Diurnal variation in stature: is stretching the answer?

L D Voss, B J R Bailey

Abstract

***Aims*—To investigate the extent and timing of diurnal variation in stature and to examine the effectiveness of the stretched technique in reducing the loss in height.**

***Setting*—A Southampton school.**

***Design*—Fifty three children, divided into two groups, were measured by two independent auxologists using a Leicester height measure. Each child was measured four times, at 0900, 1100, 1300, and 1500, using both an unstretched and a stretched technique.**

***Outcome measures*—Height loss after each of the three time intervals for both unstretched and stretched modes.**

***Results*—There was a clear decrease in stature during the morning, but no further loss occurred after the subjects had been up for around six hours. The mean height losses for the unstretched (stretched) modes were 0.31 cm (0.34 cm) and 0.20 cm (0.23 cm) for the periods 0900 to 1100 and 1100 to 1300, respectively, but only 0.045 cm (-0.019 cm) from 1300 to 1500. Stretching did not reduce the effects of diurnal variation, but significantly affected the recorded height by an average of 0.28 cm. There was no significant difference in reproducibility using either technique (SD 0.30 cm stretched *v* 0.31 cm unstretched).**

***Conclusions*—Diurnal variation in stature may substantially affect the reliability of height data and careful consideration should be given to the timing of repeat measurements. As most height loss occurs in the morning, afternoon clinic appointments would be preferable. The standard stretched technique does not appear to reduce diurnal variation, nor does it affect precision. Measurements made using an unstretched method are recommended to avoid interobserver differences, known to occur where different observers are used.**

(*Arch Dis Child* 1997;**77**:319–322)

Keywords: diurnal variation; height measurement; measurement technique

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Accepted 2 July 1997

The importance of minimising measurement error in the assessment of growth has been well documented.[1–4] One potentially significant source of error, diurnal variation in stature, first noted in 1724,[5] has, however, been largely ignored in clinical practice. Early studies, reviewed by Redfield and Meredith[6] and Boyd,[7] were conducted with varying degrees of scientific rigour, but did confirm the presence of diurnal variation in the adult. Most agreed that the total loss amounted to between 2 and 3 cm, and the evidence suggested that the greater proportion of the decrease in height was occurring in the trunk.

Similar effects have been shown in children,[8–13] some studies also showing that much of the height loss can be restored by taking a short nap.[7 14] Almost all reports agree that the greater proportion of the decrease in stature appears to occur soon after rising,[6 9 10 12] though it is assumed that, without a nap, further loss continues throughout the day.

There is some disagreement about the total daily loss to be expected, but no two studies have measured their subjects over exactly the same period. Some studies used so few children that their results are dependent on the particular characteristics of those individuals. Even in studies using larger numbers, one found a mean decrease in height of 1.54 cm in 100 children between rising and late afternoon, whereas another found a mean decrease of just 1.0 cm in 70 boys between early morning and bedtime.[8 10]

At the end of the last century attempts were made, largely by the physical anthropologists, to standardise the method of measurement.[15] Technique has changed little over the years, clinicians showing little interest in the subject. A stretching technique did become widely adopted about 20 years ago, however, after Whitehouse *et al* suggested that 'gentle upward pressure on the mastoid processes' could minimise the effects of diurnal variation.[11] Indeed, these authors claim to have shown that, using this technique, loss in stature between morning and afternoon, though not entirely eliminated, can be reduced to a maximum of 0.46 cm. Thomsen *et al* have compared the precision or reproducibility of the stretched and unstretched methods and report no difference.[16]

The aims of the present study were twofold: (a) to ascertain the time of day at which height loss effectively ceases; and (b) to examine the effectiveness of stretching in reducing diurnal variation in height.

Subjects and methods

Fifty three children, aged from 3 years 1 month to 11 years 0 months were divided into two groups of 27 and 26 and were measured by two independent, experienced auxologists (LDV and PM). Each subject was measured on four occasions close to 0900, 1100, 1300, and 1500, always by the same observer (LDV or PM), using the Leicester height measure. The preci-

sion of this instrument has already been reported.[4] On each occasion the subjects lined up in random order and were measured twice. The first measurement used an unstretched technique whereby the subject was placed in the correct position, with the head in the Frankfurt plane, but no further contact was made with the child, nor any verbal instructions given, while the cursor was brought down to rest on the child's head. With the child still standing in the same position, the second measurement was made with the observer placing both hands under the child's mastoid processes and applying the usual gentle upward traction. This procedure allowed investigation of the errors involved in the measurements and, in particular, their correlation. All measurements were 'blind'—that is, an independent recorder noted the heights on every occasion, giving the measurer no feedback on performance.

