Evaluation of Growth Rate in Height over Periods of Less than One Year

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Marshall, W. A. (1971). *Archives of Disease in Childhood*, **46**, 414. **Evaluation of growth rate in height over periods of less than one year.** The stature of 260 well-nourished children aged between 7 and 10 years was measured at intervals of approximately 1 month over 13 months. The growth rate of each child was calculated over periods of 3 months and 6 months ending in each month of the year. Children who missed one or more measurements, due to absence from school, were excluded from the calculations

Centiles of growth rate for these periods are presented. A growth rate of 3–4 cm/yr is well within normal limits for a period of 3 or 6 months ending in December or January, but is below the 10th centile for periods ending between March and June.

Most children reach their maximal 3-monthly rates in the periods of either 3 or 6 months ending between March and July, and their slowest in the periods ending between September and February.

A child's growth rate over the 3 months of fastest growth is most frequently 2 to 3 times his slowest rate, but may be 7 or more times the slowest if the latter was very low. There may be no measurable growth during a single period of 3 months in a normal child, but maximal rates of up to 10 cm/yr are not necessarily abnormal. An individual's maximal 6-monthly rate may be up to 3 times his minimal.

A satisfactory assessment of a child's growth cannot be made over a period of less than one year.

Charts and tables showing the variation in growth rate of normal children at different ages have been published by Tanner, Whitehouse, and Takaishi (1966). The data given in that paper represent the average growth rate over periods of one year. Strictly speaking, their clinical use is therefore limited to the evaluation of growth rate in children who have been measured at intervals of approximately a year. In practice, it is often convenient to measure children at intervals of 3 to 6 months. From any pair of measurements on the same child it is possible to express his growth rate in centimetres per year by dividing the increment in height by the time interval between the two measurements. However, normal children tend to grow in stature more quickly in the spring and early summer than they do in the autumn and winter (for review see Fitt, 1941; more recent papers by Reynolds and Sontag, 1944; Bransby, 1945; Robson, 1964; and Takahashi, 1966). As the charts of Tanner *et al.* are based on the rate of growth over the whole year, the lowest normal rates in the spring and summer will be higher than the lowest normal yearly rate. Conversely, if a child is measured in June and December (in the northern hemisphere) his rate of growth in centimetres per year may appear subnormal in relation to the yearly chart but in fact be quite normal.

The existing literature is concerned mainly with seasonal differences in growth rate of groups of children. There is little information on the variation between individuals in different seasons and none of this is suitable for clinical use. There is also little known about the extent to which the individual child's growth may vary between one season and the next. Bransby (1945) states that, in the year 1941–42, only 27–29% of the children he studied had their smallest increase and 33–36%

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had their greatest increase in the same season as the groups of which they formed part. The children were measured in June, September, December, and March. He concluded that relatively few individual children conform to the average seasonal pattern.

The data presented in this paper include centiles of growth rate in normal preadolescent schoolchildren over periods of 3 and 6 months at different times of year; the data also include the distribution of months in which maximal and minimal growth rates may be observed in normal individuals and the relation between the maximal and minimal rates in individuals.

Subjects and Methods

The subjects were 260 well-nourished children (143 boys, 117 girls) attending a state primary school in a London suburb. The distribution of their ages at the beginning of the study is shown in Table I. This age range was chosen as the one in which there is least overall change in the annual growth rate, so that the seasonal variations would not be obscured by the overall deceleration of growth in the first few years of life or by the adolescent growth spurt. The stature of each child was measured at intervals of approximately one month for a period of 13 months. No measurements were taken during August as the children were on holiday. A Harpenden stadiometer was used with the technique described by Marshall (1966). All measurements were taken by the same experienced observer. Several children missed one or more measurements through minor illness. Each absence resulted in the loss of two measures of growth velocity, i.e. the velocity over the period ending on the day of absence and the velocity over the period beginning on that day.

