Current Trends in Endocrinology
Vol. 9, 2017

Original Communication

Knemometry is a valuable method to estimate health in infants

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ABSTRACT

Preterm and term infants often become sick and need different forms of medical or surgical interventions. During sickness, infants' appetite decreases which results in nutritional problems. The consequences of inadequate nutrition can be changes in growth. The options to measure growth during short periods, from a few days up to one week, in unhealthy preterm infants have been limited to body weight. Weight can be hard to estimate because of intensive care limiting our possibilities to handle the infant. However, increasing weight is not always associated with good growth/health and in contrast it can be associated with decreased kidney function or given pharmacy. Knemometry is a validated and reliable method for measuring the distance from the heel to the upper side of the 90 degree-flexed knee, the knee-heel length (KHL). The daily increase in KHL is about 0.5 mm. The precision of the instrument is 0.05 mm, and therefore daily measurements can be done. The aims of this study were to 1) estimate the KHL in healthy newborns and 2) to compare KHL in unhealthy preterm-term infants up to ten months of life. The study group included about fifty term and preterm healthy (reference group) and sick infants (case group). A validated mini-knemometer produced by the Medical Technical Department at Aarhus University, Denmark was used. At each measurement, five estimations were done consecutively, and the mean value and standard deviation (SD) were estimated. The total number of occasions of analysis for each child differed. The period of analysis varied from a few weeks up to 10 months of age. A reference curve for KHL from birth up to 10 months, adjusted for preterm births, is presented. The curve shows a continuous decrease in linear growth. Four selected cases with different etiologies and outcomes are illustrated and marked in separate reference curves. Knemometry is a simple, painless, validated and reliable method to measure the linear growth rate (knee-heel length) in preterm-term infants. A normal KHL progress is associated with good health.

KEYWORDS: growth, health, infants, knemometry.

ABBREVIATIONS

KHL	:	Knee-heel length
LLL	:	Lower leg length
AGA	:	Appropriate for gestational age
SGA	:	Small for gestational age
CPAP	:	Continuous positive air pressure
CV	:	Coefficient of variation

1. INTRODUCTION

It is common that preterm and term infants become sick and need different forms of medical or surgical interventions. The consequences of sickness can be nutritional problems. Inadequate nutrition can then result in changes in growth rate. The approach to calculate growth during short periods, from a few days up to one week, in unhealthy preterm infants previously has been to estimate body weight. Changes in weight can be hard to estimate in the very preterm infants because of intensive care limiting our possibilities to handle the infant. Increasing weight is not always associated with

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good growth/health and in contrast can be associated with decreased kidney function or consequences of the given pharmacy. For instance, corticosteroids decrease the longitudinal growth. Previous studies have shown that there is a correlation between the number of doses and amount of steroid given antenatal and during neonatal period [1, 2]. After the end of repeated administration of antenatal corticosteroids there was a postnatal growth acceleration, catch up, 3-5 weeks after birth [1]. Keller *et al*. have found that short-term growth of premature infants treated with dexamethasone for BPD, was decreased for up to 72 hours after stopping therapy [2]. Comparison of given inhalations versus oral doses shows less negative effects with inhalations. The mode of treatment, long-term continuous or pulses [3] and type of administration, inhalations versus oral treatment, of steroids have different effects and disadvantages [4].

Therefore, new methods have been developed to estimate linear growth. One is knemometry, which is explored in this study. Knemometry measures the knee-heel length (KHL) also called lower leg length (LLL). Initially, it was only useable practically for older infants but nowadays there are smaller hand-held instruments that can be adapted for very preterm infants [5-7]. This method was introduced in the middle of 1980s and has been an established method [5, 8-11]. This method has been validated [6, 12] and found to be a good method for estimating short term linear growth [1, 2, 7, 13, 14]. There is a good correlation between KHL/LLL and weight and/or postmenstrual age [7, 15].

2. MATERIALS AND METHODS

The knemometer, is an electronic caliper that measures the distance between two plates, from the heel to the upper side of the 90 degree-flexed knee, the knee-heel length (lower leg length (LLL)). The infant is positioned on the left lateral position (with the right side free) or supine. The knee is placed against the fixed plate while the leg is gently held in place. The sliding arm is then gently pushed against the heel until a predetermined pressure is applied, triggering data recording. This process is repeated five times for each measurement. Each individual measurement is recorded and the mean and variance of each set of five readings are calculated.

