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Reference Values of Isometric Trunk Muscle Strength in School Age Children using a Hand Held Dynamometer: A cross- sectional study

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Abstract

Aims: To establish isometric muscle strength reference values for trunk flexors, trunk extensors, trunk lateral flexors and trunk rotators by using a hand held dynamometer in 6 to 12 years of age children.

Methodology: In thiscross-sectional study a total number of 280 children in the age group of 6 to 12 years, with 140 from each gender, were recruited for measuring the trunk muscle strength values using a baseline hand-held dynamometer.

Major findings: The reference values of the trunk flexors, trunk extensors, trunk lateral flexors and trunk rotators were established. It was observed that the height and weight of the children proportionately increased from 6 to 12 years with a few exceptions between 10-12 years in both boys and girls.

Conclusion: The normal mean value of isometric trunk muscle strength using a hand-held dynamometer ranged from 23.53N to 137.58N, in children 6 to 12 years of age. In girls it ranged from 23.53N to 121.03N whereas in boys from 41.40N to 137.58N.

Keywords: Normative data; Typically developing; Muscle power; Pediatric population; Dynamometer.

Muscle strength is defined as the force exerted by a muscle or a group of muscles to overcome a resistance in one maximal effort.[1] Muscle strength is associated with functional performance, work productivity and the efficiency of the movement. The trunk forms an intermediate segment connecting the upper and the lower parts of the body and it is the place where the kinetic chains come together. The trunk is the foundation for posture, balance, and coordinated movement all of which areimportant for maintaining spinal stability. This ability to support the body is dependent upon appropriate trunk muscle strength.[2]

The trunk muscles are comprised of the flexors, extensors, lateral flexors and rotators. Thesemuscles are chiefly responsible for moving or controlling the trunk because of their mechanical arrangement and multiple segmental innervations. They have a peculiar property of contracting in part and not just as a whole, thus making possible the enormous variety of trunk movements and postures. The function of the trunk muscles is an essential factor for the balance, gait, transfers, and the wide range of activities performed in daily living.[2]

Skeletal muscle strength is a key feature of childhood and adolescenceand is a fundamental parameter of the motor system which is very often tested during neurological examination in children.[3] Muscle strength assessmentsprovide important clinical

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information about any weakness that may relate to functional limitations. Clinical decisions on the management of patients who have sustained musculoskeletal or neurological injuries or patients recovering from surgery are taken after assessing muscle strength.[4] It is therefore important to have a reliable method for the assessment of muscle strength. There are different methods by which trunk muscle strength can be measured. These include manual muscle testing and testing using Isokinetic dynamometer or a hand-held dynamometer. [4,5]

Manual muscle testing remains a conventional method of measuring muscle strength because it has some drawbacks. The shortcomings encountered by MMT can be overcome by using a hand-held dynamometer. The hand held dynamometer is a battery-operated device consisting of strain gauges that records the force in newton's/pounds/ kilograms.[5] It has gained popularity as a tool to measure muscle force production in clinical settings and these measurements have been found to co-relate with the isokinetic strength scores.[6]The isokinetic dynamometer measures muscle strength as well as torque throughout the range of motion. However, the length of time needed to perform the testing procedure, complicated use; high cost and decreased portability of the unit usually preclude its use in pediatric settings.[5,6]

Hand-held dynamometry seems to be a good alternative. Most clinically important muscle groups can be measured easily with a dynamometer. The Baseline™ digital hand-held dynamometer offers an objective, portable and relatively inexpensive method to quantify the muscle strength. Usually it weighs less than 2 pounds, requires no setup and can be used in many kind of environment. [6] It is a reliable and valid method of obtaining muscle force measurements in adults and children. [7]

Objective measurements of muscle strength can provide the therapist with information about muscle performance and are used when making a diagnosis, developing goals and treatment plans, assessing the effects of therapeutic and surgical interventions or assessing change in longitudinal studies and clinical trials. By measuring the strength accuratelyone can examine the effect of muscle weakness on function. This information may assist the therapist in early identification of loss of strength before functional failure is observed.[8]

To determine whether pathological muscle weakness is present or develops during the course of a disease reference values for maximum isometric muscle force are needed. Though there have been studies on the limb musculature strength in the adult as well as in the pediatric population using the hand-held dynamometer, there was no retrievable data for trunk muscle strength in the pediatric population.