The maximum number of measurements of velocity over separate 3-month periods that could be obtained for any one child was nine. Seven or more were obtained for 92 boys and 67 girls. The remaining children were excluded from analysis of the data. The maximum number of velocities over 6-month periods which could be observed for any one child was six. Five more were observed for 106 boys and 79 girls.

Results

Each child's growth rate was calculated over every period of 3 or 6 months for which data were available. The stature at the beginning of the period was subtracted from that at the end. The difference was divided by the exact time interval between the two measurements, expressed as a decimal of a year, to give a growth rate in cm per year. The mean and standard deviation of the growth rates over each period were determined and, from these results, the centiles were calculated.

Seasonal changes in growth rate of whole sample. Table II gives the centiles of growth rate over the three-month period preceding the dates stated. The dates are expressed as decimals of the year. The relation between decimal dates and calendar dates is shown in the Appendix. For example, the figures corresponding to the date '0·400' give the centiles of growth rate (in cm/yr) during the interval March to June. If a patient is measured in June having been previously measured in March, his stature increment (in cm) divided by the time interval between the two measurements (as a decimal of the year) gives the growth velocity which may be compared with the table, in the row 0·400–.

Table III is similarly constructed but gives velocities over the 6-month period preceding each of the stated dates.

The tables were incomplete because measurements were taken only over 13 months and therefore velocities could not be calculated for the 3 or 6 months preceding all calendar months. In order to complete the table the assumption was made that each child's growth velocity had been the same in each month of the preceding year as it was in the year in which the observations were made. On this basis each child's stature was estimated for each of the 6 months before he was first measured. The velocities based on actual observations will be referred to as 'observed data'. Those obtained from both observed and estimated statures will be referred to as 'cycled data'.

Fig. 1 and 2 are charts prepared from cycled data. The velocity centiles for the 3 or 6 months preceding each calendar month were plotted and the resulting curves smoothed by eye. The sexes are

TABLE I

Age Distribution of Subjects at Beginning of Study

Age (yr)	7·0–7·49	7·5–7·99	8·0–8·49	8·5–8·99	9·0–9·49	9·5–9·99
Boys	12	42	34	35	19	1
Girls	7	31	35	26	18	—
Total	19	73	69	61	37	1

TABLE II

*Centiles of Velocity (cm/yr) over Periods of 3 Months Ending Within Limits of Decimal Date Stated for Children aged 7–10 years in January**

Date	SD	3rd	10th	25th	Mean	75th	90th	97th
Boys								
0·000–	1·2	1·8	2·5	3·3	4·1	4·9	5·6	6·3
0·100–	1·9	2·0	3·1	4·3	5·5	6·8	8·0	9·1
0·200–	1·6	3·9	4·8	5·8	6·9	7·9	8·9	9·9
0·300–	1·6	3·5	4·5	5·5	6·6	7·7	8·7	9·6
0·400–	1·6	3·3	4·3	5·2	6·3	7·4	8·4	9·3
0·500†–	1·7	3·5	4·5	5·5	6·6	7·7	8·8	9·7
0·700–	1·2	3·0	3·7	4·4	5·2	6·0	6·7	7·5
0·800–	1·3	2·1	2·8	3·6	4·5	5·3	6·1	6·9
0·900–	1·5	1·9	2·8	3·7	4·7	5·7	6·5	7·4
Girls								
0·000–	1·5	1·5	2·4	3·4	4·4	5·4	6·3	7·2
0·100–	2·0	1·7	2·9	4·2	5·5	6·9	8·1	9·4
0·200–	1·9	3·2	4·4	5·5	6·8	8·0	9·2	10·3
0·300–	1·7	3·4	4·5	5·5	6·7	7·9	8·9	10·0
0·400–	1·9	2·9	4·0	5·2	6·5	7·7	8·9	10·0
0·500†–	1·8	3·8	4·9	6·0	7·3	8·5	9·6	10·7
0·700–	1·4	2·9	3·7	4·5	5·4	6·4	7·2	8·0
0·800–	1·4	2·0	2·8	3·7	4·7	5·6	6·5	7·3
0·900–	1·6	1·8	2·7	3·7	4·7	5·8	6·7	7·7

*For relation between decimal date and calendar date see Appendix.
†There are no data corresponding to date '0·600–' as the children were not measured in August.

