Development of an Evidence-Based Clinical Practice Guideline on Linear Growth Measurement of Children

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Growth is an important indicator of child health; however, measurements are frequently inaccurate and unreliable. This article reviews the literature on linear growth measurement error and describes methods used to develop and evaluate an evidence-based clinical practice guideline on the measurement of recumbent length and stature of infants, children, and adolescents. Systematic methods were used to identify evidence to answer clinical questions about growth measurement. A multidisciplinary team critically appraised and synthesized the evidence to develop clinical practice recommendations using an evidence-based practice rating scheme. The guideline was prospectively evaluated through internal and external reviews and a pilot study to ensure its validity and reliability. Adoption of the clinical practice guideline can improve the accuracy and reliability of growth measurement data.

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GROWTH IS WELL established as an important and sensitive indicator of health (Hindmarsh & Brook, 1988; Tanner, 1986a, 1986b), and growth monitoring is a component of child health care around the globe (De Onis, Wijnhoven, & Onyango, 2004b; Grote, Oostdijk, Dekker, Verkerk, & Wit, 2005; Tomkins, 1994; Ulijashek, 1994). Since impaired or abnormal growth is a common consequence of a wide range of conditions, its measurement acts as a useful early warning of possible pathology. Linear growth measurements need to be accurate and reliable to be of value. Since education alone does not always change practice, a clinical practice guideline was developed to

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bridge the gap between scientific evidence and clinical practice. A goal of this project is to empower clinicians to examine and improve growth measurement procedures in their own practice settings.

Relevant Literature

Growth data can lead to the discovery of suboptimal health conditions. These include endocrine disorders, nutritional deficiencies, metabolic disturbances, genetic disorders, psychosocial issues, and chronic diseases (Ahmed, Allen, Dunger, & Macfarlane, 1995; Alexander & Hindmarsh, 2004; Hyer, Cotterill, & Savage, 1995; Vogiatzi & Copeland, 1998; Voss, Mulligan, Betts, & Wilkin, 1992). Unfortunately, many children are not referred for evaluation or are referred too late to be treated effectively (Aynsley Green & Macfarlane, 1983; Jellinek & Hall, 1994; Lipman & McKnight, 2000) because their growth disorders are not recognized.

Change in growth over time is more sensitive than a single measurement; therefore, the adequacy and appropriateness of growth is determined by serial measurements compared with reference standards. Linear growth is a process characterized by three distinct phases: infancy, middle childhood, and puberty (Karlberg, 1989; Tanner & Davies, 1985). Infants have rapid but decelerating growth of approximately 2.5 cm per month until 6 months old and then 1.25 cm per month until 1 year old. Toddlers grow approximately 10 cm between 12 and 24 months (Boom, 2010). Growth velocity varies as children may cross percentile lines on growth charts during the first 2 years of life while they grow toward their genetic potential (Boom, 2010; Rogol, 2009). Children grow approximately 8 cm between 24 and 36 months old and approximately 7 cm between 36 and 48 months old (Boom, 2010). Growth velocity during middle childhood is relatively constant at 5 to 7 cm per year. There is often a slight deceleration in growth velocity preceding puberty. Growth velocity increases during puberty and peaks at 8 to 14 cm per year (Kerrigan & Rogol, 1992).

Effective growth monitoring requires precise linear growth measurement, and growth assessments are compromised without this precision. More than 70 years ago, Meredith (1936) reported that extraordinarily rigorous technique is needed to properly measure a child’s growth. Tanner (1986a) warned that the heights “measured” in many settings are useless for clinical purposes, let alone for research. In the 21st century, inaccurate and unreliable linear growth measurements of children are still prevalent problems. Sources of measurement error and unreliability include flawed measurement instruments, casual measurement techniques, diurnal height variation, and the posture and movement of children. Measurement error influences the interpretation of growth patterns and can result in failure to identify underlying pathology or apparent growth divergence in a normally growing child.

Lipman et al. (2000) surveyed 50 primary care practices and found that 78% used inappropriate instruments for measuring height and 18% measured children while wearing shoes. In addition, 88% used inappropriate instruments for measuring length and one practice did not measure children that could not stand alone. More than half of the practices (58%) had incorrect policies for obtaining height-versus-length measurements. Lipman et al. (2004) performed a study of 55 pediatric and family practices within eight geographical areas of the United States and found that 42% of children measured standing and 82% of children measured lying were measured with inappropriate instruments. Spencer, Lewando-Hundt, Kaur, Whiting, and Hors (1996) found that 22% of 58 child health clinics in Coventry, UK, did not have any height measuring instruments and 76% did not have instruments suitable for measuring infants.