To establish isometric muscle strength reference values fortrunk flexors, trunkextensors,trunk lateral flexors and trunkrotators by using the hand-held dynamometer in children betweensix and twelve years of age.

Methodology

In thiscross-sectional studya total number of 280 children in the age group 6-12 years, 140 from each gender were recruited from two schools of Mangalore city.The children were grouped age wise: 6, 7, 8, 9, 10,11and12 years. 40 children constituted a sub group with equal representation from both genders. There were seven such subgroups.

Only children, 6-12 years of age possessing unrestricted ranges of motion at the thoracic as well as the lumbar spine, were included in the study.Children with following abnormalities were excluded from the study: a history of any neurological, musculoskeletal, cardiovascular and systemic problems; a history of injury to the spine and the pelvis.Any history of surgery confined to the thoracic, lumbar or abdominal region and children on medication like antiepileptics and muscle relaxants.

The tester is a qualified physical therapist and instruments used area baseline push-pull digital dynamometer.(Fig 1), measuring tape, a weighing machine, a couch, straps for stabilization and a sponge pad.

The children's age (in years) from the date of birth mentioned in the admission certificate/ school register; their weight in Kilograms (kg) using a weighing machine; and height, measured in centimeters (cm) using a height

Figure 1: Measurement of trunk flexors muscle strength

The protocol of the study was approved by the scientific committee and time-bound research ethics committee. Permission from the Block Education Officer (BEO) was taken and a list of schools was obtained.

From the list of schools available, two schools were selected by random sampling using a random number table. Permission was taken from the school authorities to carry out the study. The classes where the target population is located were identified and children were selected by random sampling using the lotterymethodand initial screening for inclusion andexclusion criteria was carried out. A health questionnaire, along with a consent and assent form,was given to the children for the approval of their parentsthe selected children were explained in brief regarding the study. After the children had given assent and theirparents' consent the whole test procedure and the purpose of the study was explained in detail to the children.

scale were carefully documented. Strength measurements were taken by a Baseline™ digital push-pull hand held dynamometer (Digital-LCD,Hydraulic, New York,500 lb. =2224.11N.) for trunk flexors, trunk extensors, trunk lateral flexors and trunk rotators.A detailed explanation of the muscle to be tested, the starting position, the placement of the dynamometer and the test procedure are given in table no .1

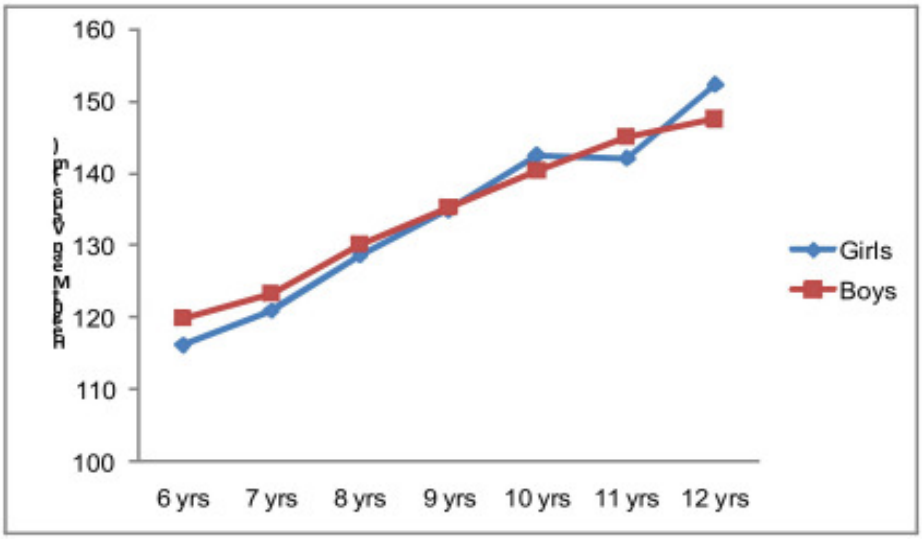
The muscle groups were tested in random and no specific sequence was followed. During the testing, verbal commands like "push as hard as you can" were given to the children in order to obtain a maximal effort.

The children were asked to do three trials for each group of trunk muscle and the mean of the three was taken into consideration. Five-second muscle contraction durations were used to allow the children to gradually achieve maximum force. A rest period of 1 minute was used in between the trials.

