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Anthropometric standards for Australian primary school children: towards a system for monitoring and supporting children’s development

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Abstract

Objectives: To provide two foundation elements of a proposed new system to support children’s physical and body status development throughout primary school: (a) age and gender appropriate achievement (anthropometric) standards and (b) a system of monitoring, feedback and support.

Design: Repeated cross-sectional sampling involving 91 schools across 5 Australian States and Territories between 2000 and 2011.

Methods: Anthropometric data from 29,928 (14,643 girls, 15,285 boys) Australian children aged between 5 and 12.5 years were used to develop progression standards (norm centiles) covering the primary school years. Measures used were: height, weight, body mass index, per cent body fat, grip strength, standing long jump, cardiorespiratory fitness, sit-ups and sit-and-reach. These norms were then used to develop a Physical Activity and Lifestyle Management (PALM) system that could form the basis for progression, monitoring and reporting of anthropometric achievement standards for children.

Results: Tables and representative centile curves (3rd, 15th, 50th, 85th and 97th) for each gender and half-year age group were produced. An illustrative example of the PALM system in operation was also provided.

Conclusions: Our research provides gender and half-year age specific anthropometric standards for Australian primary school children. Furthermore, we have developed a monitoring and progression system that could be embedded in school communities to help address the prevalence of underweight, overweight and obesity and decline in physical fitness standards. The proposed system is designed on behalf of children and families and would be administered through school settings. Change, where needed, would be delivered by the supporting school community.

Keywords: Childhood obesity; prevention; physical fitness; reference growth standards; performance standards; school community
**Introduction**

Developing and maintaining good levels of physical fitness, good diet and good body composition are considered important to children’s future health, well-being and contribution to society\(^1\)\(^2\). Yet there is compelling evidence that there has been a decline in fitness and physical activity levels\(^3\)\(^4\)\(^5\) and an increase in undesirable body composition in children over recent decades\(^6\)\(^7\). From a public health perspective, it is important to reverse these societal trends in order to forestall the adverse consequences of overweight or obesity and poor physical fitness. From an epidemiological perspective, it would be useful to have a system of monitoring and surveillance that would enable early detection of, and an earlier corrective response to, adverse changes than has been the case with the current so-called obesity pandemic and general population declines in physical conditioning.

The primary school years are important formative years in which children develop the knowledge, attitudes and behaviours that are carried through adolescence and into adult life\(^8\). It is important, therefore, that we support children in these early years and provide them with adequate opportunities to develop the physical abilities and social and psychological skills that will enable them to participate fully in and contribute constructively to society throughout life. Two important foundation elements of a well-designed system to provide such opportunities are: a set of age and gender appropriate achievement (anthropometric) standards and a system of monitoring, feedback and support such that as many children as possible are able to make good progress in all these measures throughout their primary school years. The objectives of this research were to provide these two foundation elements from a large sample of Australian primary school children.

**Methods**

The data were gathered using a repeated cross-sectional design as part of a wider evaluation of a service offered to Australian primary schools in the school years between 2000 and 2011.

The study included anthropometric data from 29,928 primary school children (14,643 girls, 15,285 boys) aged between 5 and 12.5 years from 91 different school settings. More detail on the sample and sampling process is provided in a previous publication\(^9\).
Anthropometric measures used were: height (cm), weight (kg), body mass index (BMI) (kg m$^{-2}$), per cent body fat (%), grip strength (kg), standing long jump (cm), cardiopulmonary fitness (20 m shuttle run score), sit-ups in 60 seconds (n) and sit-and-reach (cm). All measures have been shown to have adequate validity and good reliability for use in school settings$^{10,11}$. The measures were chosen because they give good coverage of the main body systems: body composition, lower limb function, upper limb function, cardio-respiratory fitness and core strength, flexibility and endurance.

Height was measured using a stadiometer (Surgical and Medical Products, Seven Hills, New South Wales, Australia) calibrated in 1 mm increments. Weight and per cent body fat were measured using Tanita TBF-522 electronic weight and body fat monitor scales. All weight and per cent body fat measures were concealed from the participants. Hand grip strength was measured bilaterally using a Jamar Digital Plus hand dynamometer and the mean of the two measures was used. Standing long jump was measured on a flat surface with a fixed strip of wood as a ‘toe’ starting line for the jump. Cardiorespiratory fitness was measured using the 20m multi-stage fitness test$^{12}$. In order to provide a quasi-continuous measure, the shuttle run score s:n was converted to the decimalised version s + n/l, where s represents the stage, n is the number of shuttles achieved and l is the number of shuttles in that stage. Sit-ups were measured with legs bent at ~90 degrees, feet flat on the floor, hands on thighs, fingers pointing along the thigh. Finally, sit-and-reach was measured with legs straight using a folding trunk flexibility tester box. Full details of the measurement protocols are provided in Supplement S2

Inter-observer reliability was assessed using two-way mixed, consistency, average-measures intra-class correlation (ICC) to assess the degree that observers were consistent in measurements across subjects. Blinded independent observations were made by two members from our small team of trained observers on a group made up of 51 children in total from 7 separate schools, visited on different days. Five measures were included: height, weight, BMI, per cent body fat and grip strength. Standing long jump, sit-ups in 60s, shuttle run and sit-and-reach were not included in this inter-observer reliability check because it was not possible to isolate observer variability from within child variability for these measures. The resulting ICCs ranged from 0.992 to 0.996, indicating that
negligible measurement error was introduced by the independent observers and that the statistical power to detect change across time would not be substantially reduced from this source of error.