To be able to pool the data from the two observers, a further group of 20 children was measured, on one occasion only, by both auxologists (LDV and PM), each on her own stadiometer, in both the unstretched and stretched positions. This allowed the estimation of any differences in the mean heights achieved on the two instruments so that any necessary corrections could be made to the data arising from the main group of 53 children.

Results

The measurements on 20 children made by both auxologists revealed that one of them (LDV) produced a mean height greater than the other (PM) by 0.20 cm in the unstretched position and 0.18 cm in the stretched. The near equality of these two values suggests a slight difference in the settings of the two instruments being used, despite their being self calibrating, rather than a difference in measuring techniques. Moreover, as the two values were significantly different from zero ($p = 0.027$ and $p = 0.015$, respectively), the heights obtained by PM were increased by the above amounts in the ensuing analysis. (As this is based essentially on differences between height measurements, it is immaterial whether one auxologist's observations are increased or the other's decreased.)

Table 1 summarises the results of the main experiment with the 53 children. The mean height losses between 0900 and 1100 and between 1100 and 1300 were highly significantly different from zero ($p < 0.001$) whether measured in the stretched or unstretched mode. The mean for the second of these intervals was noticeably smaller than for the first. By the end of the second interval the children's heights effectively levelled out so that the height loss between 1300 and 1500 did not differ significantly from zero (p=0.44 for unstretched, p=0.75 for stretched). The mean (range) loss over the whole six hour period was 0.555 cm (1.9 to −0.4 cm) unstretched and 0.551 cm (1.8 to −0.6 cm) stretched. Figure 1 shows the individual losses.

Table 1 Mean height loss of 53 children over three two hour time intervals, together with the accumulated six hour loss for unstretched and stretched modes. The SE of each entry is 0.059 cm, for each unstretched decrement, or 0.060 cm, for a mean stretched decrement

	Mean height loss (cm)	
Period	Unstretched	Stretched
0900–1100	0.31	0.34
1100–1300	0.20	0.23
1300–1500	0.045	−0.019
0900–1500	0.555	0.551

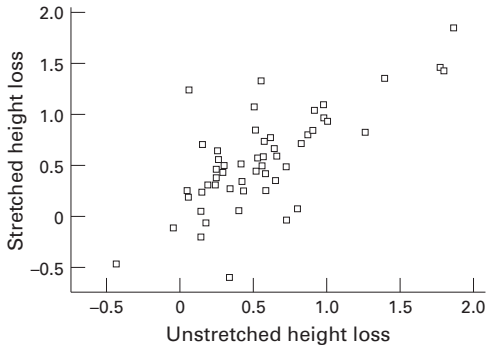

Figure 1 Scatter diagram of total height loss (cm) recorded on 53 children between 0900 and 1500, measured in stretched and unstretched modes.

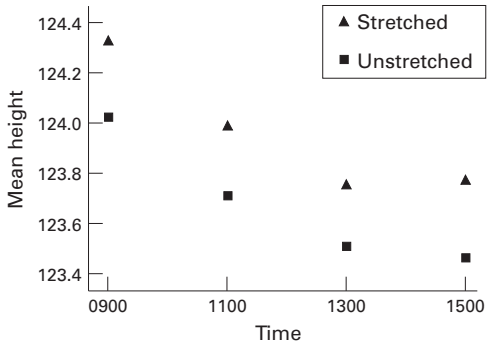

Figure 2 Mean heights (cm) of 53 children, aged 3–11 years, measured on four occasions during the course of one day, using both stretched and unstretched techniques.

Figure 2 clearly shows that, on average, stretching added a constant amount to the unstretched height, but did nothing to reduce the diurnal loss of height. The degrees of stretching on the four occasions did not differ significantly ($p = 0.39$), with the result that the effect of stretching can be said to have increased the height, on average, by 0.28 cm in this experiment. (In view of the large number of observations it would be possible to construct a narrow confidence interval around this value. This would, however, be of use only to the two particular auxologists who carried out these measurements because, as we have described previously, different measurers can effect quite different degrees of stretching on their subjects.[2 4])

The SD of a single stretched height measurement found in the main experiment, 0.31 cm, is compatible with the value (0.25 cm) found by us previously.[2–4] The SD for a single unstretched measurement, 0.30 cm, might be expected to be somewhat smaller. The extra variability arising from the stretching

procedure is, however, offset by the negative correlation between the unstretched height and the extension due to stretching, estimated to be −0.32. A child who happens to stand tall on a particular occasion cannot be stretched by as much as when standing in a more relaxed manner.