Table 1: Trunk muscle strength measurement

Muscle to be tested	Starting position	Placement of the dynamometer	Test procedure
Trunk flexors	Child was in supine lying position on the couch with his hands placed behind neck, with the hip and the knee joints extended.	Just below the sternomanubrialsymphysis.	The child performed trunk flexion and was asked to push the base of the dynamometer with maximum force and hold it for 5 seconds.
Trunk extensors	The child was in prone lying position with hands on the side of the couch.	Posteriorly at the T4 spinous process level.	The child performed trunk extension and was asked to push the base of the dynamometer with maximum force and hold it for 5 seconds.[10]
Trunk lateral flexors	Child was inside lying position on the couch.	Under the arm on the rib cage	The Child performed side flexion and was asked to push the base of the dynamometer with maximum force and hold it for 5 seconds.
Trunk rotators	Child was in supine lying position on the couch.	On the bulk of the Pectoralis major muscle	The child was asked to perform rotation and push the base of the dynamometer with maximum force and hold it for 5 seconds.

Figure 2: Gender wise comparision of mean values of height with age



Data Analysis

The Statistical Package for Social Science (SPSS) Version 16.0 was used for analysis.Descriptive statistics were obtained for normal values of trunk muscle strength for trunk flexors, trunk extensors, trunk lateral flexors and trunk rotators for all age groups with a 95% confidence interval established based on mean and standard deviation (SD).

Results

The aim of the current study was to establish isometric muscle strength normative data for trunk flexors, trunk extensors, trunk lateral flexors and trunk rotators by using a hand-held dynamometer. A total of 280 children, 140 boys and 140 girls from the age of 6 to 12 years were tested and the normative scores for both were obtained. The demographic data such as age, gender, height and weight were obtained. The mean and standard deviation of each gender and the total children are shown in Table 2.

Table 2: Demographic data with Mean and Standard Deviation of Height and Weight of both the Genders

AGE	GENDER	HEIGHT(cm) (MEAN±SD)	WEIGHT(kg) (MEAN±SD)
6	Girls-20	116.20 ± 4.37	20.47 ± 3.36
	Boys-20	119.00 ± 7.18	20.50 ± 4.86
	Total-40	118.00 ± 6.61	20.48 ± 4.12
7	Girls -20	120.90 ± 5.66	21.35 ± 3.97
	Boys -20	123.35 + 5.20	21.30 + 2.43
	Total-40	122.13 ± 5.51	21.32 ± 3.25
8	Girls-20	128.65 ± 4.66	25.90 ± 6.40
	Boys-20	130.20 ± 5.72	26.55 ± 5.47
	Total-40	129.43 ± 5.21	26.22 ± 5.89
9	Girls-20	135.00 ± 6.80	32.50 ± 9.28
	Boys-20	135.35 ± 6.63	29.95 ± 7.68
	Total-40	135.18 + 6.63	31.22 + 8.51
10	Girls-20	142.60 ± 7.05	33.65 ± 6.74
	Boys-20	14O.40 ± 4.33	37.00 ± 7.30
	Total-40	141.50 ± 5.88	35.32 ± 7.14
11	Girls-20	142.10 ± 6.60	32.80 ± 6.09
	Boys-20	145.15 + 5.65	33 .00 + 7.18
	Total-40	143.63 ± 6.26	32.90 ± 6.57
12	Girls-20	152.45 ± 6.68	42.35 ± 7.30
	Boys-20	147.60 ± 6.59	39.80 ± 9.43
	Total-40	150.03 ± 7.00	41.07 ± 8.42

Height and weight increases withage. In girls height seems to level off at the age of 10 and 11 years whereas in boys there is a linear increase in the height as the age advances until 12 years (Graph 1). There is a linear increase in the weight of both the genders except at the age of 11 years where there is decrease in the weight of both the genders(Graph 2) (Table 2).

The reference values of the trunk flexors, trunk extensors, trunk lateral flexors and trunk rotators were established. The mean, standard deviation and the range of these values are given in Table no. 3-5.The trunk muscle strength values ranged from 23.53N to 121.03N in girls, and 41.40N to 137.58N in boys.

