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BRIEF COMMUNICATION

Anthropometric measurement standardization for a multicenter nutrition survey in children with spinal muscular atrophy

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Abstract

Spinal muscular atrophy (SMA) is a neuromuscular disease associated with nutritional status derangement and altered body composition. New drugs are changing the natural history of the disease, so now more than ever is important to focus on the correct assessment of nutritional status in SMA. We implemented a standardization process for the anthropometric measurement as part of our ongoing longitudinal study of growth patterns in SMA patients. It features a procedural manual, included in this communication, observers training and reliability assessment, of which we publish the values obtained in our pilot study. The standardization process was able to produce inter-observer reliability values in agreement with the literature and a procedure manual is now available for multicentre studies of nutritional status and body composition in SMA and possibly other pediatric neuromuscular disorders.

Introduction

Spinal muscular atrophy (SMA) is a rare and severe neuromuscular disease associated with feeding disorders [1], changes in energy metabolism and impairment of nutritional status [2]. The recent advent of new drugs and clinical trials for SMA are changing the natural history of the disease [1], so now more than ever is important to focus on the correct assessment of nutritional status in SMA patients.

Body composition assessment is paramount to the assessment of nutritional status, and, despite the challenges that it poses, anthropometry is still the most widely used method in the clinical setting. Indeed, there is a lack of literature on standardized procedures suitable for neuromuscular or SMA patients and, due to the rarity of the disease, data collection needs to be carried out by multiple centers and observers, introducing sources of error.

To longitudinally evaluate body composition in SMA children, we started a four center study supported by the Telethon Onlus Foundation (GUP15014), for which we implemented a standardization process for the collection of anthropometric measurement. This communication describes the standardization process and the reliability values obtained.

Materials and methods

Study design

The first step in designing the standardization process was to create a procedural manual for the anthropometric measurements. Based on this manual, a two-day workshop was held to provide a training and standardization setting for the five observers involved in the study, Then, the reliability of the anthropometric measurements was calculated.

The pilot study was approved by the Institution Review Board (Ethic Committee of University of Milan n.7/16) and

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Table 1 Inter-observer TEM, %TEM, and R

	TEM	%TEM	R
Recumbent length (cm)	2.5	2.3	0.963
Segmental lengths (cm)			
Arm length	1.7	7.0	0.830
Femur length	0.9	3.8	0.977
Circumferences (cm)			
Arm circumference	0.6	3.5	0.899
Thigh circumference	0.8	2.5	0.980
Waist circumference	0.6	1.2	0.986
Skinfold thicknesses (mm)			
Biceps skinfold	1.9	25.8	0.721
Triceps skinfold	1.7	14.5	0.917
Subscapular skinfold	1.1	14.4	0.898
Suprailiac skinfold	2.1	18.4	0.929
Anterior thigh skinfold	2.6	12.0	0.952

TEM technical error of measurement, *%TEM* relative technical error of measurement, *R* coefficient of reliability

complies with the Helsinki declaration tenets. Before the study, the parents of the children gave their written informed consent.

Anthropometric manual and anthropometric procedures

The procedures to be included in the manual (Annex A) had to be relevant to the description of body composition and growth of the pediatric patient, but also had to be suitable for use in SMA patients, taking into consideration their reduced muscle mass and tone, muscle contractions, inability to stand, scoliosis, other bone deformities. These procedures are based on those found in other established anthropometric manuals [3–6] and also in approaches previously used in studies of SMA patients [7] or other neuromuscular diseases [8]. Included in the manual are the technical specifications for the instruments needed and the technical procedures to be used for each anthropometric measurement.

Training of anthropometry personnel and error assessment

The first day of the training workshop consisted of a theoretical and practical session in which the techniques included in the manual were presented by the lead anthropometrist and tested by all the observers. The second day was used to assess inter-observer reliability, through the collection of a complete set of measurements on children affected by SMA, measured by each observer once.

Accuracy was assessed computing coefficient of reliability (R) between each observer and the lead anthropometrist. Observers with a mean R below 0.9 were scheduled for retraining. Inter-observer reliability was assessed computing technical error of measurement (TEM), relative TEM (%TEM), and R values. [9]

Results

Six children (2 boys and 4 girls, 3 healthy and 3 SMA type 2, aged 2–7 years) were measured. After training workshop, 2 of the observers tested displayed acceptable accuracy, whereas 2 required retraining (mean R values for the 4 observers: 0.932, 0.837, 0.915, 0.789). Table 1 shows the inter-observer TEM, %TEM and R for recumbent length, segmental lengths, circumferences and skinfold thickness. Concerning lengths, TEM but not %TEM for recumbent length was higher than TEM for segmental lengths. Arm length had a low R among all measurements. For circumferences, TEMs were lower than 1 cm and R above ~0.9, with arm circumference recording relatively lower values. For skinfold thickness, %TEM was higher compared with other measurements, but R was above ~0.9 except for biceps skinfold which was the worst performer of all measurements.