Discussion

These results have important implications regarding current practice and the assessment of growth, particularly for the individual child. Firstly, little consideration is ever given to the timing of follow up visits to the clinic. Secondly, while training in measurement techniques is usually considered to be essential, little attention has been paid to the problem of interobserver error.

The present data confirm both the existence of diurnal variation and that the greater proportion of the height loss occurs during the earlier part of the day. Over the period 0900 to 1500 we found an average decrement of around half a centimetre, though several children lost well over 1 cm regardless of the method used (fig 1). On average, the largest decrement occurred during the first time interval, 0900 to 1100. Had we been able to measure the children immediately after rising, the period before 0900 would almost certainly have seen the greatest loss of height, but as few clinic appointments are earlier than this it is only of academic interest. It is of more importance to ensure that a height first recorded at 0900, for example, is not remeasured on a subsequent occasion at 1100 or 1300, but as close as possible to the original time. Even half a centimetre represents a substantial proportion of a child's annual rate of growth and will make a significant contribution to the total error.

Once a child has been up for six or seven hours there appears to be no further discernible loss of height—the timing of afternoon appointments can therefore be more flexible and measurements made after 1300 can be repeated at any other time in the afternoon.

Though commonly used, the technique of stretching does not appear to have any advantages. It simply *increases* the measured height, in this case by almost 3 mm. This amount appears to remain constant, irrespective of the time of day at which the height is measured. Until recently, most growth charts recommended 'gentle upward pressure to the mastoid processes' to ensure that the 'maximum height' was recorded. In at least one revised version the maximum height has become the 'true height'. There is some confusion over this term; there can be no such thing as the 'true height' of an animate body, only a mean height, with variability about it. This mean height will be greater or smaller depending on whether the child is stretched or not. Greater, in this instance, does not mean better. The aim is not to record the maximum height possible, but a height that can be easily reproduced.

The amount of height lost between 0900 and 1500 was almost identical using stretched (0.55 cm) and unstretched (0.56 cm) techniques. Stretching was therefore ineffective in reducing the stature lost during the course of the day, as suspected by Buckler.[12] Whitehouse *et al* had previously concluded that their new method had at least some effect in reducing diurnal variation.[11] They attributed their relatively small observed decrement (comparable with ours) to 'gentle upward pressure on the mastoid processes and verbal urging to reach upward'. Their children had also been up for a little while before the first measurement, however, and were therefore unlikely to shrink by the larger amounts reported by earlier observers. They also, crucially, did not include any unstretched measurements in their study. Had they done so, it might have been clear that, regardless of technique, only a small decrement was likely to be observed at that time of day.

This study confirms previous reports that measurements made by experienced observers using stretched and unstretched techniques are equally reproducible.[4 16] There is therefore no advantage of one method over the other in terms of the *precision* of the growth data obtained. Where there is a single experienced observer the method used is ultimately a matter of personal preference. Of more importance is the need to ensure the same method is used on subsequent occasions so that any increments observed in height are likely to be real and not attributable to differences in positioning or technique.

We have previously shown (though not on this occasion) that where stretching is used two observers, using ostensibly the same technique and the same instrument, can obtain significantly different mean heights for the same group of children.[2 4] Any difference in height obtained by two measurers over an interval of time is therefore likely to be due, in part, to the degree of stretching each observer uses. An unstretched technique removes this source of variability and is more easily reproduced from one measurer to another. There might therefore be a positive advantage in using this technique in situations where different observers will be monitoring the same child. Indeed, if universally adopted, differences between observers could be significantly reduced.

Conclusions

Diurnal variation in stature may substantially affect the reliability of height data and careful consideration should be given to the timing of repeat measurements. Even after a child has been up for two hours or so, further loss of height, amounting on average to half a centimetre, can be expected during the course of the morning. As little further loss of height is likely thereafter, growth clinics should, ideally, be held in the afternoon. The standard stretched technique does not appear to eliminate the effects of diurnal height loss, nor does it improve precision. Measurements made using an unstretched method are recommended to minimise interobserver error, known to occur where different observers are used.

We thank the pupils and staff of St Winifred's School, Southampton, for making this study possible. Grateful thanks are also due to Jean Mulligan, Pauline Mussen (PM), and Pat Tahmasaby for their assistance. LDV is supported by a grant to the Wessex Medical Trust from Pharmacia Upjohn.

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