97; α = 0.96). Table 4 shows the values of mean grip strength between the malnourished and non-malnourished children, boys and girls and between the test and retest measurements. For both children with and without malnutrition, ICC's, CI's and α's revealed a very high test-retest reliability for right and for left hand as well. For the statistical processing, a distinction is made between boys and girls. The same is true for the ICC values for boys and girls (> 0.96) for right and left hand. The same ICC results are seen in the nine subgroups and there is no distinct difference in ICC's between the age groups (table 5).

The standard error of measurement (SEM) for the total group is 20,16 hPa and the smallest detectable difference (SDD) is 55,89 hPa. For the grip strength of right hand, the SEM and the SDD are 16,57 hPa and 45,93 hPa respectively. The SEM and the SDD for the left hand are 17,69 hPa and 49,05 hPa.

Table 4: ICC, CI and α's for grip strength of the right and left hand

	RIGHT HAND			**LEFT HAND**		
	ICC	**CI**	α	**ICC**	**CI**	α
Malnourished	0,968	0.947-0.980	0.967	0,949	0.916-0.969	0.950
Non-malnourished	0,968	0.955-0.977	0.968	0,961	0.945-0.972	0.961
Males	0,976	0.965-0.984	0.976	0,962	0.943-0.975	0.963
Females	0,963	0.945-0.975	0.963	0,964	0.946-0.976	0.964
Total group test-retest*	0.971	0.962-0.978	0.971	0.963	0.950-0.972	0.963

*Mean grip strength (mean of three trials) of right and left hand between the test and retest

Table 5: Age groups for all children: ICC, CI and α's for grip strength of the right and left hand

	RIGHT HAND			LEFT HAND		
	ICC	**CI**	**α**	**ICC**	**CI**	**α**
3-3.5 y (n=7)	0.960	0.764-0.993	0.954	0.948	0.714-0.991	0.943
3.5-4 y (n=9)	0.913	0.617-0.980	0.906	0.935	0.720-0.985	0.944
4-4.5 y (n=25)	0.973	0.939-0.988	0.973	0.967	0.927-0.986	0.967
4.5-5 y (n=15)	0.899	0.695-0.966	0.893	0.928	0.784-0.976	0.923
5-5.5 y (n=29)	0.960	0.916-0.981	0.959	0.933	0.856-0.968	0.930
5.5-6 y (n=24)	0.933	0.846-0.971	0.932	0.907	0.764-0.961	0.920
6-6.5 y (n=33)	0.948	0.895-0.974	0.947	0.959	0.918-0.980	0.959
6.5-7 y (n=35)	0.941	0.884-0.970	0.940	0.908	0.818-0.953	0.908
7-7.5 y (n=22)	0.957	0.896-0.982	0.955	0.953	0.886-0.980	0.951

MALNOURISHED VERSUS NON-MALNOURISHED CHILDREN

An independent samples t-test revealed a significant difference between grip strength of children with and without malnutrition (p=0.0001) (table 6 appendix; fig. 3). Considering the subgroups one to four, there is no significant difference (0.4917<p>0.0702) in grip strength between malnutrition. For the last five age subgroups, however, a significant difference is found between children with and without malnutrition (0.0228<p>0.0002) (see fig. 4). Multiple student t-tests are used to calculate these differences.

CORRELATIONS BETWEEN GRIP STRENGTH AND ANTHROPOMETRIC AND DEMOGRAPHIC VARIABLES

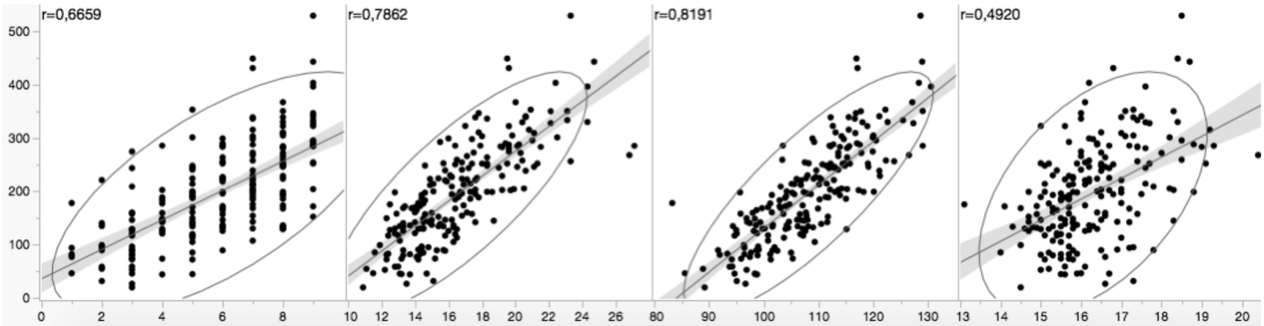

Figure 5: Total group: multiple linear correlations of grip strength with age (r = 0.67), weight (r = 0.79), height (r = 0.82) and MUAC (r = 0.49); R = correlation coefficient