Discussion

The purpose of the present study was to provide the isometric trunk muscle strength reference values for children 6-12 years of age using a hand-held dynamometer.These values can be used to quantify possible muscle weakness in children or to monitor the effects of therapy.[9]

According to our previous exposure of various dynamometers we found this base line digital hand held dynamometer was easier to handle, reliable and valid tool to measure the muscle strength. In our present study we found that children are more enthusiastic and competitive with the other children to know their muscle strength values. This was a positive factor to complete the study more easily.

Most of the previous studies have reported isometric strength values for upper limb and lower limb muscles using the hand-held dynamometer. [9-13]However, there are no studies retrieved on trunk muscles normative valuesusing the hand-held dynamometer. The present study gives reference values for the trunk muscle strength in 6-12 years age group for both the genders. This ranged from 23.53N to 121.03N in girls and 41.40N to 137.58N in boyswith a 95 % confidence interval. The upper extremity muscle strength values ranged from 67.96N to 171.96N in girls and 72.99N to 141.98N in boys whereas lower limb muscle strength values ranged from 84.96N to 264.98N in girls and 75.97N to 267.96N in boys.[9-13]

The previous studies done on upper limb and lower limb muscle strengths involved smaller sample size with arange between 41-131 children. Also the number of children in each gender (9-11) was reported to be less.[9-13]By contrast the presentstudy involves a

Figure 3: Gender wise comparision of mean values of weight with age.

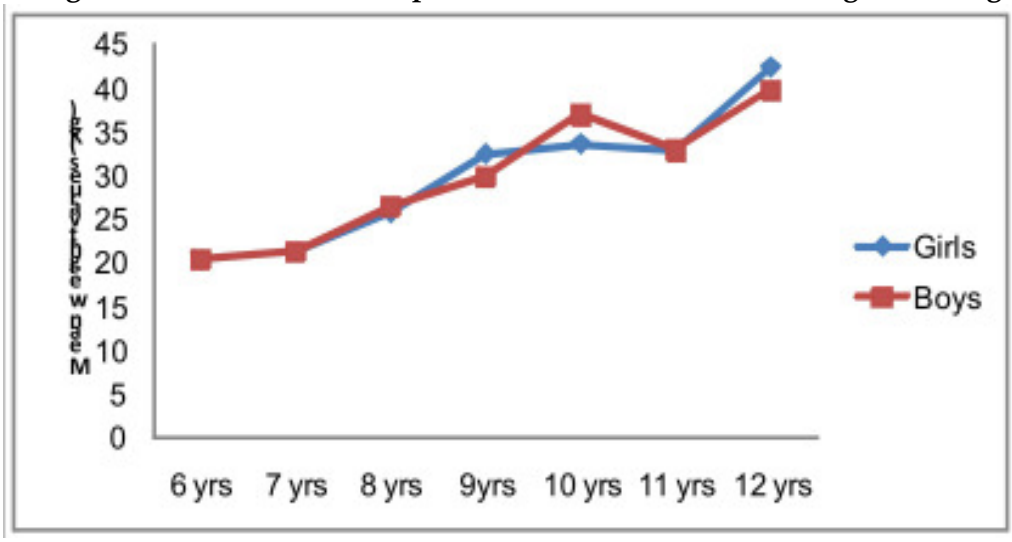


Table 3: Reference values of trunk flexors and extensorsmusclestrength in newtonswith Mean, SD and Range for both the Genders.

TM	Gender		AGE						
			6	7	8	9	10	11	12
T F	G	M± SD	26.24±7.56	40.92±6.67	52.49±9.34	68.50±10.68	91.19±13.79	95.64±18.68	81.85±29.36
		R	22.69-29.80	37.81-44.04	48.04-56.94	63.61-73.40	84.96-97.42	87.19-104.53	68.06-95.64
	B	M±SD	41.81+5.78	46.71+8.01	50.26+15.57	67.61+10.23	84.96+24.91	97.42+16.90	126.33+23.13
		R	39.14-44.04	43.15-50.71	43.15-57.38	63.16-72.51	73.40-96.53	89.85-105.87	115.65-137.01
	T	M± SD	33.81+10.23	44.04+7.56	51.60+12.90	68.06+10.23	88.52+20.02	96.97+17.35	104.09+34.70
		R	30.25-37.37	41.37-46.26	47.15-55.60	64.94-71.17	81.40-94.30	91.19-102.31	92.97-115.21
T E	G	M± SD	55.16±13.79	71.62±11.12	87.63±8.45	92.08±14.23	108.09±17.35	120.99±15.57	119.66±24.91
		R	48.49-61.39	65.83-76.51	83.18-91.19	84.96-98.75	99.64-116.10	113.43-128.11	108.09-131.22
	B	M± SD	66.28±8.45	73.40±10.68	82.74±16.01	99.64±12.90	104.98±26.69	120.55±20.91	137.45±131.22
		R	60.50-68.50	68.06-78.29	75.17-89.85	94.30-104.09	92.08-117.43	110.32-129.89	123.22-151.68
	T	M± SD	60.05+12.01	74.29+10.68	84.96+12.90	95.64+12.90	106.31+22.69	120.55+18.24	128.55+28.91
		R	56.05-63.61	68.50-75.62	80.51-88.96	91.63-99.64	99.20-113.43	114.76-126.33	119.21-134.34

