

# Grip strength is strongly associated with height, weight and gender in childhood: a cross sectional study of 2241 children and adolescents providing reference values

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**Question:** What are reference values for grip strength in children and adolescents based on a large and heterogeneous study population? What is the association of grip strength with age, gender, weight, and height in this population? **Design:** Cross-sectional study. **Participants:** Participants were recruited from schools in the northern provinces of the Netherlands. The study included healthy children and adolescents ranging in age from 4 to 15 years. **Outcome measures:** All children had their height (cm) and weight (kg) measured and were allowed a total of four attempts using the Jamar hand dynamometer: twice with each hand. Grip strength scores (kg) were recorded for the dominant and non-dominant hands. **Results:** The study population comprised 2241 children and adolescents. Reference values for both genders are provided according to age and dominance. Grip strength shows a linear and parallel progression for both genders until the age of 11 or 12, after which grip strength development shows an acceleration that is more prominent in boys. **Conclusion:** There is a significant difference in grip strength with each ascending year of age in favour of the older group, as well as a trend for boys to be stronger than girls in all age groups between 4 and 15 years. Weight and especially height have a strong association with grip strength in children. [Ploegmakers JJW, Hepping AM, Geertzen JHB, Bulstra SK, Stevens M (2013) Grip strength is strongly associated with height, weight and gender in childhood: a cross sectional study of 2241 children and adolescents providing reference values. *Journal of Physiotherapy* 59: 255–261]

**Key words:** Grip strength, Children, Jamar hand dynamometer, Reference values, Physiotherapy

## Introduction

Grip strength is used extensively in the assessment of hand function. Because it is directly affected by the neural, muscular and skeletal systems, grip strength is used in the evaluation of patients with a large range of pathologies that impair the upper extremities, including rheumatoid arthritis, osteoarthritis, muscular dystrophy, tenosynovitis, stroke, and congenital malformations. Grip strength measurements also have an established role in determining treatment efficacy, such as in the evaluation of different wrist orthoses, the effect of hand exercises in rheumatoid arthritis, and recovery after trauma. Also, they are used as an outcome measure after many different surgical interventions. Grip strength measurements provide a well established and objective score that is reflective of hand function and that is easily and quickly obtainable by a range of different health professionals.

Since comparison to normative data is important when making statements about specific patient groups or treatments, obtaining normative data for grip strength in adults has been the subject of many studies. In contrast, normative data for children is far less readily available. To identify studies on this topic we searched PubMed, MEDLINE and EMBASE using combinations of the search terms: children, adolescents, grip strength, dynamometer, Jamar hand dynamometer, JHD, normative data and reference values. Reference lists of relevant articles were then screened to identify additional articles that might not

have shown up in the search. Although we found several studies focusing specifically on grip strength in children, most of them had not assessed height and weight as factors of influence (Ager et al 1984, Bear-Lehman et al 2002, Butterfield et al 2009, De Smet and Vercammen 2001, Mathiowetz et al 1986). This is remarkable in the case of growing children, especially when weight and height are known to correlate with strength in children (Rauch 2002, Häger-Ross and Rösblad 2002, Newman et al 1984). Moreover, although some of these studies included a large number of children in total (with exception of Newman

**What is already known on this topic:** Grip strength is used widely in clinical practice and research to assess the impact of a variety of disorders on hand function. Although robust data exist for predicting grip strength in adults, the few studies that have generated normative data in children and adolescents either had a limited sample size, used a measurement device that is no longer used in clinical practice, or did not analyse factors such as hand dominance, height, or weight.

**What this study adds:** Normative equations and graphs were generated using data from 2241 children and adolescents. Grip strength increases with age, with a trend for boys to be stronger than girls in all age groups between 4 and 15 years. Weight and height have a strong association with grip strength in children and adolescents.

et al 1984, varying between 81 and 736), the number of children in each age group and/or the range of age groups is often limited and relatively small for establishing reference values. Also, a variety of methods and instruments was used. For example, some studies did not differentiate between scores of the dominant and non-dominant hand, used a device that is no longer used in clinical practice, or scored the maximum instead of the mean of attempts. Therefore, it can be concluded that there is a need for a study that assesses the development of grip strength in children, based on large groups according to age and gender and performed according to current standardised methods regarding measurement of grip strength.