Figure 5 describes the distribution of grip strength (vertical axe) for the total group versus age, weight, height and MUAC (horizontal axes). The correlations, assessed by Pearson correlation coefficients, between grip strength and age, height, weight and MUAC were all significant (table 7). There is a high correlation of grip strength of the total group with weight and height, a good correlation with age and a fair correlation with MUAC. Pearson correlations of grip strength for the malnourished and non-malnourished children are also calculated for these variables. The correlations are in this case determined as 'high' (>0.70) except the variable 'MUAC' as 'fair', for both children with and without malnutrition (table 7). Further, for the total group, a high correlation (r=0.93) was also observed between grip strength of the right hand and of the left hand (fig. 6 appendix).

Finally, a significant interaction-effect was observed for malnutrition with grip strength (p=0.0001) (table 8 appendix). This is not the case for the variable 'gender' (p=0.822) (table 8 appendix).

Table 7: Pearson correlation coefficients (R) for handgrip strength with age, weight, height and MUAC for the total group, malnourished and non-malnourished children

	TOTAL GROUP N = 199		**MALNOURISHED CHILDREN** N= 64		**NON-MALNOURISHED** N= 135	
	R	**P-value**	**R**	**P-value**	**R**	**P-value**
Age	0.666	<0.0001	0.708	<0.0001	0.721	<0.0001
Weight	0.786	<0.0001	0.757	<0.0001	0.767	<0.0001
Height	0.819	<0.0001	0.711	<0.0001	0.822	<0.0001
MUAC	0.492	<0.0001	0.306	0.014	0.446	<0.0001

DIFFERENT AGE SUBGROUPS, GENDER AND RIGHT HAND VERSUS LEFT HAND

There is a significant difference in grip strength between the different age subgroups and by using a one-way ANOVA and post-hoc analyses, a significant increase in grip strength over the nine age groups is seen (fig. 7 appendix).

When comparing the grip strength of boys and girls, an independent samples t-test is used. As a result, no significant difference in gender for the total group is seen (p=0.844) (table 9 appendix; Fig. 8). When evaluating the differences in gender in every age subgroup, multiple student's t-tests revealed only in age group nine a significant difference (p=0.0144) (fig. 9). The graph of the regression (fig. 10) shows that girls, in age group one to three, are stronger (not significant) than boys. For the third age group, there are no differences between gender. From the fourth until the eighth subgroup, boys tend to be stronger than girls. In subgroup nine, boys are significant stronger than girls (p=0.0144). Handgrip strength increases with increasing age for boys and girls.

There is also a significant difference between both hands, whereby the right hand is stronger than the left hand (paired t-test; p<0.0001). Considering the age subgroups, a one-way ANOVA is assessed and a significant difference in grip strength is seen for both hands with increasing age. The right hand is always stronger than the left hand.

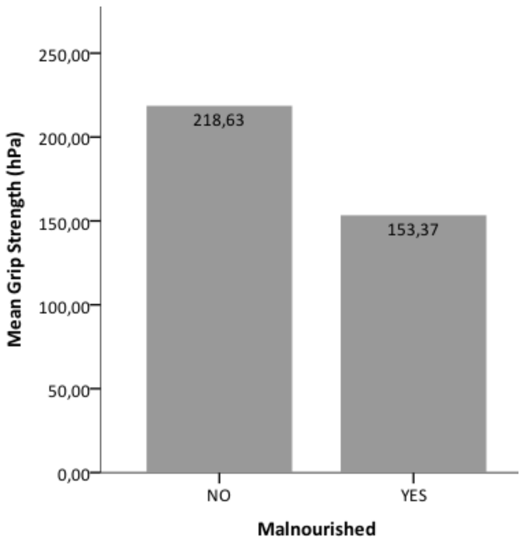

Figure 3: Mean grip strength versus nutritional status (p=0.0001): NO (n=135) and YES (n=64)

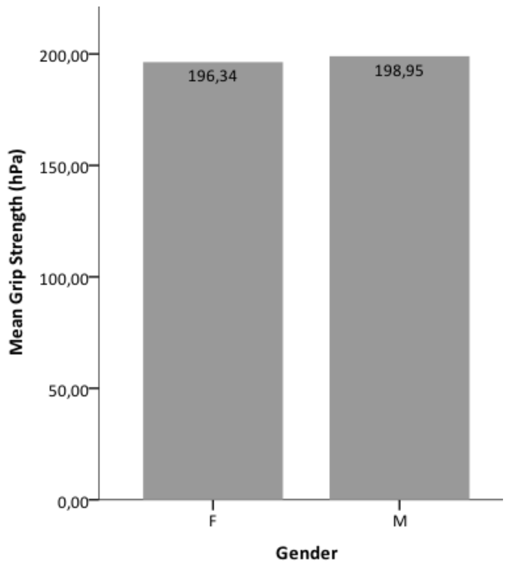

Figure 8: Mean grip strength versus gender (p=0.844): females (n=100) and males (n=99)