Where, TM=Trunk Muscles, TF = Trunk Flexors, TE= Trunk Extensors, G=Girls, B=Boys, T = Total, M= Mean SD= Standard Deviation, R= Range.

sample size of 280 children and the number of children in each gender is 20 each. This large sample size gives strength to the present study.

As seen in the present study, boys were taller and heavier than the girls, except in some age groups. Girls are taller than the boys in the age group of 12 years whereas boys are heavier than the girls except at age 9 and 12 years. This earlier growth acceleration in girls is likely to be caused by the early onset of puberty.Timing of puberty has a wide variability. In girls from 8 to 12 years and in boys from 9 to 14 years. Girls attain puberty earlier as compared to boys. This leads to earlier increase in the growth parameters.[14] Therefore it is hypothesized to cause fluctuations in the height and weight in the 9-12 years age group.

The results of the present study showed that trunk strength increase with age. It was observed that in thegirls there was increase in the flexor and extensor muscle strength from 6-11 years age, but there was decrease in the strength in the 12 year age group. However for the trunk lateral flexors andtrunk rotators there was an increase in the muscle strength in the 6- 12 year age group. This may be because of the greater amount of fat deposition in the abdominal region as well as in the breast tissue leading to an increase in trunk weightwhich might have altered the trunk flexor and extensor strength measurements.[15]

In boys, trunk flexors and trunk extensors muscle strength was found to increase progressively from 6-12 years.But in the case of trunk lateral flexors and trunk rotatorsthe

Table 4: Reference values of trunk lateral flexors muscle strength in newtons with Mean, SD and Range for both the Genders.

TM	Gender		AGE						
			6	7	8	9	10	11	12
L F (RT)	G	M± SD	24.47±7.12	44.48±3.56	50.26±8.45	52.04±10.68	54.71±20.91	76.51±16.90	67.17±20.46
		R	20.91-27.58	43.15-46.26	46.26-54.27	47.15-56.94	45.82-64.05	68.50-84.52	57.38-76.51
	B	M± SD	42.26±4.00	46.26±7.56	47.15±14.68	59.61±7.56	55.16±19.57	72.51±26.24	92.52±24.91
		R	40.48-44.04	42.70-49.82	40.03-53.82	56.05-63.16	46.26-64.50	60.05-84.96	80.96-04.09
	T	M,± SD	33.36±10.68	45.37±5.78	48.49±12.01	56.05±9.79	55.16±19.13	74.73±21.80	79.62±25.80
		R	29.80-36.48	43.59-47.60	44.93-52.49	52.49-59.16	48.93-61.39	67.61-81.40	71.62-88.07
L F (LT)	G	M± SD	23.58±6.67	41.81±5.78	48.49±8.45	47.60±12.90	51.60±19.13	75.62±16.46	63.61±20.91
		R	20.46-26.24	39.14-44.48	44.93-52.93	41.81-57.38	42.70-60.94	68.06-83.18	93.86-73.40
	B	M± SD	37.37+3.11	41.81+8.90	44.48+12.90	55.16+8.90	50.71+20.02	66.72+21.80	87.63+25.35
		R	36.03-39.14	37.37-45.82	38.70-50.71	51.15-59.61	41.81-60.05	56.49-76.95	75.62-99.20
	T	M±, SD	30.69±8.45	41.81±7.56	46.71±11.12	51.60±11.57	51.15±19.13	71.17±19.57	75.17±25.80
		R	27.58-33.36	39.59-44.04	43.15-50.26	48.04-55.16	45.37-57.38	64.94-77.40	67.17-84.07