Discussion

Due to severity and rarity of the disease, a mixed sample of healthy and SMA children was enrolled. In our sample, there were no significant differences in %TEM of the measurement performed (mean for healthy and SMA 9.1% and 7.4%, p-value 0.605), indicating that there was no difference in measurement reliability between healthy and SMA children.

Recumbent length displayed higher TEM than other length measurements but relating measurement error to measurement size through %TEM, recumbent length displayed the lowest value. SMA complicating features prevent the use of a length board to measure recumbent length, thus a composite measure was used, with possible cumulative errors for each segment.

A relative low R value was obtained for arm length, which midpoint is used as a reference point for arm circumference and biceps skinfold. As there were no differences in %TEM values between healthy and SMA children, low R values in these measurements is possibly due to difficulties in the procedure when applied on a supine patient (arm length is measured on the posterior surface of the arm).

We recorded relatively high %TEMs measuring skinfold thickness, but the absolute values of TEMs were still small relative to instrument accuracy (max TEM was 2.6 mm).

Aside from the above reported difficulties, this study shows that high R values can be sought in SMA, but a two-day workshop may be sufficient only in some observers. Concerning the limitations of this study, differences in reliability between healthy and SMA children should be assessed on a larger sample and intra-observer reliability should be assessed in addition to inter-observer reliability. The assessment of nutritional status in SMA patients is currently a topic of interest to evaluate the effects of new therapies on body composition and its role in improving motor function. Anthropometry can be a useful tool for large multicenter studies, but gold standard methods (the 4-compartment model and whole-body magnetic resonance imaging) will also be needed to validate reference and field methods in SMA. Careful consideration of every aspect of the data-collection process should lead the operator to avoid common sources of measurement error and this standardization process could be a useful tool for multicenter studies aiming to fill the gaps in the knowledge of nutritional status of SMA.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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OF NUTRITIONAL STATUS

TELETHON - GUP15014

Observational longitudinal study of growth patterns, body composition, energy expenditure and dietary intake in Italian infants and children with Spinal Muscular Atrophy type I and II

Anthropometry Procedures Manual

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Instruments, Rounding and Measurement side

Scale

A digital platform scale with a tare button large enough to accommodate an electric wheelchair is recommended. [3]

A wheelchair scale is required to safely weigh those children who cannot stand or sit alone. Moreover, a digital scale with tare function simplifies net weight calculations, avoiding input errors.

Tape

A non-extendible but flexible tape calibrated with millimeter gradations is recommended. It is also important that the tape is no wider than 0.7 cm, especially in pediatric patients. If the tape has a spring-retractable mechanism, it should be used with the tape fully extended. [7]

In addition to assessing lengths and circumferences, the tape is required to accurately locate several skinfold sites. The tape should not be extendible so as not to alter the measurement under stretching force and should not be wide enough to prevent accuracy and reliability in tight spaces (eg. wrist).

Many tapes have a spring-retractable mechanism that is activated by pressing a button. In measuring a circumference with this type of tape, the tape should be held so that the retraction spring tension of the tape does not affect the measurement. Some other types of tape are designed so that the tension of a spring necessarily affects the measurement; these tapes are not recommended for the measurement of circumferences for which tension should be minimal.

Skinfold caliper

Good calipers, accurate to 0.1 mm (a dial graduation of 0.2 mm is sufficient), with suitable jaw faces to exert constant pressure should be used. We recommend the use of Holtain T/W Skinfold Caliper as it has high accuracy and produce reliable results. [9, 10]

Calipers can differ in many ways (dial accuracy, surface area of jaw faces, pressure exerted at the jaw faces) and in performance. It is important to always use the same type of caliper for every measurement, and to use a brand that can guarantees high accuracy and consistency among the different units.

Rounding

Taking the measurement value for:

- Weight: to the nearest 0.1 kg.
- Circumference: to the nearest 0.1 cm.
- Skinfold: to the nearest 0.1 mm.
- Length: to the nearest 0.5 cm.

Rounding rules were set on the basis of the level of accuracy commonly found in scales, tapes and calipers. [2, 3, 4] The lack of clear edges in the measurement of length prevents a level of accuracy above 0.5 cm, nevertheless it is advisable to use a tape with markings every 0.1 cm. [5]

Measurement side

If possible, measurements should be taken on the left side of the body. Only take measurements on the right side when the patient has a physical disability or abnormality on the left side; has a cast, prosthesis, or amputation on the appropriate left limb; or for some other reason the measurement cannot be taken on the left side. [1, 8]

There are reported asymmetries between the right and left side of the body in prepubertal children, but they are lower than the technical error of measurement. It is still important to standardize measurement side in order to reduce imprecision between two measurements.