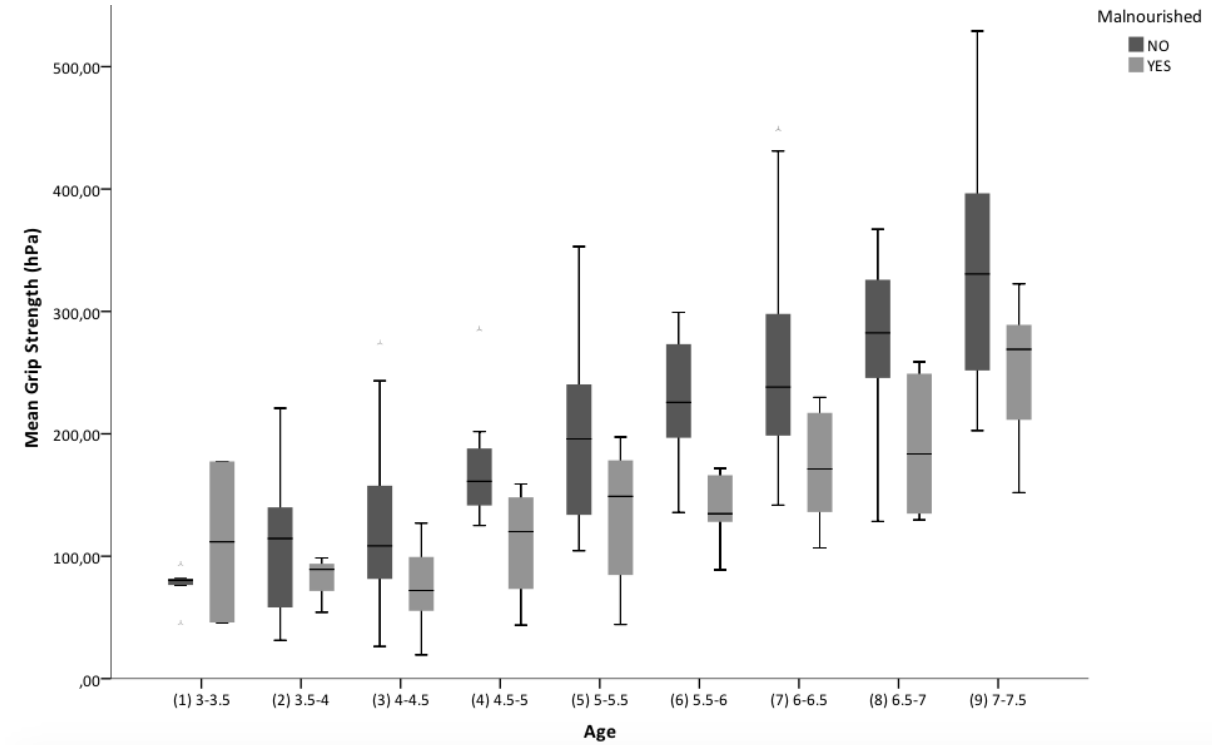

Figure 4: Mean grip strength versus age subgroups, for the variable 'malnutrition', with only a significant difference between the age subgroups 5-9 (5-7.5 years old) (0.0228<p>0.0002)