The time period to learn the above process, i.e. to measure the KHL, is rather short. The precision of the instrument is very high. The technical error for repeated measurements with one observer during a 3-week period was 0.04 mm, which corresponds to a coefficient of variation (CV) of 8% [12]. The normal growth rate for the knee-heel length is about 0.5 mm/day, which corresponds to 25% of the total longitudinal growth (crown-heel-length), and therefore daily measurements can be done. Previous studies have found that 5 consecutive measurements are optimal [12]. Previous studies have included both preterm and term infants and time intervals between measurements have been daily to weekly or varied [5, 8, 12, 14, 15]. The clinical experience is that even the normal 5-10% weight reduction, during the first days of life, results in an increase in body length. The knee-heel length increases at a constant rate, from day to day, during the first week of life.

2.1. Knemometer used

A knemometer produced by the Medical Technical Department at Aarhus University, Denmark was used; see Figure 1. The instrument was previously validated by Professor Michaelsen, Institute of Clinical Nutrition, Copenhagen, Denmark [6]. At each occasion of measurement, five consecutive measurements were done, and the mean value and standard deviation (SD) were estimated. The total number of occasions of analysis for each child differed. The period of analysis among participants varied from a few months up to five years of age. The aim of the study was primarily to estimate the knee-heel length during the first ten months of life in healthy newborns and secondarily to compare the growth rate in a selected group of preterm-term sick infants during spontaneous recovery and during/after specific treatment.

2.2. Study group

The study group included about fifty term and preterm healthy and/or seriously sick infants. First, we measured a group of healthy infants at specific intervals during their first ten months of life, representing the reference group. Thereafter, we measured a small group of sick term and preterm infants, the case group. Then, the groups were compared.

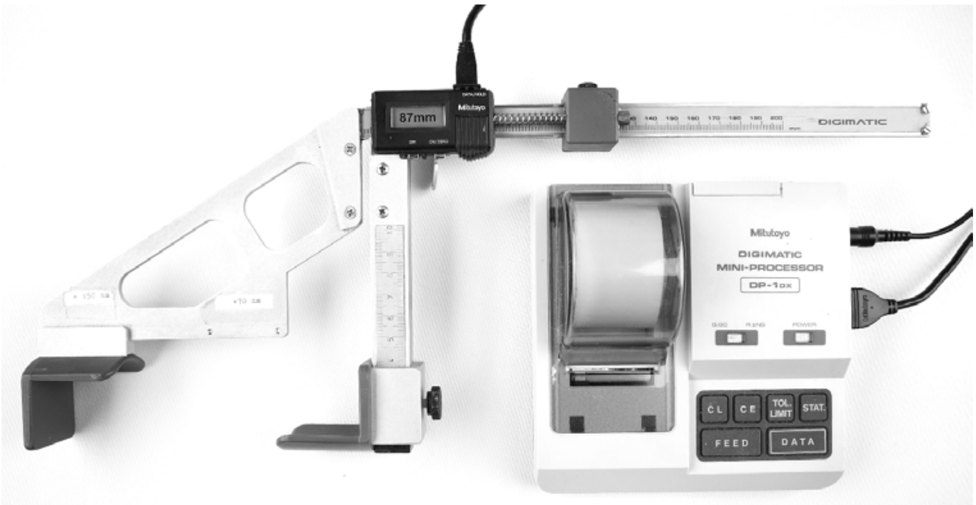

Figure 1. Knemometer and mini-calculator used in the study.