Profiles for each measure were produced for girls and boys in the age range 5 to 12.5 years using the LMS method developed by Cole and Green\textsuperscript{13,14} using the LMS Chartmaker Light software available from Harlow Healthcare, UK\textsuperscript{15}. Measures that included negative or zero values were offset such that the smallest value was set at 0.1. The offset was removed in tables and plots to retain the original scaling.

The availability of an extensive database of objective measurements performed by a small team of trained independent observers provided the opportunity to develop a set of body status and physical performance ranges for gender and age groups that could form the basis of a monitoring and progression system for school age children. The system developed, which we have called here Physical Activity and Lifestyle Management (PALM) system, was similar in concept to the National Assessment Program – Literacy and Numeracy (NAPLAN), which is an annual national assessment for all students in Years 3, 5, 7, and 9 in Australia (http://www.nap.edu.au/information/faqs/naplan--general.html). Each child’s achievement standard on each measure was characterised on the basis of their comparator reference group, in this instance the child’s gender and half-year age group in the study database. For comparison, the school average and the population average were also provided.

Ethical approval for the research was granted by the regional Health Human Research Ethics Committee’s Low Risk Sub-Committee on 5th November 2014 (ETHLR14.264). Schools involved in collection of the original data gave their informed consent and all parents gave written informed consent for their children to take part. School administrators and class teachers assisted with the coordination of the various class groups. All assessors had appropriate ‘working with children’ checks, were qualified in fitness or had related tertiary qualifications and in-house training on the assessment protocols and appropriate behaviours when testing children. All data processed by the researchers carrying out the current analysis had been de-identified so that no individual child or participating school could be identified from any of the information available. However, each record
in the data file contained both a school linkage key and an individual child key so that the original commissioners of the research would be able to consider the findings in context and respond appropriately if necessary.

**Results**

The number of children in each gender and half-year age group and ranges for body status measures are shown in Table 1.

Table 1 near here

Ranges for the physical performance measures are shown in Table 2. These ranges formed the basis for the system for monitoring of anthropometric standards discussed further below.

Table 2 near here

Representative percentiles for body status and physical performance measures for boys and girls are summarised and discussed in Supplement S1.

The complete database was used to develop a prototype monitoring and progression system for use with children of primary school age. The data for each gender half-year age group were used to construct a set of scales for each measure against which individual child scores could be referenced in terms of both actual score and percentile ranking. The system is best illustrated by means of an example which is shown in Figure 1.

Figure 1 near here

In this example for a 12 year old boy, scores on five scales are reported: BMI, grip strength, cardiorespiratory fitness, sit-ups and standing long jump, representing a broad range of anthropometric characteristics. This boy is in the obese category and his general physical condition is poor – grip strength, fitness and long jump are much lower than his peers. Thus, some supportive action to improve scores would be recommended. An example of this is shown at bottom left of Figure 1a. For further reference, the scales for each measure also include the school and population averages (for this boy’s age and gender matched peers). For ease of use and clarity of understanding, the overall profile of Figure 1a would be accompanied by a summary Table outlining the child’s status in more detail as illustrated in Figure 1b. The focus of this information is on getting nutritional
intake about right and participating in a broad range of physical activities to improve or maintain
general musculoskeletal and cardiovascular conditioning. The information provided includes ranges
for each measure, the national (reference population) average and the school average and the
individual child’s score and percentile ranking relative to their age and gender matched peers. Each
score is also colour coded with the key categories as given in Figure 1b. The orange colour flags a
need for early supportive action to improve scores, while the red colour flags a more urgent need for
action and, perhaps, intervention.

Discussion
In response to the general decline in physical conditioning and increase in the prevalence of
overweight, a number of groups worldwide have developed test batteries and published norms for
school age children. Few, however, go on to consider how best to embed such a system within
school communities so that it could be used to support better opportunities for physical development
and improved eating behaviours in children and to monitor progression throughout the school years.
This was a key objective of our research.

Opportunities for children to be active have been lost from daily life. Parents, who in the past would
have been at home and able to oversee safe places for children to play and be active, now number
among the workforce. Neighbourhood streets, once the domain of pedestrians and playing children,
are now dominated by the car and considered unsafe for children to play in 2021. Active transport to
school has declined markedly.