Measurement instruments are frequently installed improperly and uncalibrated. Voss, Bailey, Cumming, Wilkin, and Betts (1990) checked the calibration of 230 measurement instruments and found that there was a mean error of at least 1 cm using a 100-cm calibration rod (range 90.0–108.5 cm) in all four different types of instruments evaluated. In addition, most personnel using these instruments were unaware of the inaccuracies. Bunting and Weaver (1997) checked the calibration of height instruments in 12 wards of a children’s hospital and 14 outpatient clinics. They found one of six infant length boards was inaccurate and 12 of 21 stadiometers were inaccurate by 1 cm or more, with one being inaccurate by 4 cm. Laing and Rossor (1996) assessed the calibration of instruments in 59 schools. Of the 39 instruments available, only 23 (59%) measured within 0.5 cm of a 100-cm rule (range 98.0–102 cm).

In a large growth surveillance study of 20,338 children, 260 were identified as having heights less than −2 SD (approximately less than third percentile); however, measurement or recording errors were detected among 13.5% of those children (Ahmed et al., 1995). Stoddard, Kubik, and Skay (2008) found 20% to 25% of school-based measurements taken of 70 children to be unreliable. Lipman et al. (2004) found that 70% of children in 55 primary care practices across the United States were measured using incorrect techniques. They also found that using appropriate instruments and training on measurement techniques resulted in an improvement in measurement accuracy (within 0.5 cm) from 30% to 70%.

Diurnal variation in stature was recognized as early as 1777 when Count Philibert Guéneau de Montbeillard measured his son at frequent intervals between birth and 19 years old, providing the oldest longitudinal growth record in existence (Scammon, 1927). Magnetic resonance imaging has demonstrated diurnal variation in the fluid volume of intervertebral discs associated with axial loading of the spine and gravity results in changes in stature (Boos, Wallin, Gbedegbegnon, Aebi, & Boesch, 1993; Keller & Nathan, 1999; Roberts, Hogg, Whitehouse, & Dangerfield, 1998). Studies have shown that the mean height loss in children...
from morning to afternoon or evening can range from 0.47 to 2.8 cm (Buckler, 1978; Kobayashi, Kobayashi, Tanaka, Uchiyama, & Togo, 1999; Kobayashi & Togo, 1993; Lampl, 1992; Rodriguez, Moreno, Sarria, Fleta, & Bueno, 2000; Siklar, Sanli, Dallar, & Tanyer, 2005; Strickland & Shearin, 1972; Tillmann & Clayton, 2001; Voss & Bailey, 1997). Diurnal height changes can lead to misinterpretation of a child’s growth velocity when measured at different times of the day for serial encounters. After Whitehouse, Tanner, & Healy (1974) suggested that applying gentle upward pressure on the mastoid processes during measurement could minimize the effects of diurnal variation, some clinicians adopted a controversial stretching technique.

Voss et al. (1990) examined what variance in height measurement was attributable to the subject. Under blind and randomized conditions, the standard deviation of a single height measurement was generally between 0.2 and 0.3 cm, and over 95% of the variance was attributable to the movement of the child. Ahmed, Yudkin, Macfarlane, McPherson, & Dunger (1990) studied height measurements in young children performed by health visitors using simple instruments and found that the proportion of total variance attributable to the child ranged from 29% to 51%. In a longitudinal study of infant growth, 925 replicate measurements of recumbent length of three infants by the same researcher and an assistant identified that 60% to 70% of the measurement unreliability was due to child factors (Lampl, Birch, Picciano, Johnson, & Frongillo, 2001). They suggested that temperament and level of resistance, muscle tension related to fatigue or high activity levels, and endogenous factors such as hydration and the growth process itself may influence the degree of measurement error. Since a living subject does not have a fixed height or length, this has implications for whether a child should be measured once or multiple times during a single encounter to obtain a measurement closest to the true value.

After defining the challenges of linear growth measurement, a preliminary review of literature on measurement instruments and techniques was completed before proceeding with the guideline’s development. No existing evidence-based guidelines on linear growth measurement instruments and techniques were identified; however, it was determined that there was a body of scientific evidence available to formulate an evidence-based clinical practice guideline. The AGREE Instrument, a framework for assessing the quality of clinical practice guidelines, was selected as a guide to ensure a structured and rigorous guideline methodology was followed. (The AGREE Collaboration, 2001).