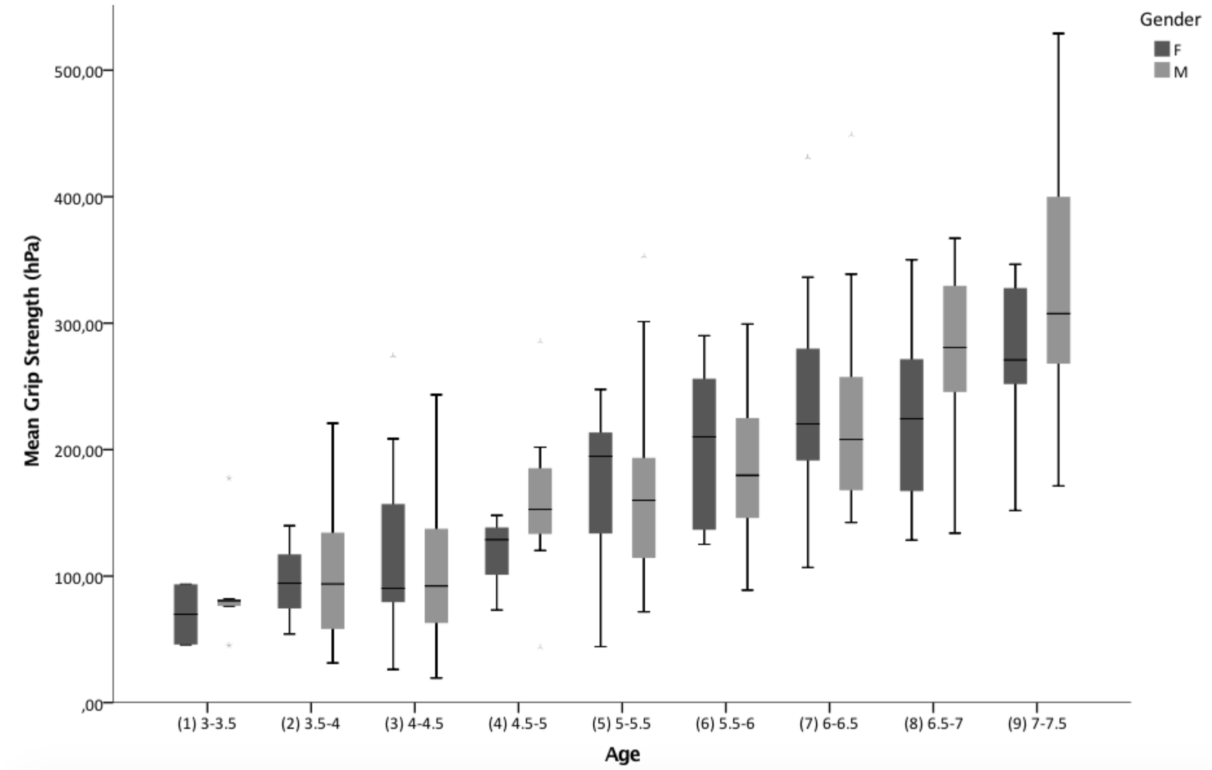

Figure 9: Mean grip strength versus age subgroups, for the variable 'gender', with a significant difference between gender in age subgroup nine (7-7.5 years old) (p=0.0144)

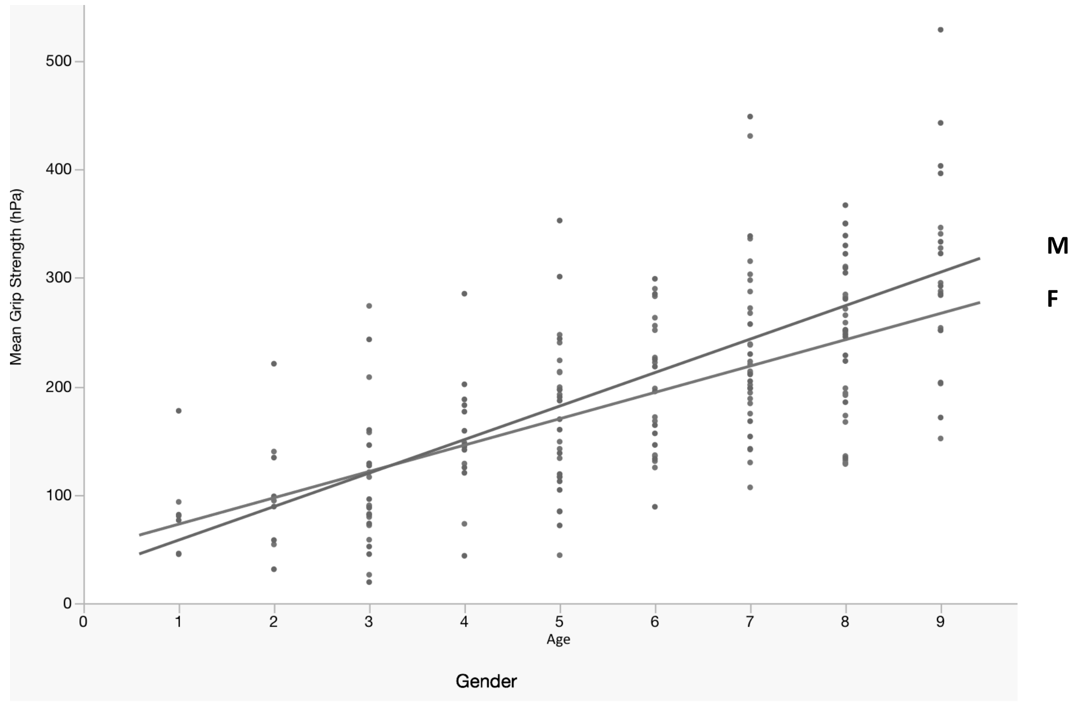

Figure 10: Mean grip strength of males and females versus age, with subgroups **1** (3-3.5 y/o; n = 7), **2** (3.5-4 y/o; n = 9), **3** (4-4.5 y/o; n = 25), **4** (4.5-5 y/o; n = 15), **5** (5-5.5 y/o; n = 29), **6** (5.5-6 y/o; n = 24), **7** (6-6.5 y/o; n = 33), **8** (6.5-7 y/o; n = 35) and **9** (7-7.5 y/o; n 22)

DISCUSSION

The main objective of this study is to determine the reliability of the Greisinger manometer in both malnourished and non-malnourished children from 3 to 7.5 years old. Other objectives were to assess the correlation between handgrip strength and several demographic and anthropometric variables and to explore if grip strength may discriminate between malnourished and non-malnourished children.