Where, TM=Trunk Muscles, LF = Lateral Flexors, Rt = Right,Lt = Left, G=Girls B=Boys, T = Total, M= Mean, SD= Standard Deviation, R= Ran

Table 5: Reference values of trunk rotators muscle strength in newtons with Mean, SD and Range for both the Genders

TM	Gender		AGE						
			6	7	8	9	10	11	12
ROT (RT)	G	M± SD	48.04±7.56	52.49±8.90	52.93±12.01	69.39±11.12	75.62±22.69	89.41±20.91	78.29±28.91
		R	44.48-51.60	48.49-56.94	47.60-58.72	64.05-74.73	65.39-86.30	79.18-99.20	65.39-92.08
	B	M± SD	48.49+9.79	52.93+11.57	57.38+15.12	70.28+11.57	81.85+20.46	93.86+25.80	110.76+28.47
		R	44.04-52.93	48.04-58.72	50.71-64.94	64.94-75.62	72.06-91.19	81.85-105.87	97.42-124.11
	T	M± SD	48.04+8.45	52.93+10.23	55.16+13.79	69.84+11.12	78.73+21.35	91.63+23.58	94.75+32.92
		R	45.37-51.15	49.82-56.49	51.15-59.61	66.28-73.40	72.06-85.85	84.07-98.75	84.07-105.42
R OT(LT)	G	M± SD	44.04±7.12	49.82±8.01	47.60±12.01	65.83±12.46	72.06±23.58	84.07±21.80	73.40±30.25
		R	40.92-47.60	46.26-53.82	41.81-52.93	60.05-71.17	61.39-83.18	74.29-94.30	59.61-87.63
	B	M ± SD	45.82±8.45	51.60±12.90	53.38±16.01	66.28±12.01	72.95±23.58	89.41±24.91	105.87±31.58
		R	41.81-49.82	45.82-57.38	46.26-60.94	60.94-72.06	61.83-84.07	77.84-100.97	91.19-120.55
	T	M± SD	44.93±8.01	50.71±10.68	50.71±14.23	65.83±12.01	72.51±23.58	86.74±23.13	89.85±34.70
		R	42.70-47.60	47.60-54.27	45.82-55.16	61.83-69.84	64.94-79.62	79.62-94.30	78.73-100.53

Where, ROT = Rotators, Rt = Right, Lt = Left, G=Girls B=Boys, T = Total, M= Mean SD= Standard Deviation, R= Range.

trunk strength increased from 6-11 years age but decreased in the 12 year age group. Normal developmental changes in ligament and musclefiber elasticity and increased resistance to the trunk motions may contribute to the increased stiffness of the soft tissues across these age groups. Skeletal maturationmilestones are achieved during the same time period. Primary ossification of the lumbar spine is completedbetween seven and nine years of age and mature lumbar facet orientation is achieved by approximately 11 years of age. Trunk lateral flexion and rotation are greater in younger children because of the frontal orientation of the facets, but as age advances the facets gradually achieve sagittal orientation constraining these movements of the trunk. This decreased range of motion and changes in the facet orientation might have decreased the child's performance at 12 years of age as observed during this study.[16]Boys were found to be stronger thangirls in all the age groups under study.

The clinical Implication of the study is that the normative data of the trunk muscle strength established can be used to quantify patterns of muscle weakness or to evaluate the possible effects of therapy in children suffering from any disease that affects the muscle strength.

The limitationsof the study include the following; children who participated in the study lived within similar geographic location; thetherapist was not blinded while reading the

measurements during the study due to manpower constraints; andthe present study determined muscle strength in terms of force values rather than torque values of the muscle strength.

This data will form the basis for future studies on trunk muscle strength in different geographical locations and it can be used as standard reference values in future studies performed on trunk muscle strength in affected children. Studies can be performed to establish reference values of trunk muscles strength in children using isokinetic dynamometers, with an independent observer.

Conclusion

The normal mean value of isometric trunk muscle strength using a hand-held dynamometer ranged from 23.53N to 137.58N, in children 6 to 12 years of age. In girls it ranged from 23.53N to 121.03N whereas in boys from 41.40N to 137.58N.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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