Guideline Development Team

A pediatric nurse practitioner served as project director (J.M.F.) and organized a 12-member multidisciplinary team of health professionals with varied expertise and perspectives to develop the clinical practice guideline. The team was comprised of nurses, pediatric and family nurse practitioners, pediatric and neonatal clinical nurse specialists, nursing educators, a nursing supervisor, a nurse researcher, a pediatric endocrinologist, a primary care pediatrician, and a pediatric dietitian. The nurse researcher had experience in evidence-based practice processes and served as a process expert. The team members were respected role models and leaders within their own disciplines who shared an interest in growth assessment and evidence-based practice. Together, they represented the views of practice, research, education, and administrative stakeholders, as well as intended guideline users. The team met once or twice a month over a 1-year period, with team members having assignments between meetings.

Scope of the Clinical Practice Guideline

Focused clinical questions drive the evidence-based practice process. A foreground question was developed for this project using four components, termed PICO (an acronym for patient/population/problem, intervention/exposure of interest, comparison of intervention or measure, and outcome) (Nollan, Fineout-Overholt, & Stephenson, 2005). The PICO question for this project was: “What are the best instruments and techniques (comparison) to measure (intervention) the linear growth (outcome) of children (population)?” This overall question was divided into eight specific and searchable clinical questions to be answered by the most relevant and best evidence.

- What instruments will measure the length of children accurately and reliably?
- What instruments will measure the height of children accurately and reliably?
- Can less expensive instruments measure children’s length and height accurately and reliably?
- How often should measurement instruments be calibrated?
- What techniques will measure the length of children accurately and reliably?
- What techniques will measure the height of children accurately and reliably?
- How should practitioners address the diurnal variation in height?
- How many times should a child be measured at each encounter?

The purpose of the clinical practice guideline is to assist health professionals in applying evidence-based knowledge to the process of measuring linear growth in infants, children, and adolescents using standardized instruments and techniques. The intended guideline users are nurses, nurse practitioners, clinical nurse specialists, physicians, physician assistants, dietitians, allied health personnel, and other health care providers who practice in pediatric and family practice primary care, pediatric specialties, hospitals, schools, and community health settings. Guideline users should be able to
implement accurate and reliable techniques for measuring recumbent length and stature using appropriate instruments in their own practice settings.

The guideline excludes other anthropometric measurements (e.g., weight, head circumference, segmental lengths), the use of growth charts, and the interpretation of growth patterns. Although measuring weight is not included in the guideline, it should be noted that accurate measurements of both growth and weight are necessary to calculate an accurate body mass index (in children aged 2 years and older) and weight per length (in infants and younger children), which are important indicators of overweight and obesity. The guideline does not include recommendations for when or how often to measure growth in various settings. However, the American Academy of Pediatrics has recommended a schedule of growth measurements for preventive pediatric health care (Hagan, Shaw, & Duncan, 2008).

**Search Strategy**

Terms derived from the clinical questions were used by the project director and a health sciences librarian to search these databases: COCHRANE, MEDLINE, CINAHL, EMBASE, OCLC, and ERIC. Additional studies and alternative literature were identified through the mining of article reference lists, contact with experts in the field, anthropometric and endocrinology textbooks, and informal discovery. Secondary searches were performed throughout the project to identify gaps in the literature and near the completion of the guideline to identify any new literature that had been published during the course of the project.

**Data Extraction and Quality Assessment**

The project director reviewed the candidate literature, with the assistance of a second team member when necessary, for pertinence to at least one of the clinical questions to determine what should receive a full review. Each full-text article was critiqued by the project director and several team members to minimize the risk of bias. Literature not available in English was excluded, but no limits were established on the publication dates. The guideline includes 128 references that were used in its development, while more than 200 were excluded because they did not provide relevant or sufficient evidence to answer the selected clinical questions.

Forms modified from a toolkit for promoting evidence-based practice (Titler, 2002) were used to critique the research articles and summarize the non-research literature. The research critiques and literature summaries were discussed at guideline development team meetings. The quality of evidence from each individual article was rated according to the U.S. Preventive Services Task Force (USPSTF, 1996) Evidence-Based Practice Ratings (Table 1). Any disagreements about the quality of evidence among reviewers were reconciled by consensus among the team members.

Once all of the literature had been reviewed, the evidence was organized according to the eight specific clinical questions. The aggregate body of evidence was then synthesized and used to formulate explicit clinical practice recommendation statements. The strength of evidence supporting each recommendation was graded according to modified USPSTF (1996) Evidence-Based Practice Ratings (Table 1).

### Internal and External Reviews

The drafted guideline was internally reviewed by several stakeholder groups including a pediatric nurse practitioner, a neonatal nurse practitioner, a family nurse practitioner, two pediatricians, a neonatologist, an adolescent medicine physician, two pediatric endocrinologists, two pediatric inpatient nurse managers, two pediatric unit-based nurse educators, and five members of the organization’s multidisciplinary Evidence-Based Practice Committee. The guideline was reviewed externally by nine experts from the Pediatric Endocrinology Nursing Society Research Committee who were chosen for their scientific and clinical expertise in children’s growth. To provide consumer stakeholder input, the guideline was also reviewed by five parent representatives.