Malnutrition is found in 32.2% of the children, stunting was the largest group with a prevalence of 25,1% within the total study population. Underweight represented 6.0% of the study population and wasting 1,0%. These percentages are slightly lower than the percentages (38.4%, 35.7%, 28,5% respectively) found for stunting, underweight and wasting in the NFHS-4 (*National Family Health Survey-4*, 2015-16). The prevalence of malnutrition was equally distributed between boys (50%) and girls (50%). This result is in contradiction with the studies of Priyanka, Vincent, Jini, and Saju (2016) and the National Nutrition Monitoring Bureau (India) (2011-12) who indicated that the prevalence of malnutrition is higher among boys.

The current study used the Greisinger Manometer GDH 200-13 combined with the Baseline dynamometer bulb to evaluate the handgrip strength in children with and without malnutrition and shows for the same age range (3-7.5 years old), a higher test-retest reliability than the Jamar, Lode dynamometer and the Martin Vigorimeter.

ICC values of the total group (0.96-0.97) and the internal consistencies (Cronbach's alpha 0.96-0.97) of the test-retest measurements indicate a very high test-retest reliability. In preliminary research, four reliable instruments are found for measuring handgrip strength in children from three to six years old, respectively Jamar dynamometer, Lode dynamometer, Martin Vigorimeter and Grippit. The test-retest reliability of the Lode dynamometer is moderate, ICC values of 0.73-0.91 respectively (Molenaar, Zuidam, Selles, Stam, & Hovius, 2008). For the Martin Vigorimeter, ICC's of 0.76-0.79 and α's of 0.80-0.91 are found (Benefice, Fouere, & Malina, 1999; Molenaar et al., 2008). The Grippit shows a high test-retest reliability (ICC's of 0.95-0.98) (Svensson, Waling, & Häger-Ross, 2008). Also for children with symptoms of myopathy, high ICC values (0.91-0.93) are found, using the Jamar dynamometer (Van den Beld, A. Van der Sanden, G. A. Sengers, R. C. Verbeek, & A. L. Gabreels, 2006) . The results of Svensson et al. (2008) and Van den Beld et al. (2006) are in line with the ICC's of this study. An interesting and useful finding is the significant difference in handgrip strength between children with and without malnutrition for the total age group. This result is different from the results of preliminary research of Vanderaspoilden (2013), which was not able to find a difference in handgrip strength between children with and without malnutrition using the Greisinger Manometer GDH 200-13. However, the number of children included in our study is higher in every age subgroup. For the youngest group (3-4 y/o), there are twice as many children included, i.e. 16 versus 8 children (Vanderaspoilden, 2013). Same findings are seen in other subgroups: 40 vs 19 children (group 4-5 y/o), 53 versus 40 children (group 5-6 y/o), 90 versus 29 children (group 6-7.5 y/o). When comparing the grip strength between children with and without malnutrition within every subgroup (1-9), there is only a significant difference in grip strength for the subgroups five to nine (5-7.5 years old). In that way, grip strength might be a useful tool to discriminate between children with and without malnutrition starting from the age of five years old. Detection of malnutrition in children living in developing countries is of great importance to early intervene and for follow-up within intervention studies of malnourished children.

In this study, there was no significant interaction effect between handgrip strength and gender. Besides the correlations of grip strength with age, height, weight and MUAC, there was also a significant interaction effect between grip strength and malnutrition. Ploegmakers, Hepping, Geertzen, Bulstra, and Stevens (2013) and Vanderaspoilden (2013) also revealed a significant correlation of handgrip strength with age, height and weight.

Another goal of the current study was to evaluate the differences in age subgroups, gender and right hand versus left hand. Our study can confirm the results of Bear-Lehman, Kafko, Mah, Mosquera, and Reilly (2002), Vanderaspoilden (2013) and Ploegmakers et al. (2013), which show a significant difference of grip strength between the ages of 3, 4, 5 and 6 years old for gender and for right and left hand. Our study and several other studies (Benefice et al., 1999; Link, Lukens, & Bush, 1995; Molenaar et al., 2010; Vanderaspoilden, 2013) observe a positive trend in increasing handgrip strength with age.