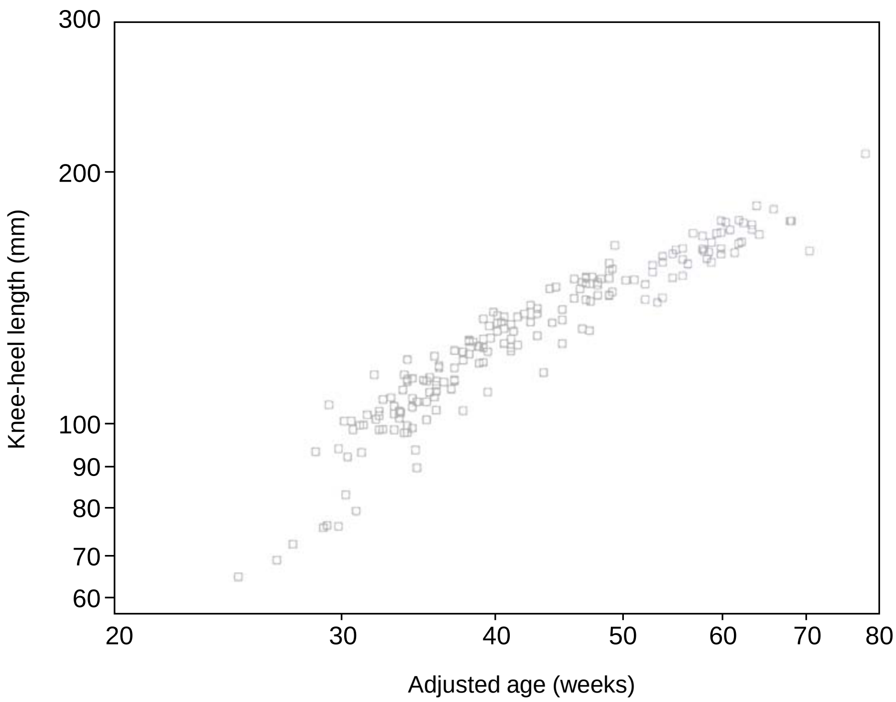

Figure 2. Reference curve for knee-heel length adjusted for age.

2.3. Ethics

An oral consent from each parent was obtained before their participation.

3. RESULTS

All KHL measurements were performed by the author. After recording all knee-heel length results these values were converted to a graphic form. A reference curve for knee-heel length from birth up to 10 months of age, adjusted for age in preterm births, was estimated. This reference curve shows a symmetric distribution of knee-heel length points in relation to adjusted age. The reference curve is presented in Figure 2.

This report also presents four cases with different etiologies and outcomes, illustrated and marked in the reference curves (Figures 3-6).

3.1. Presentation of cases

3.1.1. First case

It is a healthy preterm twin pair born after 36 weeks of age. They grew well. Their KHL progresses are illustrated in Figure 3.

3.1.2. Second case

These two siblings were born after full term (38 weeks). Both had a maternal thyroid receptor antibody-induced transient neonatal thyrotoxicosis requiring pharmacy. The first child (2A) was treated with Thacapzol™ and Levaxin™ and the other girl (2B) was treated only with propanolol (Inderal ™) with success. Their birth weights and lengths were normal, 3300 g/49.0 cm and 3052 g/ 49.0 cm, respectively. Their KHL progresses are illustrated in Figure 4.

3.1.3. Third case

It was a girl born after 26 weeks of gestation. Her birth weight and length were 815 g/34.0 cm, and her body proportions were appropriate for gestational age (AGA). Initially, she had a respiratory distress syndrome requiring continuous positive air pressure (CPAP). In her third-fourth day of life she had necrotizing enterocolitis and a bowel perforation. Then, she required assisted ventilation and surgical treatment for the bowel perforation. Twenty cm of ileum was resected and she got a double ileostomy. She required ileostomy for 14 weeks. She was fed breastmilk and additional Pepti-junior™ with success. She was well at six months of age, actual weight 3840 g and length 52.5 cm. When compared her growth rate for length it was slower than that of age-matched healthy neonates/infants, as shown in Figure 5.

3.1.4. Fourth case

This girl was born after 27 weeks of gestational age, extremely small for gestational age, with a birth weight of 448 g and birth length of 25.0 cm. Her minimum weight, at her third day of life, was 372 g! She never required assisted ventilation in spite of recurrent septicemia, severe cholangitis and peritonitis requiring treatment with ampicillin, metronidazole, ceftazidim and fat-reduced nutrient,