Weight and Recumbent length

Weight

Preparation for weighing. Remove outer clothing, diapers and removable medical appliances. If these conditions cannot be met be sure to record it in the data collection form.

Tared weighing. Patients who cannot stand alone on the scale will be weighed with the assistance of an adult. The guardian will stand alone on the scale while the examiner clicks the tare button on the scale. This sets the scale readout to zero. The child is then handed to the adult on the scale. In this way the scale will read only the child's weight. Record the result. [1, 2, 3]

- The same procedure can be followed with a platform scale suited to weigh patients in a wheelchair.
- If a scale with a tare button is not available, the examiner can subtract the weight of the adult from the weight of the adult bearing the patient.

Recumbent length

Position the patient supine on the exam table with the spine, hip joint, and knee joint straightened as much as possible. Recumbent length will be measured in segments using a straight edge from the top of the head to the greater trochanter of the hip, from the hip to the femoral epicondyle of the knee, and from the knee to the distal point of the calcaneus. To identify the top of the head a vertical headboard should be used and the tape should be positioned on a line parallel to the sagittal plane, passing through the greater trochanter of the hip. Record the sum of the segments. [5]

Segmental Lengths

Segmental lengths will be measured with a tape directly in contact with the segment being measured. No projected measurements are to be used.

Arm length

Locate the end of the spine of the scapula by following the scapula out to the arm until it makes a sharp V-turn to the front of the body. Hold the zero end of the measuring tape at this mark and extend the tape down the posterior surface of the arm to the tip of the olecranon, the bony part of the mid-elbow. The tape must be centered on the posterior surface of the arm. Record the result. [1, 2, 3, 4]

- Make a horizontal mark at the midpoint and cross this mark with a perpendicular line. This mark defines the site at which the arm circumference will be measured.

Ulna length

With the elbow bent at 90°, find the proximal end of the ulna by palpating along its length. The tip of the styloid process can be felt at the wrist by palpating down the length of the bone distally until its end is felt. Hold the zero end of the measuring tape at the proximal end of the ulna and extend the tape down to the distal end. Record the result. [3, 6]

Femur length

Mark the proximal border of the patella on the anterior surface of the thigh. Place the zero end of the measuring tape at the inguinal crease, just below the anterior superior iliac spine. Starting from the inguinal crease, extend the tape down the anterior midline of the thigh to the mark at the patella. Record the result. [2, 3, 6]

- Make a horizontal mark at the midpoint and cross this mark with a perpendicular line. This mark defines the site at which the thigh circumference will be measured.

Tibia length

Place the zero end of the tape at the proximal end of the medial border of the tibia and extend the tape down to the distal tip of the medial malleolus. The tape is maintained parallel to the long axis of the tibia. Record the result. [3]

Circumferences

Circumferences should be recorded with the zero end of the tape held in one hand above the remaining part of the tape held by the other hand. Differences among observers in positioning the zero end of the tape can affect measurement reliability. [3]

The positioning of the tape for each specific circumference is important because inconsistent positioning reduces validity and reliability. For each circumference, the plane of the tape around the body is perpendicular to the long axis of that part of the body.

Also the tape tension applied by the measurer affects measurement validity and reliability. For head circumference, the tape is pulled tightly to compress the hair and soft tissue of the scalp. For all other circumferences, the tape is held snugly around the body part, but not tight enough to compress the subcutaneous adipose tissue. For these circumferences, the examiner should check to ensure that the tape is not indenting the skin. For some circumferences there may be gaps between the tape and the skin in some individuals. If the gap is large, a note should be made in the subject's record, but in most instances, this gap is small and of little concern. Attempting to reduce the gap by increasing the tension of the tape is not recommended.

Head circumference

Place the tape around the child’s head so that the tape lies across the frontal bone of the skull, slightly above the eyebrows and ears, and over the occipital prominence at the back of the head. Move the tape up and down over the back of the head to locate the maximal circumference. Tighten the insertion tape so that it fits snugly around the head and compresses the hair and underlying soft tissues. Record the result. [1, 2, 3]

Arm circumference

Arm circumference is measured at the midpoint of the upper arm marked during the measurement of arm length. Place the tape around the arm so that it is touching the skin, but not compressing the soft tissues. The tape is positioned perpendicular to the long axis of the arm at the marked midpoint. Record the result. [1, 2, 3. 4]

Make a horizontal mark using the tape as a ruler on the anterior aspect of the arm and cross this mark with a perpendicular line. This mark defines the site at which the biceps skinfold will be measured.