Looking at the differences in grip strength between gender, from 3 to 4.5 years old, girls tend to be stronger than boys. From the age of 4.5 to 7 years, boys tend to be stronger than girls but the latter is not significant. In the last age group (7-7.5 y/o), boys are significantly stronger than girls. As a conclusion, it can be said there is no significant difference between the handgrip strength of boys and girls between the age of three and seven years old (p=0.844). This may suggest opportunities to develop combined normative data tables for gender in the future. Molenaar et al. (2010) already made combined tables even though there was a significant difference between boys and girls for the age group of 4-12 y/o. The use of one growth diagram is more practical in clinical situations (Molenaar et al., 2010). Our results are also in contrast with findings of Ploegmakers et al. (2013), who states boys are significant stronger than girls on the age of 4.5 and 6 years old. The same difference in gender for children of 3-6.5 years old is also noted in the studies of Benefice et al. (1999) and Eruva Indira (2015). Similarities of our study are seen in the studies of Link et al. (1995), Hager-Ross and Rosblad (2002) and Vanderaspoilden (2013), which found also no significant difference between boys and girls in the same age range.

The current study confirms the results of Hager-Ross and Rosblad (2002), where a significant difference is found between the grip strength of right and left hand. The right hand is significantly stronger than the left hand. On the contrary, Link et al. (1995) says there is no significant difference in grip strength between right and left hand. Other studies, including Vanderaspoilden (2013), investigated the difference in grip strength of the dominant and the non-dominant hand and these results cannot be compared with our results.

One of the limitations we experienced initially in our study, were the changes needed to be made to the standard ASHT-measurement protocol of handgrip strength. However, these adjustments were necessary due to cultural factors, such as no availability of chairs in the schools. Sitting on the floor is a cultural habit in India. In order to meet the cultural habits, we had to change the starting position of measuring grip strength from a sitting position on a chair to tailor's seat with the back supported against the wall, arms 90 degrees flexed and palms facing up. Hence, a cultural bias is being avoided. The original ASHT-protocol was designed for a Western population whose resting position differs from an Indian population, who spend large amount of time sitting on the floor (eating, school, prayer). This altered protocol needs to be taken into account when comparing data from other studies.

Next, Scharoun and Bryden (2014) state that children under the age of 6 years are not consistent in choosing a hand of preference. Therefore, the current measurement protocol starts with the standardised measurement of the right hand followed by the left hand. This is an important remark for future research especially when working with very young children.

Another limitation is still a small sample size of the youngest groups. Due to the limited amount of time and because of only few young children attend school in India, it was hard to find this young group of children.

After all, we can conclude that the Greisinger manometer (in combination with the Baseline dynamometer bulb) is a reliable instrument to measure handgrip strength in children between 3 and 7.5 years old. The significant difference in handgrip strength between malnourished children and children without malnutrition, refers to the possibility of handgrip strength to discriminate between these two groups. Measuring handgrip strength with the Greisinger in combination with the Baseline dynamometer bulb is an easy, cheap and fast way to make an estimation of a child's physical status and apparently for its nutritional status.

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APPENDIX

FIGURES

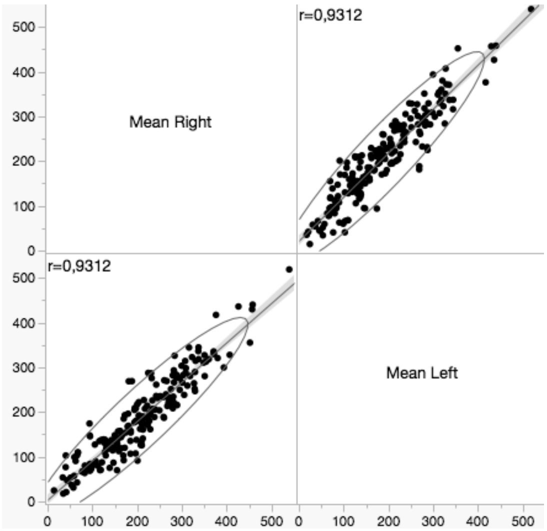

Figure 6 appendix: Correlations of mean grip strength between right and left hand (r=0.93)