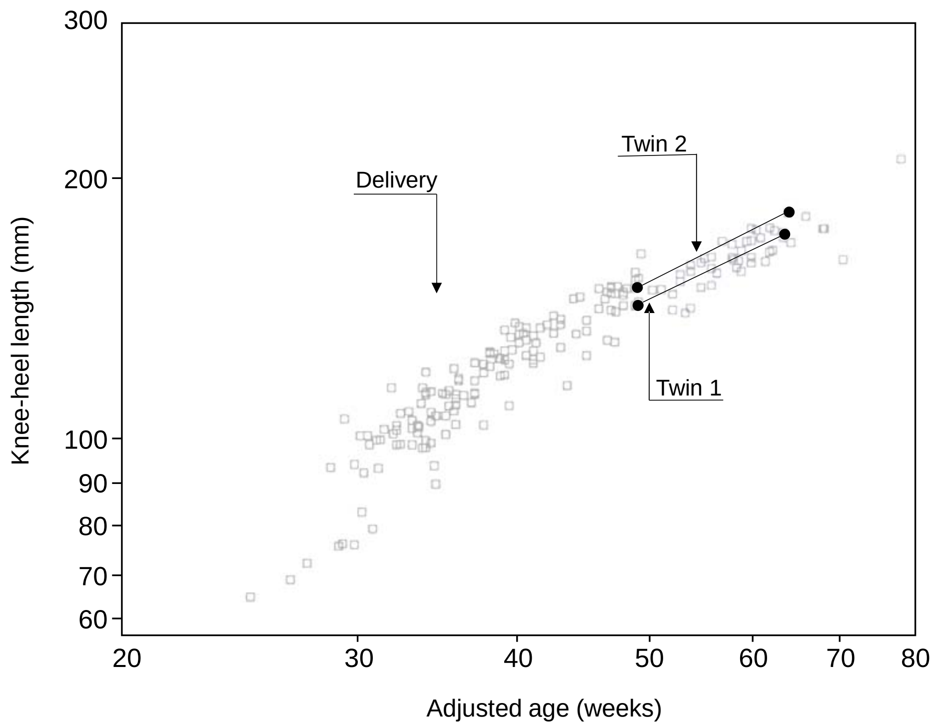

Figure 3. Preterm healthy twin pair.

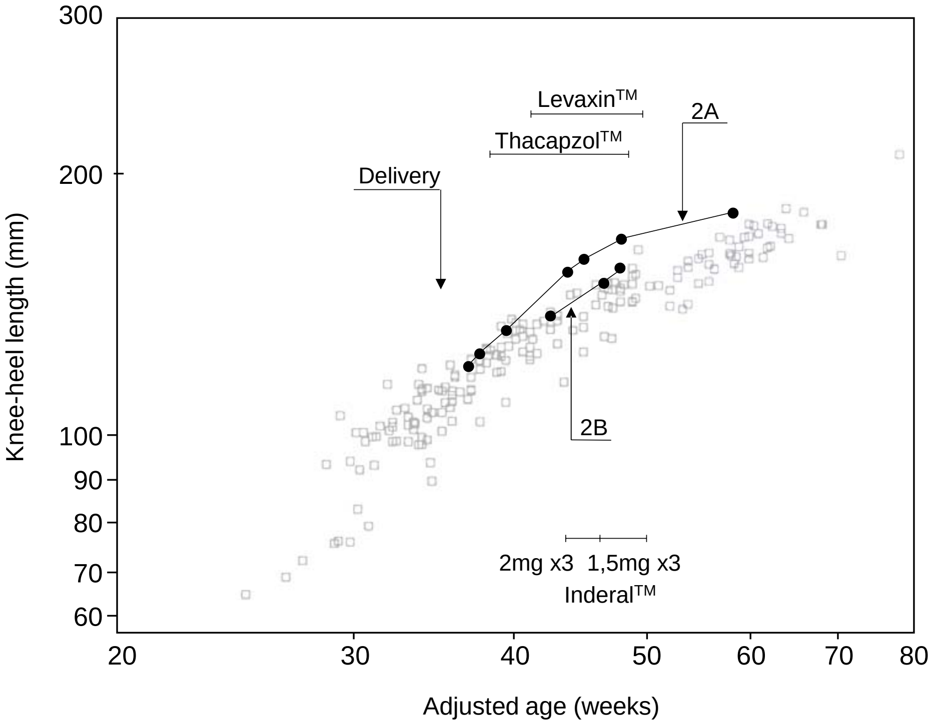

Figure 4. Maternal-induced neonatal thyrotoxicosis in two siblings.

