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Reference values of maximum isometric muscle force obtained in 270 children aged 4–16 years by hand-held dynamometry

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Abstract

Since muscle force and functional ability are not related linearly; maximum force can be reduced while functional ability is still maintained. For diagnostic and therapeutic reasons loss of muscle force should be detected as early and accurately as possible. Because of growth factors, maximum muscle force in children varies with age, which makes detection of force loss difficult. The purpose of this study was to establish reference values for muscle force in children aged 4–16 years, obtained by hand-held dynamometry in 11 muscle groups. In boys muscle force was predicted best by weight whereas in girls weight and age were best predictors. At age 14 boys become significantly stronger for nearly all tested muscle groups. These age-related reference values can be used to quantify muscle weakness in individual muscle groups in children aged 4–16 years and to evaluate the effects of therapy.

Keywords: Isometric contraction; Hand-held dynamometry; Reference values

1. Introduction

Muscle function and muscle force are two fundamentally different parameters of the motor system that are closely related and are often tested during neurological examination in children. To determine whether pathological muscle weakness is present or develops during disease and in evaluating the effects of (physio) therapy, reference values for maximum isometric muscle force are needed. Functional grading systems, such as the Hammersmith motor ability score [1], are not suitable to detect force loss at an early stage of disease since there is no direct association between loss of myofibres and functional ability. Another disadvantage of these grading systems is that they are, to some extent, subjective. The Medical Research Council scale (MRC) can determine muscle force. In this scale strength can be classified between 0 (no contraction) and 5 (normal power). Van der Ploeg et al. [2] compared the non-parametric MRC scale with parametric hand-held dynamometry in adult male elbow flexors. They concluded that MRC grade 4 covers a wide range of forces: from 10 to 250 Newton. This inaccuracy makes MRC-grading unsuitable for quantification of normal and slightly decreased muscle strength. To measure muscle force non-hand-held dynamometers like the Cybex (Cybex Division of Lumex, Inc., Ronkonkoma, NY) and Biodex (Biodex, Biodex Corp., Shirley, NY) can be used. These systems consist of a framework that allows a subject to be tested. Because of their size, complicated use and high costs, these dynamometers cannot be used in bedside investigation. Hand-held dynamometry seems to be a good alternative. Most clinically important muscle groups can be measured easily with a dynamometer. Its portable size, rapid application and low price makes it very suitable for use in bedside investigation and in outpatients' departments. Most studies reporting reference values are performed in adults [5,7]. Only a few articles published at least 10 years ago report reference values obtained in children [3,4]. The results show that height and weight are important predictors of muscle force. Since mean weight and height in children have increased in the past decade [8] new reference values are needed.

The purpose of this study is to establish reference values of maximum isometric muscle force in 11 muscle groups obtained with hand-held dynamometry in normal children aged 4–16 years and to provide summed scores for upper and lower extremities as well as for distal and proximal muscle groups. The relationship between anthropometric values and muscle force was investigated also.

2. Patients and methods

In this study a calibrated hand-held dynamometer type

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CT 3001 (C.I.T. Technics, Groningen, The Netherlands) was used. This dynamometer could measure forces up to 999 Newton (N). For reliable measurements the upper range was subjectively chosen at 500 N based on the actual force of the investigator. Measurements were taken from 270 normal children, 139 boys and 131 girls, aged 4–16 years, after informed consent. Each different age group comprises 1 year. Age, weight and height were recorded in all participants. Maximum isometric contraction values were measured in 11 different muscle groups by using the 'break' technique in which the examiner gradually overcomes the muscle force and stops at the moment the extremity gives way. Table 1 presents the position of the subject and dynamometer. To assure optimal attention in children aged 4 and 5 years an adjusted protocol was used in which at least five muscle groups were tested. With the exception of neck flexors each muscle group was tested bilaterally. The highest value of three contractions with an interval of at least 30 s was recorded if an inadequate performance was suspected, e.g. in case of great differences between left and right muscle groups. The whole testing procedure took approximately 30 min. Children were randomly selected from the class register. None was under medical treatment for diseases that could affect muscle force negatively. All measurements were performed by the first author. Verbal encouragement was given during the test. The number of subjects in each age group and mean values for weight and height are presented in Table 2. In bilaterally tested muscle groups mean values were calculated to prevent the influence of left–right differences. Summed scores were calculated by adding up a selection of muscle groups and were made for upper and lower extremities as well as for distal, proximal and all muscle groups. Student's *t*-test was used to compare mean force values between boys and girls in the tested age groups. Significance was accepted if two-sided *P* values were below 5%. To evaluate the association between muscle force, age, weight and height, Pearson correlation coefficients (*r*) were calculated. Correlation was assumed to be significant at the two-tailed 5% level.