On the other hand, the school setting has the potential to offer children a range of opportunities to be
active during the school day. Bassett et al. reviewed strategies for increasing physical activity in
children and adolescents and concluded that schools and communities can reach the 60-minute goal
for daily physical activity in several ways. Three primary ways: mandatory physical education (23
minutes), classroom physical activity breaks (19 minutes) and active transport to school (walk,
bicycle, scooter) (16 minutes) alone could provide 58 of the recommended 60 minutes per day. To
these we could add the opportunities offered by active recess.
The tests are relatively simple to perform and have good contextual validity. Inter-observer reliability in our study was very good. The majority of the fitness measures have also been linked to health outcomes. Thus it is reasonable to expect that improvements in general fitness would lead to better long term health outcomes in cardiovascular health, metabolic health, skeletal health and mental health. The increase in population levels of physical activity would also be likely to make a significant contribution to reducing the prevalence of overweight and obesity. The earlier the onset of monitoring and intervention the easier it is to reverse any excess build-up of body fat, raising the possibility of prevention of overweight and obesity.

Monitoring and communicating anthropometric standards in children is not without significant challenges and opposing points of view. The logical public health stance should be in favour of early detection and intervention so that more serious health problems may be mitigated or even prevented. Stubbs and Achat argue that ongoing population-based anthropometric measurement of children is fundamental to such efforts and we would support this point of view. Detractors on the other hand point out that such a system infringes individual rights and introduces potential harms for children such as negative labelling that may progress to stigmatization, poor self-concept, disordered eating, anxiety, depression or negative impact from parental concerns. The latter perspective is the dominant position in Australia and this has meant that childhood overweight and obesity has grown largely unchecked for at least the last 4 decades. Around a quarter of all children are significantly overweight by the time they leave primary school and, as of today, we appear to be unable to do anything much about this status quo. We have proposed previously that this societal norm needs to change. Fundamentally, we need to value a lifetime commitment to regular physical activity and maintaining healthy body weight more highly and to put in place systems that enable these behaviours to become the norm. The collection of timely, comprehensive, valid and reliable population anthropometric data is an important first stage in this process. However, the availability of such information alone is unlikely to be sufficient to achieve the societal shift required to reduce population levels of overweight and obesity. Nonetheless, knowing where we stand and having in place a system
of monitoring and feedback, as proposed here, would be valuable first steps in the process of change and would allow collective resources to be much more effectively and equitably targeted.

Further, we would advocate that the ‘system’ should be designed to ensure that children in their primary school years have sufficient opportunities to develop physically, socially and psychologically so that they are given the best possible start in life. Thus, we propose that the support system, of which monitoring and feedback is an important part, should be owned by and embedded in schools and their support communities. Where a need to re-balance the opportunities available to children, for example, to increase physical activity, to reduce opportunities to consume excess calories or to be sedentary, it becomes the responsibility of the support community to deliver this change, not just that of individual parents, who may not be in a position to deliver such change anyway.

Our proposed monitoring and progression system was designed with this objective in mind. Individual status measures would be fed back to parents or guardians only so that they know where their child stands in relation to their age and gender matched peers and, importantly, receive specific guidance and support (only if needed) on how they might help in their child’s development. However, schools and their communities would receive reports on where their cohorts of children stand in relation to other school communities and in relation to the achievement of national standards. Resources could then be aligned so that shortfalls in access to the right sort of opportunities or excesses in the wrong sort of opportunities can be addressed efficiently and effectively. Over time, it is anticipated that environments and behavioural norms would be reset in favour of healthier, more active lifestyles.

The key strengths of our study include: the large sample size drawn from schools located in five of Australia’s States and Territories collected over a sustained period; coverage of all primary school years – to our knowledge, the first time that this has been done in Australia; objective measurement of all data using a small team of independent, trained observers; a comprehensive set of anthropometric measures that could form the basis for progression planning and monitoring of children’s development throughout the primary school years; and adequate data to allow norms to be estimated
for each gender and half-year age group – an important consideration in this period of rapid
development in children.

Notwithstanding these strengths, there were some limitations that should also be considered in the
interpretation of our findings. Firstly, our sample was not developed a priori as a representative
random sample from the population of interest. This limits the generalizability of the findings,
although the size of the sample and its geographic spread mean that the data must capture many of the
characteristics of primary school-aged children in Australia. Secondly, we have used the LMS method
to estimate centiles. The IDEFICS study\textsuperscript{19} used an extension of the LMS method called Generalised
Additive Model for Location Scale and Shape (GAMLSS) that offers some theoretical and practical
advantages but we were unable to obtain satisfactory convergence using this approach with the much
larger data sets included in our analyses.