<table>
<thead>
<tr>
<th>Quality of Evidence</th>
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<tbody>
<tr>
<td>I. Evidence obtained from at least one properly randomized controlled trial.</td>
</tr>
<tr>
<td>II-1. Evidence obtained from well-designed controlled trials without randomization.</td>
</tr>
<tr>
<td>II-2. Evidence obtained from well-designed cohort or case-control analytic studies preferably from more than one center or research group.</td>
</tr>
<tr>
<td>II-3. Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled experiments could also be regarded as this type of evidence.</td>
</tr>
<tr>
<td>III. Opinions of respected authorities, based on clinical experience; descriptive studies and case reports; or reports of expert committees.</td>
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</table>

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<tr>
<th>Strength of Recommendations (Modified)</th>
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<tbody>
<tr>
<td>A. There is good evidence to support the recommendation.</td>
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<tr>
<td>B. There is fair evidence to support the recommendation.</td>
</tr>
<tr>
<td>C. There is insufficient evidence to recommend for or against, but recommendations may be made on other grounds.</td>
</tr>
<tr>
<td>D. There is fair evidence to support exclusion of the practice.</td>
</tr>
<tr>
<td>E. There is good evidence to support exclusion of the practice.</td>
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</table>

from The Magic Foundation (2010) (Major Aspects of Growth In Children), a nonprofit organization that provides support services for the families of children affected with a wide variety of chronic and/or critical disorders, syndromes, and diseases that affect childhood growth. The internal and external reviews were essential to ensure that the guideline was valid, clear, and practical and that recommendations could be implemented in a manner likely to influence clinical practice.

**Pilot Study**

Following approval by the appropriate institutional review boards, a pilot study was conducted in a pediatric clinic that includes primary and specialty care. The primary purpose of this descriptive study was to ensure that the guideline was easy to understand and practical to implement. A secondary purpose was to collect preliminary data on reliability and measurement variability. The pilot study consisted of educating staff members and then collecting data about the guideline’s clarity, applicability, and feasibility; spot checking and correcting existing measurement instruments; and determining intraexaminer and interexaminer measurement reliability and variability.

Without prior warning, existing measurement instruments were evaluated by two observers for proper calibration and necessary components (according to the guideline) using Perspective Enterprises calibration rods, a standard non-stretchable tape measure, a Johnson magnetic angle locator no. 700, and a Macklanburg–Duncan top reading magnetic torpedo level. A 100.0-cm aluminum rod was used to check the accuracy of installation of seven height measuring devices (one Harpenden & Holtain 602VR, five less expensive Accustat measuring devices, and one steel tape measure mounted to the wall between two strips of wood), and a 60.0-cm aluminum rod was used to check the accuracy of four length boards (all of which were length and weight combination units). The recorded length of the rod was based on the mean of two readings. The range of error was least for stadiometers (−0.2 to 0.3 cm) and greatest for length boards (−5.1 to 0.3 cm). The instruments were subsequently repaired, modified, or replaced as necessary and calibrated appropriately to comply with the guideline.

Sixteen staff members (eight registered nurses, one licensed practical nurse, one registered dietitian, and six allied health personnel), who were intended guideline users, were educated on the clinical practice guideline during a 1-hour in-service. The staff members had 8 months to 42 years experience in measuring children and measured 1 to 150 children per week. The project director, who had 18 years experience in measuring children and measured 1 to 250 children per week, taught the in-service to these potential guideline users. The goals of the in-service were to promote the concept of evidence-based practice over tradition in measuring the growth of children and to standardize the staff members’ practice to the procedures outlined in the guideline. The in-service was developed using Rogers’ (1995) diffusion of innovation theory, conveying three types of relevant knowledge. Awareness knowledge was promoted through conveying the importance of growth monitoring in children and evidence-based practice. They were provided “how-to” knowledge for improving their measurement practices by reviewing the guideline step-by-step, graphical depictions of proper instruments and positioning of children, and the opportunity for demonstration and return demonstration of techniques. The principle knowledge or the “why” was conveyed by discussing the scientific rationale for each clinical practice recommendation. The staff members were asked to follow the guideline’s techniques for measuring infants, children, and adolescents in their practices. Posters of the basic steps of the guideline, graphics showing proper positioning of the child during measurement, and a list of common measurement errors were placed next to the measurement instruments in the clinic areas.