The primary aim of this study was to provide reference values for grip strength in children and to present these data graphically to allow easy comparison with patient outcomes by a range of clinicians in daily practice. Therefore the research questions were:

1. What are the reference values for grip strength in children aged 4–15 years according to age, gender and dominance based on a large, heterogeneous study population?
2. What is the association of gender, height, and weight with grip strength in children?

## Method

### Design

This cross-sectional study measured grip strength in a cohort of healthy children and adolescents. The data were used to generate normative values for grip strength.

### Participants

Children and adolescents ranging in age from 4 to 15 years were included. Participants were recruited by approaching schools in the four northern provinces of The Netherlands. All children of participating school classes were invited to take part. Exclusion criteria were: pain or restriction of movement of a hand or arm, neuromuscular disease, generalised bone disease, aneuploidy, any condition that severely interfered with normal growth or required hormonal supplementation, and children who could not be instructed in how to use the dynamometer.

All included subjects were assigned to a group based on their calendar age at the time of the assessment, thereby creating nine subgroups in total. The study aimed to include at least 200 children in each age group, with a near to equal representation of boys and girls.

### Outcome measures

Each measurement session started with a short lecture by the researchers to introduce themselves to the school class and to explain the procedures and the purpose of the study. A demonstration of the use of the dynamometer was given, using the teacher as an example. Individually, dominance was determined by asking which hand was used to write or, in the case of young children, used to perform activities such as cutting or painting. Children aged 4 and 5 years, in whom hand dominance is not yet fully established, and any older children who displayed uncertainty regarding hand dominance, were asked to draw a circle. To avoid suggestion by the researcher, these participants had to pick up the pencil from the table themselves. The hand used to draw the shape was then scored as the dominant hand. The

height (in cm) and weight (in kg) of each participating child were then measured.

Grip strength was measured using the Jamar® hydraulic hand dynamometer<sup>a</sup>. A total of six calibrated dynamometers were at the researchers' disposal. The devices were replaced twice, at subsequent time intervals, with two used devices exchanged for two non-used devices after approximately one-third, and again after two-thirds of the total number of children we aimed to recruit had been assessed. The following standardised testing position for measuring grip strength was used, as advocated by the American Society of Hand Therapists (ASHT): the participant is seated with shoulders adducted and neutrally rotated, elbow flexed at 90 deg, wrist between 0 and 30 deg extension, and between 0 and 15 deg ulnar deviation (Balogun et al 1985, Fess 1992). The handle of the device was set to the second position for all participants, with the exception of 4 and 5 year olds, for whom the bar was set to the first position, and who were allowed to manually support the arm with the other hand. Participants were allowed four attempts using the dynamometer, two with each hand, and each individual attempt was scored. The starting hand was alternated between subjects and a 10-sec break was allowed between attempts. A Dutch translation of the Southampton grip strength measurement protocol was used as verbal encouragement (Roberts et al 2011). Encouragement was kept as consistent as possible for every participant in volume and tone, counting down from 3 to 0, followed by 'squeeze as hard as you can ... squeeze and let go'.

### Data analysis

Descriptive statistics were used to describe the main characteristics of the participants. The Mann-Whitney U test was used to compare grip strength between genders. In order to establish the correlation of gender, age, height, and weight with grip strength in more detail, we performed a multilevel analysis adding them as fixed factors. As intercept, the school the child attended was added. Results were accepted to be significant when the *p* value was < 0.05.

## Results

In total 19 schools participated, located in 12 towns and cities. Thirteen children were ineligible for participation in the study. Two children were excluded because of Down syndrome, two children because they suffered from active juvenile arthritis, four because they had pre-existing pain of a hand or arm, and one because she received hormonal therapy to improve growth. Another four children were excluded because they did not meet the inclusion criteria, but no specific reason was recorded. Nine eligible children were excluded because the form on which measurements were written was not filled in completely. In order to get an impression of how many children refused to participate we randomly recorded the number of children that refused to participate at half of the schools visited. Based on this registration it can be estimated that about 1% of invited children did not participate in the study. The reasons cited most commonly were unfamiliarity (children who just started school), problems with (self-perceived) body weight, or simply 'not feeling like it'.

The final study population comprised 2241 children and adolescents (1112 boys and 1129 girls) ranging in age from 4 to 15 years. Values for grip strength according to age,

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