Two further limitations related to the population under study. First, it is not easy to perform some of
the measurements on younger children (< 6 years), for example, shuttle run and sit-ups in 60s tests,
with a high degree of reliability. Second, the primary school years cover a period of asynchronous and
sometimes rapid growth that may also include the early stages of puberty. This means that
anthropometric measures for individual children are likely to fluctuate because of growth patterns in
addition to habitual physical activity and eating behaviours. This too needs to be taken into account
when interpreting individual trajectories for each measure. For this reason, we advocate reporting in
broad achievement categories similar to that already in use in Australian schools.

Lastly, the data were gathered in repeated cross-sectional samples over 12 years. Year on year
samples may be influenced by population trends over the 12 year period. We checked for such
influence but did not find evidence of any underlying trends in measures.

Conclusion

Anthropometric standards for Australian primary school children and a monitoring and progression
system to help reduce the prevalence of underweight, overweight and obesity and decline in fitness
standards are provided.
Practical implications

- Body status (height, weight, body mass index and per cent body fat) ranges and norms for Australian primary school children are reported,
- Achievement standards and norms for physical performance in grip strength, standing long jump, cardiorespiratory fitness, sit-ups and sit-and-reach are reported for Australian primary school children in each gender and half-year age group between 5-12.5 years and
- A Physical Activity and Lifestyle Management (PALM) system suitable for progression planning and monitoring within primary school communities is proposed.

Conflict of interest

The authors declare that there are no conflicts of interest in the research presented here.

Acknowledgements

We acknowledge the contribution of the SmartStart for Kids team in conducting the assessments and collating the data on which this research was based. We recognise, too, the valuable contribution of the 91 schools that gave us permission to involve their schools, in many cases over several years, the children who participated and their parents. Funding was provided by the ACT Government Directorate of Health for the data gathered in primary schools in the Australian Capital Territory in 2010 and 2011 (~12% of sample) as part of an evaluation of a screening service and after school programme for children with poor physical function or body composition. The funding body played no part in the design of the study; in the collection, analysis, and interpretation of data; in the writing of the manuscript; and in the decision to submit the manuscript for publication.
References


### Table 1 Sample numbers and summary of body status measures by gender and half-year age band

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<th>Age band (years)</th>
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N – number in sub-group, Min – minimum value, Max – maximum value

* Very low body fat percentages, including zero for three young, very thin boys, were recorded for some children. This may indicate a loss of accuracy of the bioelectric impedance device at this extreme end of the range.
Table 2 Summary of physical performance measures by gender and age band

<table>
<thead>
<tr>
<th>Age band (years)</th>
<th>Hand grip strength (kg)</th>
<th>Standing long jump (cm)</th>
<th>Shuttle run (score)</th>
<th>Sit-ups 60s (n)</th>
<th>Sit-and-reach (cm)</th>
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Min – minimum value, Max – maximum value
Figure legends

Figure 1 (a) Individual child physical activity and lifestyle management (PALM) card showing individual body weight status and achievement on grip strength, fitness (20 m shuttle run), sit-ups and standing long jump. Each scale shows the range for the given gender and half year age group in the reference database (colour coded into the bottom 20%, middle 60% and top 20%). Reference markers are also included showing the school class group average (Sav) and the national average (Nav) on the given measure for the child’s peer group (gender and half-year age matched); (b) Summary card (for parents only) showing the child’s nutritional intake status and physical performance achievements in more detail. Weight status is characterised into 6 bands: severe thinness, moderate thinness, mild thinness, normal, overweight and obese according to standard definitions. Physical performance is characterised into 5 achievement bands: limited, partial, average, high and excellent according to those observed in the half-year age and gender matched reference group.
Supplementary materials relating to the paper:

**Anthropometric standards for Australian primary school children: towards a system for monitoring and supporting children’s development**

**Representative percentiles**

Representative percentiles for the body status measures for boys and girls are summarised in Figure S1 and Table S1, and for the physical performance measures in Figure S2 and Table S2. The 3rd, 15th, 50th, 85th and 97th percentiles were chosen here mainly to reflect the needs of families and schools, for whom the proposed system would be designed, as opposed to those recommended for clinical purposes such as identifying severe thinness or severe obesity. Relative to the available range, these percentiles correspond to categories that are similar to the five grade system used to categorise achievement in literacy and numeracy (limited, partial achievement, average, high and excellent) in the National Assessment Program – Literacy and Numeracy (NAPLAN) system (http://www.nap.edu.au/information/faqs/naplan--general.html).

Figure S3 compares boys and girls at the 3rd, 50th and 97th percentiles for the body status measures and Figure S4 compares the same three percentiles for the physical performance measures. Girls and boys were very similar on measures of height, weight and body mass index throughout the primary school years, though an earlier maturation growth spurt at around 11 years can be seen for girls on the height-for-age and weight-for-age plots. Per cent body fat was consistently 5-8% higher for girls except at the uppermost percentiles, where the gap between boys and girls narrowed somewhat especially towards the upper end of the age range.