After using the guideline for 6 weeks, all 16 staff members were surveyed about the clarity, applicability, and feasibility of the clinical practice guideline. Using a four-point Likert scale, they agreed or strongly agreed with all the statements in Table 2. They found the guideline to be understandable and the clinical practice recommendations to be logical and reasonable. Use of the guideline gave them more confidence in the accuracy of their measurements, and they would recommend use of the guideline to others.

A convenience sample of children was measured to determine intraexaminer and interexaminer reliability, with the consent of their parents or guardians. These children were attending appointments for health maintenance visits, acute illnesses, and chronic diseases. Thirty-five infants and young children (aged 4 days to 30 months 1 week; 17 girls and 18 boys) had their lengths measured on one of three different length boards (two Ellard length boards PED LB 35-107-X and one Perspective Enterprises Easy-Glide Bearing Infantometer PE-RILB-BRG2) by one of eight staff members and the expert (project director). Thirty-seven children and adolescents (aged 2 years 6 months to 17 years 6 months; 19 girls and 18 boys) had their heights measured on one of five different stadiometers (one Harpenden & Holtain 602VR, one Perspective Enterprises Easy-Glide Bearing Stadiometer PE-WM-60-76-BRG, and three Accustats) by 1 of 11 staff members and the expert. They were measured on accurately installed and calibrated instruments under standard clinical conditions in nonblind and successive order. They were each measured to the last completed millimeter three times by a staff member and three times by the expert. Parents and guardians acted as assistant measurers for the infants and young children in whom length was measured because a second health professional is not routinely available in many clinical settings. The instruments were checked for calibration throughout the pilot study, and none required adjustment.
There were no significant differences between the reliability results of individual staff members or types of instruments used to measure the children, and consequently, the values for length measurements and the values for height measurements were each pooled. Table 3 shows the reliability of measurements taken by the same examiner was greater than .99 for length and height measurements for both the staff and the expert ($p < .0001$). Table 4 shows the reliability of length and height measurements taken by different examiners was also greater than .99 for single measurements, the mean of the first two measurements, and the mean of all three measurements for both length and height ($p < .0001$).

All measurements have intrinsic variability or precision error when repeated because living subjects do not have fixed heights/lengths. Measuring subjects more than once and using the mean can reduce the effects of measurement error. For quality assurance purposes, there must be a set limit of agreement between repeated measurements, such as 0.3 to 0.5 cm. Table 5 shows the variation in length and height measurements taken by the same examiner as percentage of differences within 0.3 cm and within 0.5 cm between the first two measurements and between all three measurements for the staff and for the expert. Table 6 shows the variation in length and height measurements taken by different examiners as the percentage of differences within 0.3 cm and within 0.5 cm between the staff’s and the expert’s single or first measurements, the mean of the first two measurements, and the mean of the all three measurements. A majority of repeated measurements within and between examiners were within 0.3 cm and nearly all were within 0.5 cm. This degree of precision is recommended because errors can be magnified over the course of serial growth monitoring, leading to misinterpretation of growth patterns. Based on normal growth velocities per age, larger measurement errors are clinically intolerable.

The range of differences between the three length measurements was 0 to 1.1 cm ($M = 0.39$ cm) for the staff and 0 to 0.4 cm ($M = 0.17$ cm) for the expert. The range of differences among the three height measurements was 0.1 to 0.5 cm ($M = 0.24$ cm) for the staff and 0 to 0.3 cm ($M = 0.13$ cm) for the expert. The range of differences between three

| Table 2 | Guideline User Survey (n = 16): Frequency of Likert Responses by Item |
|---|---|---|---|---|---|---|
| Strongly Agree (4) | Agree (3) | Disagree (2) | Strongly Disagree (1) | M Score |
| 1. Growth is a sensitive indicator of health in children. | 81.25% (13) | 18.75% (3) | 0 | 0 | 3.81 |
| 2. The clinical practice guideline is applicable to my practice. | 68.75% (11) | 31.25% (5) | 0 | 0 | 3.69 |
| 3. The recommendations are clear and understandable. | 81.25% (13) | 18.75% (3) | 0 | 0 | 3.81 |
| 4. I can identify appropriate and inappropriate measurement instruments. | 62.5% (10) | 37.5% (6) | 0 | 0 | 3.63 |
| 5. I can identify appropriate and inappropriate measurement techniques. | 62.5% (10) | 37.5% (6) | 0 | 0 | 3.63 |
| 6. I can identify common errors in measuring children. | 62.5% (10) | 37.5% (6) | 0 | 0 | 3.63 |
| 7. Clinical practice recommendations are linked with scientific evidence and rationale. | 56.25% (9) | 43.75% (7) | 0 | 0 | 3.56 |
| 8. Rationale for each recommendation is logical and reasonable. | 62.5% (10) | 37.5% (6) | 0 | 0 | 3.63 |
| 9. The key recommendations are easily identifiable. | 66.67% (10) | 33.33% (5) | 0 | 0 | 3.67 |
| 10. The modifications for special situations are understandable. | 62.5% (10) | 37.5% (6) | 0 | 0 | 3.63 |
| 11. I have more confidence in the accuracy of my measurements. | 56.25% (9) | 43.75% (7) | 0 | 0 | 3.56 |
| 12. Patient care will be enhanced by improved measurement accuracy & reliability. | 68.75% (11) | 31.25% (5) | 0 | 0 | 3.69 |
| 13. I would recommend use of this clinical practice guideline to others. | 62.5% (10) | 37.5% (6) | 0 | 0 | 3.63 |
| 14. Use of this guideline should be a competency for those who measure children. | 53.33% (8) | 46.67% (7) | 0 | 0 | 3.67 |
| Total scores | | | | | 3.66 |