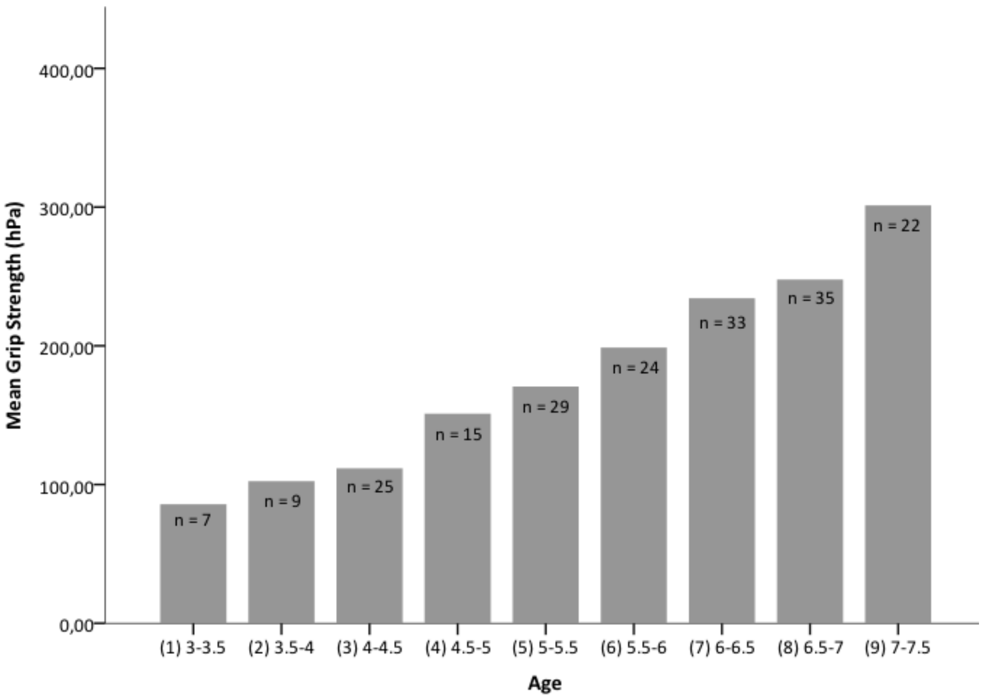

Figure 7 appendix: Total group: mean grip strength of the different age subgroups, with subgroups **1** (3-3.5 y/o; n = 7), **2** (3.5-4 y/o; n = 9), **3** (4-4.5 y/o; n = 25), **4** (4.5-5 y/o; n = 15), **5** (5-5.5 y/o; n = 29), **6** (5.5-6 y/o; n = 24), **7** (6-6.5 y/o; n = 33), **8** (6.5-7 y/o; n = 35) and **9** (7-7.5 y/o; n 22)

TABLES

Table 6 appendix: Independent samples t-test showing a significant difference in handgrip strength between children with and without malnutrition (p>0.0001)

Group Statistics

	Malnourished	N	Mean	Std. Deviation	Std. Error Mean
MeanGripStrengthhPa	YES	64	153,365234	70,0736277	8,75920346
	NO	135	218,629407	95,3655513	8,20775982

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
MeanGripStrengthhPa	Equal variances assumed	6,721	,010	-4,883	197	,000	-65,264173	13,3660082	-91,622998	-38,905348
	Equal variances not assumed			-5,437	163,090	,000	-65,264173	12,0037897	-88,967054	-41,561292

Table 8 appendix: Interaction-effects of mean grip strength with gender (p=0.822) and malnutrition (p<0.0001)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	92,330	29,927		3,085	,002		
	Gender	-2,826	12,517	-,015	-,226	,822	1,000	1,000
	Malnourished	65,275	13,398	,329	4,872	,000	1,000	1,000

a. Dependent Variable: MeanGripStrengthhPa

Table 9 appendix: Independent samples t-test showing no significant difference in handgrip strength between gender

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
MeanGripStrengthhPa	M	99	198,953990	103,671304	10,4193581
	F	100	196,339000	81,6086507	8,16086507

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
MeanGripStrengthhPa	Equal variances assumed	4,775	,030	,198	197	,843	2,61498990	13,2192186	-23,454354	28,6843337
	Equal variances not assumed			,198	185,875	,844	2,61498990	13,2349062	-23,494949	28,7249293