With respect to physical performance measures, grip strength and standing long jump were consistently higher for boys throughout the primary school years, with the gap for the latter increasing slightly with age. Cardiorespiratory fitness for boys and girls was similar at the lower end of the fitness scale but showed an increasingly widening performance gap (in favour of boys) with age and with increasing fitness. Sit-ups performance was similar in the early primary school years but progressed more for boys in the late primary school years. Sit-and-reach performance was greater for
girls across the scale and showed an increasingly widening performance gap (in favour of girls) with age and with increasing flexibility.
Figure S1 Anthropometric percentile curves for height, weight, body mass index (BMI) and per cent body fat
**Table S1** Representative percentiles of body status measures: height, weight, body mass index and per cent body fat for boys and girls

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Figure S2 Physical fitness percentile curves for hand grip strength, standing long jump, shuttle run fitness score, sit-ups in 60s and sit-and-reach
### Table S2 Representative percentiles of physical performance measures for boys and girls

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NA – not available for girls in this age band
Figure S3 Comparative percentile curves between boys and girls for height, weight, body mass index (BMI) and per cent body fat
Figure S4 Comparative percentile curves between boys and girls for hand grip strength, standing long jump, shuttle run fitness score, sit-ups in 60s and sit-and-reach

Comparative Q-Q plots for each measure are included as Supplement S3.
International comparisons

We also compared our anthropometric norms for grip strength, standing long jump and shuttle run score with those obtained in the IDEFICS study to develop physical fitness reference standards in European children\(^1\). These studies used similar tests, were conducted within a similar time period by small teams of trained observers and included children of primary school age (although data for 6 to 9 year olds only were available from the European study). The comparative data are shown in Figure S5.

**Figure S5** Comparison of 3\(^{rd}\), 50\(^{th}\) and 97\(^{th}\) percentiles of grip strength, standing long jump and shuttle run score (fitness) for Australian (A) boys and girls with those of European (E) boys and girls derived from the IDEFICS study\(^1\)
For grip strength, performance norms were similar at the 50\textsuperscript{th} and 97\textsuperscript{th} percentile but European children scored higher at the 3\textsuperscript{rd} percentile. Performance scores on standing long jump were similar across the range, with European children scoring slightly higher on all three percentiles. For cardiorespiratory fitness, performance scores were similar at the 3\textsuperscript{rd} and 50\textsuperscript{th} percentiles, while Australian children performed better at the 97\textsuperscript{th} percentile. It is likely that some of these differences will be explained by methodological differences or differences in the way the various tests were scored and not just by differences in the populations of children being compared. Nevertheless, the fact that the measures were broadly comparable gives hope that, with greater standardisation, it should be feasible to develop a battery of tests that will enable international comparison and tracking of children’s general physical development throughout the important formative years in primary school.

References
ACTIVITY AND EDUCATION SESSION

MEASUREMENT PROTOCOLS
Measurements
All children involved in the program must be provided with a positive, fun educational opportunity. It is our aim that the self-esteem of every child is enhanced through their involvement in the program. To achieve this, staff must conduct themselves in a professional and enthusiastic manner at all times. It is important for staff to encourage all children to be supportive of their classmates also, as this creates an ideal environment for every child to enjoy a positive experience with us.

Physical Contact with children
Be aware of the implications of physical contact with children. Students will react in a variety of ways to physical contact by an unknown adult. This may be influenced by a number of issues, including their cultural background and previous experiences. While physical contact with children is a necessary component of the measures conducted by our team, it should be minimised where possible. When contact is required ensure that the back of the hand is used and that the student is informed of the exact nature of what is going to happen. It may be an idea to ask permission of the child prior to any physical contact occurring.

Physical Measurements

- **Body Composition** – Height, Weight, % Body fat using Bioelectric Impedance Analysis (BIA) and Body Mass Index (BMI)
- **Aerobic Fitness** – Multi Stage Shuttle Run
- **Upper limb Strength** – Hand Grip strength
- **Core Strength Endurance** – Sit Ups
- **Leg Power and Coordination** – Standing Long Jump
- **Flexibility** – Sit and Reach

Recording of Results

- The group leader will have a data entry form on which to enter the measure result details. There is a maximum of ten pupils per sheet.
- The class will be split into groups. Each group will then rotate through the stations with the same Measurement Team Leader throughout.
- For the Multi-Stage Shuttle Run each child will be given a randomly allocated number (which will be on the front and back of a bib) for easy identification.
- The Group leader will record all data, unless aided by an appropriate helper.
Equipment

Body Composition
- 1x Stadiometer
- 1x Tanita Body TBF 522 composition scales and one backup unit
- Spare batteries (AA)

Multi Stage Shuttle Run
- 1 portable CD/ Tape player
- 6 x witches hats
- 1x 50m measuring tape
- 1 fluoro string line or 1 chalk line
- 1 Box of chalk
- 1 power cord –30 meters/15 amp
- Spare CD player (at the office)
- Shuttle run CDs x 2
- 50 x Bibs with black numbers on back and front

Abdominal Endurance
- 2 x Stop watches
- 2 x Mats for sit ups (generally available form the school)
- 3 x Hand counters

Power and Coordination
- 3 x interlocking mats
- Non-slip underlay
- A retractable builders steel tape.
- Fluorescent dots
- A rigid board (90cm by 38cm) secured to a piece of specially constructed wooden beam.