| Table 3 | Intraexaminer Reliability: Comparison of Repeated Length and Height Measurements (First, Second, and Third) Taken by the Same Examiner (Staff or Expert) |
|---|---|---|---|---|---|
| Measurement 1 vs. 2 | 1 vs. 3 | 2 vs. 3 |
| Length ($n = 35$) | | | |
| Staff | .99970 | .99918 | .99961 |
| Expert | .99990 | .99993 | .99993 |
| Height ($n = 37$) | | | |
| Staff | .99997 | .99995 | .99996 |
| Expert | .99998 | .99999 | .99999 |
| Note: Reliability estimates are Pearson correlation coefficients ($p < .0001$). |
Intraexaminer Measurement Variability: Percentage of Length and Height Measurements (First, Mean of First Two, and Mean of All Three) Taken by Different Examiners (Staff and Expert) That Varied by ≤0.3 and ≤0.5 cm

<table>
<thead>
<tr>
<th>Measurement</th>
<th>1</th>
<th>(M_1 + 2)</th>
<th>(M_1 + 2 + 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length ((n = 35))</td>
<td>99.981</td>
<td>99.990</td>
<td>99.983</td>
</tr>
<tr>
<td>Height ((n = 37))</td>
<td>99.997</td>
<td>99.999</td>
<td>99.998</td>
</tr>
</tbody>
</table>

Note: Reliability estimates are Pearson correlation coefficients \((p < .0001)\).

Internal and external reviewers, as well as guideline users in the pilot study, were asked to identify barriers to implementing the clinical practice guideline. Potential barriers included lack of awareness of the guideline itself as well as the scientific evidence supporting its recommendations, unfamiliarity with terms, lack of appropriate and calibrated measurement instruments, forgetting or neglecting important steps of the measurement procedures, the need to make modifications for special situations, adherence to the guideline, and sustaining practice changes. Awareness of barriers to practice change helps with tailoring knowledge translation interventions (Straus, Tetroe, & Graham, 2009).

Analyses of data from the reviews and the pilot study were used by the guideline development team to improve and finalize the guideline and to tailor implementation tools. The evidence-based clinical practice guideline provides clinical practice recommendations for measurement instruments, measurement techniques, use of less expensive instruments, calibration of instruments, when to measure length versus height, diurnal height variation, and replicate measurements. Graded recommendations are linked with scientific rationale and supporting references (refer to Table 7 for a short excerpt from a section of the guideline). Modifications for special circumstances (e.g., obesity, genu valgum, leg length asymmetry, and scoliosis) are provided. Although using alternative methods to measure children with special needs was not within the scope of the project, some recommendations with references are provided in the guideline.

The clinical practice guideline and implementation tools are available at the Blank Children’s Hospital Web site (http://www.blankchildrens.org/linear-growth-measurement.aspx) and through the National Guideline Clearinghouse (http://www.guideline.gov). The guideline is also being disseminated through educational presentations to a variety of national and international audiences. Implementation tools include a glossary of terms, lists of common errors in measuring length and height, a sample instrument calibration log, an audit tool to measure ongoing adherence, and a list of sources for measurement instruments. Posters on length and height measurement procedures with graphics that show proper positioning of children (Figures 1 and 2, respectively) are also available to facilitate implementation of the guideline. Placing these posters in the measurement areas

Table 4 Interexaminer Reliability: Comparison of Length and Height Measurements (First, Mean of First Two, and Mean of All Three) Taken by Different Examiners (Staff and Expert)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>1</th>
<th>(M_1 + 2)</th>
<th>(M_1 + 2 + 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length ((n = 35))</td>
<td>0.99981</td>
<td>0.99990</td>
<td>0.99983</td>
</tr>
<tr>
<td>Height ((n = 37))</td>
<td>0.99997</td>
<td>0.99999</td>
<td>0.99998</td>
</tr>
</tbody>
</table>