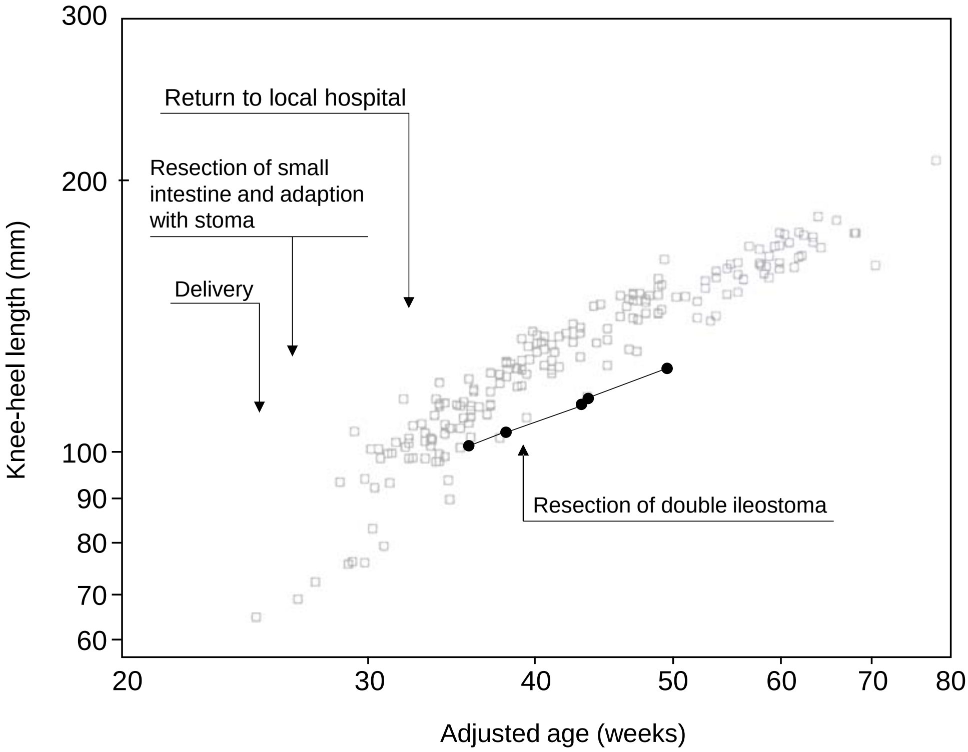

Figure 5. Premature infant with necrotizing enterocolitis and double ileostomy.

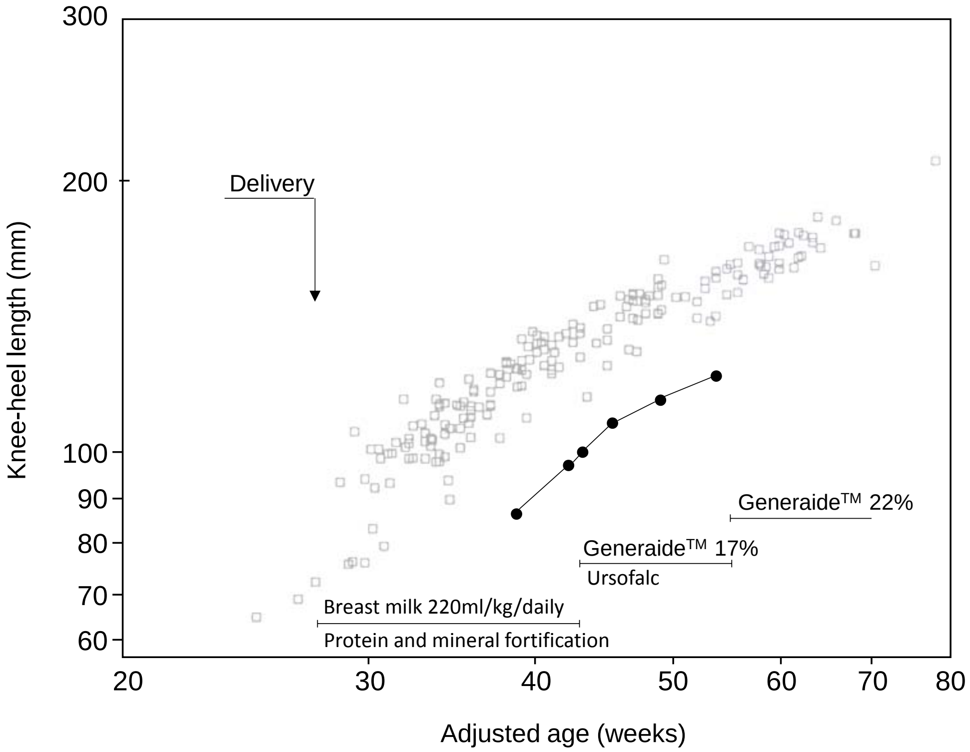

Figure 6. Extremely premature, small for gestational age infant with cytomegalovirus infection.