Flexibility
- 1 x Sit and Reach box
- 2 x Interlocking mat

Strength
- 1 x Hand dynamometer
- 2 x Chairs (from school)
Measurement Protocols
Participants must remove their鞋子 and 袜子 prior to participating in the measurement activities. Although they are required to wear appropriate footwear to complete the Multi-Stage Shuttle Run.

Height

Equipment
- Stadiometer
- Ensure the floor surface used is even and firm and that the Stadiometer is against the wall, preferably where there is no skirting board.

Procedure
1. The participant stands erect in bare feet with the heels, buttocks and upper back pressed against the stadiometer.
2. The heels are together with the back of the heels pushed up against the wall or the wooden board. The arms hang freely by the side (palms facing the side of the body).
3. The measurer places the hands along the jaw of the participant with fingers reaching behind the ears to ensure the body is fully stretched (ensure the head is not tilted backwards).
4. The participant is instructed to take and hold a deep breath, whilst stretch is being applied.
5. The Measurer applies a gentle upward lift while keeping the head in the Frankfort plane*.
6. Ensure the participant’s heels are not raised and the head position is maintained.
7. Lower the platform until it makes firm contact with the vertex of the head – crushing the hair as much as possible.

Note: -
The “Frankfort Plane” is when the orbitale (lower edge of eye socket) is in the same horizontal plane as the tragion (the notch superior to tragus of the ear). When aligned, the vertex is the highest point of the skull as illustrated in Figure 1. (Norton, K & T Olds, Anthropometrica (1996) UNSW Press).

Figure 1.
Trouble-shooting
- Do all the heights first so that another group can use the stadiometer.
- Ensure that the participant’s hair (particularly females) is flat on top of the head. This means that all hair ties and head bands need to be removed prior to measuring the height.
- If a participant is wearing a head dress that cannot be removed (for religious reasons), measure the height as accurately as possible and ensure that this information is recorded in the health status section.

Scoring
- Record standing height to the nearest 0.1cm
- Measurement is taken at the end of a deep inward breath.

Background Information
Generally subjects are taller in the morning and shorter in the evening. The effect of this diurnal variation can be reduced by using the stretch stature method described.

Weight and BIA

USEFUL TIP - Do all the heights first so that another group can use the stadiometer.

Prior to conducting this measure ensure that there is no participant with a pacemaker

Equipment
- Tanita TBF 522 Scales and Bioelectric Impedance Analyser

Procedure
1. Dial in participant’s height, category (child, adult or athlete) and gender.
2. When the scales have calibrated to zero, ask the participant to place themselves on the scales with bare feet. The heels must be on the round electrode at the rear, with the feet facing the front and the participant must not be supported.
3. Ask the participant to place their arms by their side, look straight ahead and keep still until both measures have been taken. They may then remove themselves from the scales.
4. Results are to remain confidential, do not allow the child or other participants to see results.

Trouble-shooting
- Participants should be measured with minimal clothing. This means that heavy jumpers and jackets should be removed prior to the measurement taking place.
- An ‘Error’ message is displayed, instead of a Body Fat Indicator result:
  - The participant has dirty feet (dusty from the floor).
  - The participant’s pants are under their heels not allowing good contact with the electrodes.
  - The participant weighs less than 15 kg.
- If an ‘Error’ message is displayed, turn off the Tanita machine, determine the cause and try again.
- If the “Error” message is continually displayed, the batteries may need replacing.
  - “Lo” = Low battery. All of the batteries should be replaced.
- Participants should be requested to “step on” to the Tanita scales – not to “jump on” or “hop on”.

Scoring
- Record the participant’s exact weight and BIA. Both measures will flash up one after the other.
- The Tanita BIA should be turned off between each participant.