The pilot study demonstrated that using the guideline to measure the recumbent length and stature of children can result in strong intraexaminer and interexaminer reliability. Single measurements did not compare as well as the mean of two or more measurements \((p < .001)\), providing additional evidence for measuring children more than once during each encounter. Overall, pilot study results were comparable to previously reported studies with acceptable levels of reliability and measurement variability (De Onis et al. 2004a; Gordon, Chumlea, & Roche, 1991; Roche & Sun, 2003; Tanner & Whitehouse, 1982; Ulijaszek & Kerr, 1999; Ulijaszek & Laurie, 1994; WHO Multicentre Growth Reference Study Group, 2006). Most importantly, the guideline users found the clinical practice guideline to be clear, applicable, and feasible to implement.

Results

The best evidence was critically evaluated to answer clinical questions about measuring recumbent length and stature of infants, children, and adolescents. There was strong evidence for most of the major clinical practice recommendations. Expert opinion was included as an adjunct to other evidence and where good evidence was lacking. Prospective evaluation of the guideline was conducted through internal and external reviews including expert reviews, as well as a pilot study that was conducted under standard clinical practice conditions.

Table 5 Intraexaminer Measurement Variability: Percentage of Length and Height Measurements (First Two and All Three) Taken by the Same Examiner (Staff or Expert) That Varied by ≤0.3 and ≤0.5 cm

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Staff</th>
<th>Expert</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>(1 + 2)</td>
<td>(1 + 2 + 3)</td>
</tr>
<tr>
<td>Length ((n = 35))</td>
<td>82.9</td>
<td>51.4</td>
</tr>
<tr>
<td>% differences ≤0.3 cm</td>
<td>100</td>
<td>82.9</td>
</tr>
<tr>
<td>% differences ≤0.5 cm</td>
<td>91.9</td>
<td>67.6</td>
</tr>
<tr>
<td>Height ((n = 37))</td>
<td>91.4</td>
<td>94.6</td>
</tr>
<tr>
<td>% differences ≤0.3 cm</td>
<td>94.6</td>
<td>97.3</td>
</tr>
<tr>
<td>% differences ≤0.5 cm</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

The clinical questions about measuring recumbent length and stature of infants, children, and adolescents. There was strong evidence for most of the major clinical practice recommendations. Expert opinion was included as an adjunct to other evidence and where good evidence was lacking. Prospective evaluation of the guideline was conducted through internal and external reviews including expert reviews, as well as a pilot study that was conducted under standard clinical practice conditions.

Table 6 Interexaminer Measurement Variability: Percentage of Length and Height Measurements (First, Mean of First Two, and Mean of All Three) Taken by Different Examiners (Staff and Expert) That Varied by ≤0.3 and ≤0.5 cm

<table>
<thead>
<tr>
<th>Measurement</th>
<th>1</th>
<th>(M_1 + 2)</th>
<th>(M_1 + 2 + 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length ((n = 35))</td>
<td>% differences ≤0.3 cm</td>
<td>91.4</td>
<td>97.1</td>
</tr>
<tr>
<td>% differences ≤0.5 cm</td>
<td>100</td>
<td>100</td>
<td>94.3</td>
</tr>
<tr>
<td>Height ((n = 37))</td>
<td>% differences ≤0.3 cm</td>
<td>91.9</td>
<td>94.6</td>
</tr>
<tr>
<td>% differences ≤0.5 cm</td>
<td>94.6</td>
<td>97.3</td>
<td>100</td>
</tr>
</tbody>
</table>
of practice settings informs patients and families as well and can help engage them in proper measurement procedures.

Limitations

Some studies and review articles used in the development of this guideline were historical in nature; however, they were relevant and of good quality. Many of the studies were descriptive and there were few randomized controlled trials due to the nature of the topic. Some of the studies cited were conducted for purposes other than determining measurement reliability, but they reported the reliability data for their measurement instruments and/or techniques.

Baseline data on measurement reliability was not obtained in the pilot study; however, there is sufficient evidence from other studies that measurements are frequently inaccurate and unreliable when using faulty instruments and non-standardized techniques. Other limitations of the study include lack of power analysis, the small sample size of children, and the fact that staff member participants were employed in the organization where the guideline was developed. The Hawthorne effect may have been a factor in the results of the pilot study since the staff members knew that their measurements were being studied. The staff members read their own measurements, as is done routinely in clinical situations. They were reminded that some variance is expected to offset any attempts to obtain replicate measures of expected values. Technical errors of measurement were not reported due to the measurements being performed at different times with different instruments.