3. Results

The number of boys and girls as well as mean values for weight and height are presented in Table 2 for each age group. Weight and height increase with age. In girls height seems to level off at age 13 whereas in boys height continues to increase until age 16. A significant sex-difference in height can first be seen at age 4 in favour of boys. Ten-year-old boys are heavier and significantly taller than 10-year-old girls. In general boys are taller and heavier than girls. However, at age 11–13 girls are taller and heavier although not always significantly. This difference gradually decreases. At age 15 boys are significantly taller and heavier than girls. In boys weight correlates best with muscle force for individual muscle groups as well as for summed scores, whereas in girls weight and age correlate best with muscle force. The relationship between total muscle strength, age and weight is shown in Figs. 1 and 2. Pearson correlation coefficients in boys range from 0.76 (hip flexors) to 0.87 (shoulder abductors, wrist extensors, three-point grip and knee-extensors) for weight, in girls from 0.61 (elbow extensors) to 0.89 (foot dorsal flexors) for weight, and from 0.55 (elbow extensors) to 0.85 (foot dorsal flexors) for age. Table 3 presents age-related reference values for 11 different muscle groups for both sexes. The highest values of muscle strength were found in the oldest age groups. In each age group leg muscles were the strongest muscles for both sexes. In older children muscle strength variation is more pronounced. The highest force values in children aged 6–9 years were found in knee flexors and hip flexors, whereas in children aged 10–16 highest values were found in knee

Table 1
Muscle group, subject and dynamometer position: standard protocol

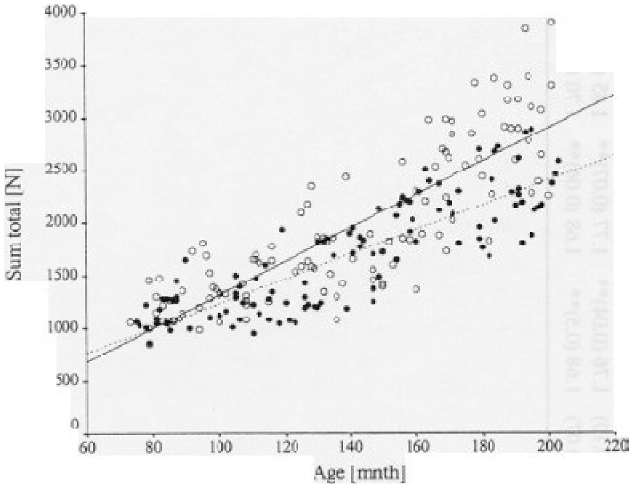
Muscle group	Subject position	Dynamometer position
Neck flexors	Sitting upright; head up at 90°	Centre of forehead, just above eyebrows
Shoulder abductors[a]	Sitting upright; shoulder 90° abducted, elbow 135° flexed, forearm pronated	Lateral epicondyle of humerus
Elbow flexors[a]	Supine; shoulder adducted, elbow 90° flexed, forearm supinated	Just proximal to wrist crease (flexor surface)
Elbow extensors	As for elbow flexors	Just proximal to wrist crease (extensor surface)
Wrist extensors	Sitting; forearm supported and pronated, wrist in neutral position, fingers flexed	Just proximal to third metacarpal head
Three-point grip[a]	Sitting; forearm pronated, wrist extended	Distal phalanx of thumb under applicator, distal two phalanges of dig 2 and 3 above collar
Hip flexors	Supine; hip and knee 45° flexed, ankle supported by examiner	Anterior surface of distal thigh
Hip abductors	Supine; hip 45° flexed, knee 90° flexed, contralateral knee supported by chest of examiner	Lateral epicondyle of knee
Knee extensors	Sitting; knee 90° flexed	Anterior surface of distal shunt just proximal to ankle joint
Knee flexors[a]	Sitting; knee 45° flexed	Heel
Foot dorsiflexors[a]	Supine; foot 90° dorsiflexed	Just proximal to metatarsophalangeal joints (dorsal surface)

[a] Adjusted protocol.

Table 2
Number of boys and girls in each different age group[a]

Age (years)		4	5	6	7	8	9	10	11	12	13	14	15	16
Controls	Boys	10	11	9	10	10	11	10	11	9	12	13	12	11
	Girls	10	10	9	10	11	10	11	9	11	11	7	11	11
Weight (kg)	Boys	20.7 (2.2)	21.3 (1.9)	24.1 (4.9)	27.0 (3.9)	30.7 (5.8)	32.0 (5.0)	42.1 (6.5)	39.8 (10.2)	41.1 (8.2)	49.4 (7.8)	57.3 (8.4)	60.9 (7.3)*	71.6 (10.0)**
	Girls	18.6 (2.3)	20.1 (2.6)	23.8 (3.8)	27.8 (4.2)	27.5 (4.6)	32.3 (6.9)	37.0 (6.0)	46.0 (7.0)	46.3 (9.4)	54.2 (8.0)	51.0 (5.3)	55.6 (5.9)*	60.6 (6.7)**
Height (m)	Boys	1.16 (0.33)*	1.16 (0.04)	1.29 (0.09)	1.31 (0.06)	1.37 (0.07)	1.42 (0.07)	1.54 (0.05)**	1.51 (0.06)*	1.56 (0.04)	1.64 (0.10)	1.76 (0.04)**	1.77 (0.07)**	1.85 (0.05)**
	Girls	1.10 (0.36)*	1.15 (0.04)	1.26 (0.05)	1.29 (0.06)	1.37 (0.07)	1.44 (0.05)	1.45 (0.05)**	1.57 (0.06)*	1.57 (0.05)	1.66 (0.07)	1.68 (0.5)**	1.68 (0.06)**	1.70 (0.08)**

[a] Mean values (SD) are calculated for weight (kg) and height (m). Significant differences indicated at $*P \leq 0.05$ and $**P \leq 0.01$.



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Sum total [N]
60
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140
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180
200
220
Age [mnth]