**Sit Ups – Strength Endurance**

**Equipment**
- Gymnastic or exercise mats (generally available at the school)
- Stopwatches and manual counters

**Procedure**

<table>
<thead>
<tr>
<th>Kindergarten</th>
<th>Year 1 to Year 6</th>
<th>High School</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Sit ups</td>
<td>60 seconds</td>
<td>60 seconds</td>
</tr>
</tbody>
</table>

1. The participant lies on their back (on the mat) with their head resting on the mat, knees bent at 90° with the feet flat on the mat.
2. Make sure that the feet are **not** anchored or held.
3. The hands should be placed on the thighs and the head rests on the mat.
4. The measurer places the backs of their finger tips on the tibial tuberosity (bone below the knee cap) of the participant’s legs, with the hands and wrists extended toward the ceiling.
5. One sit up is registered when the participant, by contracting the abdominal muscles, raises their head and shoulders off the floor, whilst sliding their hands up their thighs, to touch the measurer’s hands with both of their hands.
6. The participant **must** then return to the starting position with their head on the floor.
7. Ensure that the participant’s hands remain on their thighs at all times.

**Trouble-shooting**
- Explain to the participant about the importance of breathing (exhale on contraction and inhale on relaxation) and pacing themselves so as to avoid “burn out”.
- 1 or 2 practice goes are okay, but care must be taken not to induce pre-test fatigue.
- Throughout the 60-sec period the measurer should provide cues to the participant regarding correct technique etc…

**Scoring**
- Count the number of “correctly performed” sit ups in the allocated time as follows:

<table>
<thead>
<tr>
<th>Kindergarten</th>
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<th>High School</th>
</tr>
</thead>
<tbody>
<tr>
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<td>60 seconds</td>
<td>60 seconds</td>
</tr>
</tbody>
</table>

- Resting during the allocated time is permitted, as it is the total number of curls performed that is important.
- A full sit up is defined by a full contraction of the rectus abdominis.
- Stretch out the abdominal muscles after the measure (prone stretch) and explain about Delayed Onset Muscle Soreness (DOMS).

**Flexibility - Sit and Reach**

**Equipment**
- A flat wall and a clear level area are required
- A Sit and Reach box
- Mats

Procedure
1. Extend both legs in front of body with both feet flat against the front of the box (the knees should be straight).
2. The measurer should place either their hand (palm up position) or the folder, on top of the participant’s knees to ensure that the knees remain in contact with the ground at all times.
3. The participant places one hand on top of the other, palms down and middle fingers aligned.
4. The participant then reaches the body forward over the measuring scale and pushes the plate as far forward as possible in a slow smooth motion, with the hands remaining aligned.
5. The participant is required to hold the position for 2 seconds. Make sure the forward motion is very slow and controlled with no ballistic movements.

Scoring
- Read the measurement at the point of the fingertips (where the plate stops).
- Repeat the measure and record the highest score to the nearest 0.5cm (reading is taken from the scale that is on the left hand side that measures from -14 cm to +27 cm).
- Record “Did Not Reach” (DNR) if a participant can not reach the Sit and Reach box.
- Use the appropriate '+' or '-' sign when recording all results.

Upper limb Strength

Equipment
- Hand Dynamometer
- Chairs x 2 (one for the subject and one for the measurer)

Hand dynamometer
1. The participant should be sitting on a chair with the feet flat on the floor.
2. One hand should grip the dynamometer around the centre of the grip / pressure handle (adjusted to suit the child’s hand size).
3. The arms are held by the side – the arm being measured should be bent to 90° and the other hand should be placed on the knee.
4. The participant should then apply maximum pressure to the hand grip dynamometer. One or two practices are allowed.
5. Do one maximal effort with each hand, ensuring correct body position throughout and record a score for each hand.
6. Manually reset to zero after each measure

Scoring
- Record measurement to the nearest 1kg

Trouble-shooting
- Ensure that the hand being measured does not touch any other object, including the body.

Standing Long Jump

Equipment
- 5m tape measure, accurate to 0.1cm.
- Coloured ‘sticky’ labels (to mark the mat where the heel of the participant has landed).
- 3 x interlocking mats to land on, that will minimise impact.
- Non-slip underlay
- A rigid board that sits under the mat to mark take-off point so that each participant has to take off from exactly the same spot. This rigid edge also makes the measuring process fast and accurate.

**Procedure**
1. The participant stands with toes behind the board, with feet shoulder width apart.
2. The participant starts with their arms raised in front at shoulder level and knees bent.
3. The participant swings the arms backwards once, bends the knees, and as the arms swing forward, the participant jumps over the mat as far forward as possible.
4. The measurer marks the landing point on the mat at the back of the heel closest to the starting line with a coloured sticky label.
5. This process is repeated.
6. Record the best jump (up to three attempts).

**Trouble-shooting**
- Ensure the participant only uses one swing of the arms.
- Ensure the participant is encouraged to jump forward rather than high.
- Ensure the participant attempts to remain standing on the same spot following their jump.
- Measurers must retract the tape measure every time it is used.

**Scoring**
- Measure the shortest distance from the starting point to the furthest landing mark (at the front of the coloured sticky label), to the nearest 0.1cm.
- Ensure tape measure is perpendicular to the take off board.