Implications for Practice

A recurring theme in the literature review was the importance of regular education sessions for staff. Educating staff to measure the growth of children properly is one step toward ensuring quality health care. In the pilot study, there was agreement among staff members that the guideline should be a competency for those who measure children’s growth. The guideline development team recommends educational sessions and/or demonstrated competency on an annual basis for health care personnel who measure children. Additional refresher sessions should occur when a lack of standardization is observed.

The guideline development team assumes that health professionals will use their clinical knowledge and judgment in applying the guideline’s clinical practice recommendations to the measurement of individual children in their own practices. Health care decisions regarding children’s growth should be based upon accurate and reliable measurements using appropriate instruments and techniques rather than on casual techniques using flawed instruments. Adoption of this guideline will provide practitioners and parents with accurate and reliable information about children’s growth. Accurate growth assessments are necessary to recognize, diagnose, and treat growth disorders and other pathology in a timely manner, as well as to avoid unnecessary referrals and costly evaluations in children with normal growth.

Growth measurement is a relatively inexpensive method of monitoring and improving child health. Sources for measurement instruments, including some less expensive models, are included with the guideline. A systematic review supported the utility and cost effectiveness of growth monitoring to increase the detection of stature-related disorders (Fayter et al., 2008). Cernerud and Edding (1994) also found that investment costs and running expenses of growth surveillance were very low. They noted additional benefits to measuring growth including discussions with children and their parents about growth and what is normal, reassurance of adolescents about their developing identity and body image, the revealing of conditions such as maltreatment during the measurement procedure, and the use of growth data in the field of public health research.

Implications for Research and Evidence-Based Practice Projects

During the process of reviewing the literature and developing the guideline, the team identified several areas for further research. It would be beneficial to conduct
Figure 1  Blank Children’s Hospital’s poster on length measurement procedures showing proper positioning of children.

Health professionals and parents are interested in the growth of children. Growth is an important health indicator in children. Impaired or abnormal growth may be a warning of pathology.

FOLLOW THESE STEPS TO ENSURE ACCURATE AND RELIABLE LENGTH MEASUREMENT:

1. Use a CALIBRATED instrument with the necessary components.
2. Remove all clothing and shoes. Remove or loosen the diaper.
3. Remove hair ornaments and undo any hair styles upon the crown of the head.
4. Cover length board with thin cloth or soft paper. Clean instrument between uses.
5. TWO PERSONS ARE REQUIRED. Explain procedure if parent/guardian is assisting.
6. Place infant/child on length board in the supine position. NEVER leave infant/child unattended.
7. Assistant stands behind headboard and holds the crown of the head against headboard.
8. Position head in the FRANKFORT PLANE.
9. Lead measurer fully extends the body along the length board.
10. Lead measurer places one hand on both knees to fully extend BOTH LEGS flat on the length board.
11. ENSURE that head remains against headboard, shoulders and hips are not rotated; back is not arched; legs are not bent. Reposition as necessary.
12. With the other hand, lead measurer moves the footboard against the HEELS OF BOTH FEET with toes pointing upward.
13. Read measurement to the LAST COMPLETED MILLIMETER.
14. REPOSITION the infant/child and REPEAT procedure. Measure at least twice (ideally three times). AVERAGE the measurements for the final value. Record immediately.
Figure 2  Blank Children’s Hospital’s poster on height measurement procedures showing proper positioning of children.
additional research on linear growth measurement with randomized controlled trials and other studies using experimental designs. More studies should address measuring children with special health care needs and measuring premature infants inside and outside of the incubator. Studies should be designed and reported using methods that allow for comparison of measurement error and reliability.

The clinical practice guideline should be implemented and evaluated in diverse clinical settings. Evidence-based guidelines are needed for performing other types of anthropometric measurements, as well as monitoring and interpreting childhood growth patterns. The guideline will be updated within 5 years, or sooner depending upon the emergence of new scientific evidence.

Funding and Conflicts of Interest

Blank Children’s Hospital provided support for the project. The Pediatric Endocrinology Nursing Society provided partial funding for development of guideline implementation tools after the guideline was finalized. The clinical practice guideline was developed independently of influence from commercial or other interest groups.

Conclusions

Growth is an important health indicator in children. The clinical practice guideline on linear growth measurement is based on the best available evidence and was developed using rigorous methods. Prospective evaluation of the guideline was performed to ensure its validity, clarity, applicability, and feasibility and to confirm its reliability. Implementation and adoption of the guideline can assist practitioners in obtaining accurate and reliable measurement data so appropriate health care decisions can be made. Widespread dissemination and adoption of the guideline can have a significant impact on the growth monitoring of children.

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