Generaide™. Her cholangitis was possibly caused by a cytomegal virus infection/hepatitis after a blood transfusion. Her growth rate, both weight/length, and head circumference, was very fast after treatment. Her body weight was increased more than 10-fold after 8 months of age. At 4 years of age she was diagnosed with Silver Russel syndrome and she started treatment with growth hormone up to 14 years of age with success. At 17.5 years of age her length was 150.0 cm and her weight was 48 kg. She was in full puberty. The only sequela was a moderate one-sided non-neurogenic hearing loss.

During her first 10 weeks of life, the KHL increased with a little catch up. Thereafter, her linear growth decreased and her KHL was abnormal. For details see Figure 6.

4. DISCUSSION

4.1. Measurement of linear growth

Nowadays, intensive care of premature infants is very successful with few pulmonary, cardiovascular and neurologic sequelae. However, to optimize the outcome including linear growth even more you also have to control blood electrolytes, liver function, gastrointestinal loss and urine content loss and lastly give adequate supplements with minerals, vitamins and reduce energy loss. Multiple analyses of biochemical parameters such as growth factors IGF1, IGF BP3, IGF BP1, collagen-synthesizer and destructing factors in blood can be valuable. Previous studies have found that lower leg length (LLL) and growth rate were well-associated with concentrations of IGF1, IGF BP3, Phosphorylated IGFBP1 and different factors involved in the synthesis of collagen such as Procollagen type 1C-terminal propeptide (PICP) or collagen breakdown (Type I collagen telopeptide (ICTP)) [16]. These blood samplings can be hard to do and difficult to evaluate and moreover there can be some delay in analysis and obtaining results. However, conversely the KHL gives an easy, immediate, accurate analysis of the linear growth and health condition. Previously, the linear growth has been difficult to measure in very premature infants. Nowadays, new mini-knemometers can give us a valid view of the progress [7, 13]. It is important to follow the linear growth rate because a non-optimal linear growth in the first period of life can result in a decreased final length. In this study, the knee-heel length (KHL) was measured repeatedly in a small cohort during their neonatal period and policlinic follow-up up to 10 months of age. All measurements and analyses were performed by the author. The knemometer used in this study was identical to the previously validated instrument of Michaelsen with very good results, a technical error of 8% and a mean error of 0.04 mm/day when measuring during a 3-week period [6]. From the results of KHL measurements, a reference curve for healthy preterm infants was constructed. This reference curve shows a symmetric distribution of knee-heel length points in relation to adjusted age. The reference curve seems to agree with previous curves constructed using similar mini-knemometers [7, 14].

4.2. Cases presented

The four case reports presented herein represent different ages, health conditions and treatment given. It is obvious that there is a decrease in linear growth during sickness and a catch up in linear growth after severe diseases/sickness when care/health is optimized. Therefore, repeated measurements of KHL can give an adequate view of the health of the infants.

4.3. Limitations and strengths of the method

4.3.1. Limitations

Learning period: At the start, there are some difficulties in handling the instrument, to ensure a correct 90^{o} angle of the knee and to fix the heel correctly to the sliding metal plate. Therefore, the inter-observer difference is up to 20% at start of the learning period but decreases to about 5% when optimal. If the premature infant has swollen legs and/or heels there could also be mismeasurements.

4.3.2. Strengths

The method is nearly painless, simple to perform, and measurements are automatically registered when a predetermined pressure is applied against the heel-plate and the variance of repeated analyses (mean, SD) is automatically calculated and recorded immediately. The technical error is low and therefore daily measurements are possible to do [6]. One more advantage of the method is that you can measure the linear growth even during periods of severe sickness. Then there can be nutritional deficiency and serum protein/albumin decreases which can cause water retentions and given false weight gain simulating good health.

5. CONCLUSION

Knemometry is a simple, painless, validated and reliable method to measure growth rate (knee-heel length) longitudinally in preterm-term infants during and after spontaneous recovery and/or after specific treatment up to ten months of age. The linear growth rate (KHL progress) is well-correlated with the infants´ health.

ACKNOWLEDGEMENTS

Many thanks to all parents and infants who participated.

FUNDS

None.

CONFLICT OF INTEREST STATEMENT

There is no conflict of interest.

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