**Multi Stage Shuttle Run**

**Equipment**
- CD for Multi Stage Fitness Test (from Australian Coaching Council) or Cadence audiotape, if CD not available.
- Masking tape or chalk
- Cassette/CD player and extension cord
- 20m marked distance on a surface that is flat, even and slip resistant
- Witches hats (x 6)
- Record sheet (one per measurer)
- Bibs with numbers for participants

**Procedure**

**Set-up**
1. This activity should be performed with the class split in two or more groups. With participants under the age of 8 it seems best to run 2 or more groups of 12 to 15 to minimise confusion.
2. Ensure all participants have been issued with a bib with a legible ID number, and that this ID number has been recorded against the participant’s name.
3. Ensure all shoe laces are done up tightly and not touching the ground.
4. **Important:** Check for injuries, illness and asthma (Puffers). Participants with injuries, severe asthma (if they do not have their puffers) or illness should not participate.
5. It is very important to demonstrate the run first and then run with the participants for the first stage (Up to Level 2 – 1) to set the pace.
6. Using either a CD or the audiotape of the 20m shuttle run test provided by the Australian Coaching Council.
7. If using an audiotape, check the speed of the cassette player using the one-minute calibration period and adjust the running distance if necessary (this is described on the tape and the tape manual).
8. Mark the cassette tape as used and replace it when it has been used 30 times.
9. Measure the 20m distances and mark with tape / chalk and witches hats.
10. Cue the cadence audiotape.

Protocol
1. Instruct participant(s) to run to the opposite end and place one foot on the line by the time the next beep sounds. If they arrive before the beep, they should turn (pivot) and wait for the beep, then run to the opposite line to reach this in time for the next beep.
2. At the end of each minute the time interval between beeps is decreased, causing running speed to become progressively faster.
3. Ensure the participants reach the end line each time and do not turn short. Emphasise to the participants that they should pivot and turn rather than run an arc, which they sometimes tend to (this takes more time and energy).
4. A Measurer Leader is to run the first level with the participants to demonstrate the proper technique and speed. The Measurer Leader should always stop at Level 2-1.
5. Each participant continues running for as long as possible until he/she can no longer keep up with the tape. The criterion for eliminating a participant is two lengths in a row where he/she is more than two steps from the end (participant to receive a warning after the first length).
6. To inform participant that they should stop, lightly tap the participant on the shoulder after they have not completed two line touches to indicate they should withdraw from the activity. Do not call out their number, as it seems to confuse all of the other runners. Although if their name can be used (as identified on the roll next to their number) it is not usually as distracting to the other participants.

Trouble-shooting
- Ensure that each participant is given one warning before they are stopped.
- Ensure that the running surface is clean, clear and as flat as possible.
- Participants may need to be reminded to run in a straight line, so as to avoid collisions.
- Participants should try to run in time with the recorded beeps – it is very important that they do not run too fast at the beginning of the activity, resulting in fatigue.
- Communication between Measurer Leaders at opposite ends of the 20m track is required with regard to warnings issued to participants.
- Participants should be encouraged to walk around slowly and stretch upon completion of the Shuttle Run. This will aid in their recovery and reduce possible muscle soreness (DOMS).

Scoring
- It is the responsibility of all measurers to record the last shuttle completed by any participant – not only those assigned to the Measure Leader. These results should be collated at the completion of the measure.
- Record the location and the surface on which the activity was conducted.
- Record the last level and shuttle the participant successfully completed.
- To record the result write down only the number of each participant as they finish.
Translate the number later to the corresponding name using the following format: Level - Shuttle.

**Other Important Information**

- Set up at the school requires a maximum of 30 minutes.
- Reconnaissance of facilities is essential prior to the Activity and Education session commencing.
- Data entry forms with class names in appropriate groupings must be checked and ready for the entire school **BEFORE** starting any measurement activity in the school.
- The timetable for the school must be organised and copies distributed to teachers and staff before the day of measurement.
- Hand written numerals should be written as follows –
  Cross the “zeros”, Cross the “sevens”, Close the “fours”
- Each measurer is responsible for checking to ensure that the data collected is legible and complete before handing their data sheets in.
- All shuttle run results should be finalised by the completion of each measurement session.
- Each Measure Leader should hand a certificate to each of the participants in their group at the completion of the session.
- Whilst the final address is being given, the measuring equipment should be made ready for the next session or be stored in an appropriate locked room (if this is available) unless it is being transferred to another area.
- Data collection forms and shuttle run forms should be stapled to the appropriate class sheet and placed in secured brief case folder and kept together until all classes in the school have been measured.
- If there is to be any press or media presence then it is essential that permission be obtained from the parents of all of the subjects in the group beforehand. This is a legal requirement and must be observed.
Figure S3.1 Comparative Q-Q plots between boys and girls for height, weight, body mass index (BMI) and per cent body fat
Figure S3.2 Comparative Q-Q plots between boys and girls for grip strength, standing long jump, 20m shuttle run, sit-ups in 60s and sit and reach