Table 3 appendix: Descriptive statistics

	3-3.5 years N= 7		**3.5-4 years** N= 9		**4-4.5 years** N= 25		**4.5-5 years** N= 15		**5-5.5 years** N=29		**5.5-6 years** N= 24		**6-6.5 years** N= 33		**6.5-7 years** N= 35		**7-7.5 years** N= 22	
	Mal	**Nmal**	**Mal**	**NMal**	**Mal**	**NMal**	**Mal**	**NMal**	**Mal**	**NMal**	**Mal**	**NMal**	**Mal**	**NMal**	**Mal**	**NMal**	**Mal**	**NMal**
Participants	2	5	3	6	7	18	5	10	11	18	8	16	8	25	12	23	8	14
Male	1	4	2	4	3	9	2	9	6	9	3	7	4	6	4	13	6	6
Female	1	1	1	2	4	9	3	1	5	9	5	9	4	19	8	10	2	8
Length (cm)	84.45 ± 1.63	96.38 ± 3.41	92.33 ± 3.79	99.27 ± 7.28	93.96 ± 2.36	102.36 ± 6.18	97.24 ± 1.64	105.74 ± 4.49	100.66 ± 3.21	108.98 ± 5.70	101.68 ± 2.28	112.45 ± 6.56	102.90 ± 3.98	114.18 ± 5.00	107.19 ± 3.53	117.71 ± 4.14	110.04 ± 3.39	121.49 ± 6.60
Weight (kg)	12.85 ± 1.91	13.64 ± 0.91	12.10 ± 1.11	14.45 ± 1.81	12.24 ± 0.65	15.24 ± 1.74	13.84 ± 0.91	16.16 ± 1.89	13.51 ± 0.99	16.66 ± 2.20	14.14 ± 0.79	18.38 ± 3.35	14.11 ± 1.26	18.56 ± 2.29	15.77 ± 1.05	19.59 ± 2.04	16.64 ± 1.81	21.06 ± 2.33
MUAC (cm)	16.50 ± 0.71	16.20 ± 0.91	15.40 ± 1.01	16.63 ± 0.65	15.43 ± 0.59	16.26 ± 0.80	15.82 ± 0.46	16.37 ± 1.19	15.52 ±0.72	16.09 ± 0.94	15.15 ± 0.55	16.61 ± 1.40	15.35 ± 1.15	16.92 ± 1.30	16.04 ± 1.16	16.65 ± 1.02	15.61 ± 1.09	17.43 ± 1.00
Grip strength (hPa)	111.67 ± 93.06	75.47 ± 18.06	80.62 ± 23.40	113.20 ± 67.58	75.39 ± 37.30	125.88 ± 66.17	108.85 ± 49.23	172.06 ± 47.84	132.92 ± 54.80	193.64 ± 69.31	139.84 ± 27.65	228.30 ± 51.82	173.20 ± 45.34	253.84 ± 77.66	191.50 ± 52.75	277.13 ± 61.19	251.71 ± 60.15	329.55 ± 92.00
Grip strength right (hPa)	107.13 ± 88.91	80.72 ± 24.60	89.32 ± 21.33	118.88 ± 62.64	74.24 ± 41.79	128.09 ± 69.01	107.14 ± 55.20	179.79 ± 55.32	142.64 ± 66.68	210.44 ± 70.41	150.91 ± 41,75	240.86 ± 51.01	190.67 ± 42.53	264.57 ± 76.18	202.29 ± 65.95	287.17 ± 66.92	264.01 ± 45.88	348.37 ± 92.54
Grip strength right test (hPa)	107.80 ± 95.84	79.62 ± 26.58	78.61 ± 32.72	120.39 ± 75.36	67.09 ± 41.79	128.02 ± 70.84	100.73 ± 63.83	181.92 ± 55.38	143.91 ± 67.22	210.20 ± 66.40	145.37 ± 37.77	239.19 ± 59.72	195.74 ± 40.27	263.94 ± 78.15	210.85 ± 73.42	285.07 ± 60.17	265.61 ± 42.55	349.18 ± 88.43
Grip strength right retest (hPa)	106.47 ± 81.98	81.83 ± 27.13	100.02 ± 16.99	117.36 ± 52.04	81.40 ± 43.24	128.15 ± 69.08	113.56 ± 49.57	177.65 ± 64.59	141.37 ± 70.06	210.68 ± 77.20	156.45 ± 46.55	242.53 ± 49.30	185.61 ± 45.83	265.20 ± 79.10	193.74 ± 60.72	289.26 ± 78.57	262.40 ± 55.82	347.57 ± 100,19
Grip strength left (hPa)	116.20 ± 97.20	70.21 ± 20.25	71.93 ± 25.70	107.52 ± 73.67	76.55 ± 35.77	123.66 ± 66.71	110.56 ± 47.77	164.34 ± 46.95	123.20 ± 48.18	176.85 ± 71.08	128.77 ± 22.33	215.73 ± 63.19	155.74 ± 51.63	243.11 ± 80.35	180.70 ± 50.77	267.09 ± 61.04	239,42 ± 77.75	310.73 ± 95.98
Grip strength left test (hPa)	116.28 ± 112.97	73.95 ± 14.08	55.17 ± 23.34	104.25 ± 78.94	67.71 ± 38.48	124.21 ± 66.34	107.32 ± 50.78	167.57 ± 52.90	123.67 ± 53.26	175.62 ± 72.81	122.02 ± 24.54	205.67 ± 66.14	151.29 ± 49.28	240.15 ± 84.55	182.44 ± 47.44	260.36 ± 63.88	240.67 ± 76.43	307.95 ± 89.71
Grip strength left retest (hPa)	116.12 ± 81.43	66.47 ± 29.82	88.69 ± 37.21	110.79 ± 70.22	85.38 ± 37.64	123.12 ± 68.51	113.81 ± 44.85	161.11 ± 47.16	122.73 ± 48.63	178.08 ± 74.35	135.53 ± 26.99	225.79 ± 67.52	160.19 ± 60.15	246.08 ± 79.35	178.95 ± 58.81	273.83 ± 66.77	238.18 ± 82.32	313.50 ± 107.23

*all values are mean values ± SD
*Mal = malnourished children
*NMal = Non-malnourished children

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Handgrip strength at malnourished and non-malnourished Indian children aged 3 to 7.5 years using the Greisinger manometer - Test-retest reliability

Richting: **master in de revalidatiewetenschappen en de kinesitherapie-revalidatiewetenschappen en kinesitherapie bij neurologische aandoeningen**
Jaar: **2017**

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