Wrist circumference

An inelastic tape is placed just distal to the styloid processes of the radius and ulna. The tape is positioned perpendicular to the long axis of the forearm and in the same plane on the anterior and posterior aspects of the wrist. The measurement is made with the tape touching the skin around the whole circumference but not compressing the soft tissues. Record the result. [3]

Waist circumference

Place the zero end of the measuring tape at the lower margin of the last palpable rib and extend the tape down the mid-axillary line to the top of the iliac crest (hip bone). Make a vertical mark at the midpoint and cross this mark with a perpendicular line. The tape is positioned perpendicular to the long axis of the trunk at the marked point, making sure to wrap the tape over the same spot on the opposite side. Make sure to keep the measuring tape snug but not tight enough to cause compression of the skin. The measurement should be taken at the end of a normal expiration. Record the result. [4]

Thigh circumference

The measuring tape is placed horizontally around the thigh midway between the midpoint of the inguinal crease and the proximal border of the patella. The measurement is made with the tape touching the skin around the whole circumference but not compressing the soft tissues. Record the result. [3, 4]

Calf circumference

An inelastic tape measure is positioned horizontally around the calf and moved up and down to locate the maximum circumference in a plane perpendicular to the long axis of the calf. The level is marked so that a calf skinfold can be measured at the same level. The maximum circumference is recorded with the tape in contact with the whole circumference but not indenting the skin. [3, 4]

Skinfolds

The thumb and index finger of one hand are used to elevate a double fold of skin and subcutaneous adipose tissue on a line perpendicular to the natural cleavage lines of the skin (Langer's lines) of the respective skinfold. To not affect the measurement, the skinfold is elevated about 1 cm proximal to the measurement site. Care must be exercised so that only skin and adipose tissue are elevated, especially with a patient who has reduced fat free mass and low muscle tone. [3, 4]

The measurement is made about 4 seconds after the pressure is released, with the caliper and measurer positioned so that errors due to parallax are avoided. If the caliper exerts force for longer than 4 seconds, a smaller measurement will be obtained because fluids will be forced out of the tissues. Timing in seconds is preferable to judgments based on the end of the rapid decrease in the measurement. If possible, the measurement should be repeated several times and the mean recorded. If the subcutaneous adipose tissue is soft and mobile it is possible that repeated measurements will yield progressively lower values, in that case the first measurement should be recorded.

Error due to skin thickness variations is small, but large errors can be caused by subcutaneous edema. If it is impossible to elevate a skinfold with parallel sides, or the skinfold is outside the maximum range of the caliper, a measurement is not made.

Biceps skinfold

Biceps skinfold thickness is measured as the thickness of a vertical fold raised on the anterior aspect of the arm, over the belly of the biceps muscle. The skinfold is raised 1 cm superior to the line marked for the measurement of triceps skinfold thickness and arm circumference, on a vertical line joining the anterior border of the acromion and the center of the antecubital fossa. The caliper jaws are applied at the marked level. Record the result. [3]

Triceps skinfold

The triceps skinfold is measured at the upper arm mid-point mark on the posterior surface of the arm. Using your thumb and index finger, grasp a fold of skin and subcutaneous adipose tissue approximately 1.0 cm above the mid-arm circumference mark. Place the tips of the caliper jaws over the complete skinfold. Wait 4 seconds for the needle on the caliper dial to settle on an accurate measurement. Record the result. [1, 2, 3, 4]

Subscapular skinfold

Mark a cross (+) on the inferior angle of the scapula. Make the first line at 45 degrees to the spine and cross this with a line that bisects the inferior angle of the scapula. Using your thumb and index finger, grasp a fold so that the index finger remains situated roughly 1.0 cm above and medial to the inferior angle of the scapula. With the other hand, set the top jaw of the caliper on the + mark. Wait 4 seconds for the needle on the caliper dial to settle on an accurate measurement. Record the result. [1, 2, 3, 4]

Suprailiac skinfold

The suprailiac skinfold is measured in the midaxillary line immediately superior to the iliac crest. An oblique skinfold is grasped just posterior to the midaxillary line following the natural cleavage lines of the skin. It is aligned inferomedially at 45° to the horizontal. The caliper jaws are applied about 1 cm from the fingers holding the skinfold. Wait 4 seconds for the needle on the caliper dial to settle on an accurate measurement. Record the result. [3, 4]

Anterior thigh skinfold

The thigh skinfold site is located in the midline of the anterior aspect of the thigh, midway between the inguinal crease and the proximal border of the patella. The caliper jaws are applied about 1 cm distal to the fingers holding the fold. Wait 4 seconds for the needle on the caliper dial to settle on an accurate measurement. Record the result. [3, 4]

Calf skinfold

The level of the maximum calf circumference is marked on the medial aspect of the calf. The examiner raises a skinfold parallel to the long axis of the calf on its medial aspect, when viewed from the front. The caliper jaws are applied about 1 cm from the fingers holding the skinfold. Wait 4 seconds for the needle on the caliper dial to settle on an accurate measurement. Record the result. [3, 4]

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