TABLE III

*Centiles of Velocity (cm/yr) Over Periods of 6 months Ending within Limits of Decimal Date Stated for Children aged 7–10 years in January**

Date	SD	3rd	10th	25th	Mean	75th	90th	97th
Boys								
0·000–	0·9	2·7	3·2	3·7	4·3	4·9	5·4	5·9
0·100–	1·2	2·9	3·6	4·4	5·2	6·0	6·7	7·4
0·200–	1·2	3·3	4·0	4·8	5·6	6·4	7·2	7·9
0·300–	1·2	4·0	4·7	5·4	6·2	7·0	7·7	8·4
0·400–	1·1	4·6	5·2	5·9	6·7	7·5	8·1	8·8
0·500–†	1·2	4·4	5·2	5·9	6·7	7·6	8·3	9·0
0·700–	0·9	4·0	4·5	5·0	5·6	6·2	6·7	7·2
0·800–	0·9	3·5	4·0	4·6	5·2	5·9	6·4	7·0
0·900–	0·9	2·9	3·4	3·9	4·6	5·2	5·7	6·2
Girls								
0·000–	1·2	2·3	3·0	3·7	4·5	5·3	6·0	6·7
0·100–	1·3	2·7	3·6	4·4	5·3	6·2	7·0	7·8
0·200–	1·3	3·1	3·9	4·7	5·5	6·4	7·2	8·0
0·300–	1·3	3·8	4·5	5·4	6·2	7·1	7·9	8·7
0·400–	1·3	4·2	5·0	5·7	6·6	7·4	8·2	9·0
0·500†–	1·4	4·4	5·3	6·1	7·1	8·0	8·9	9·8
0·700	1·4	3·3	4·1	5·0	5·9	6·8	7·7	8·5
0·800–	1·1	3·4	4·1	4·8	5·5	6·3	6·9	7·6
0·900–	1·0	3·0	3·5	4·1	4·8	5·5	6·1	6·7

*For relation between decimal date and calendar date see Appendix.
†There are no data corresponding to date '0·600–' as the children were not measured in August.

combined. As the 3-monthly data were obtained from only 159 children, and the 6-monthly data from 185 children, the position of the outer centile lines is necessarily an approximation. Nevertheless, the charts are sufficiently accurate to assess the normality of an individual's growth rate for clinical purposes. The child's growth velocity over the preceding 3 or 6 months should be plotted against the month on which the second measurement was taken: not at the mid-point of the time interval between measurements as is done with the charts of Tanner *et al.* (1966).

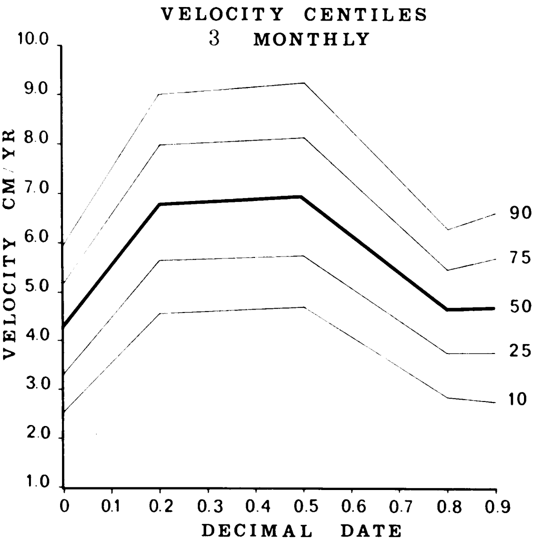

FIG. 1.—*Centiles for growth velocity over 3-monthly periods. The time scale represents the decimal date at the end of the period of observation. The scale should be read only opposite the printed numerals, as each interval on the time scale represents the period of a tenth of a year which follows it. Thus, for example, an observation ending between dates 0·1 and 0·199 should be read at the mark 0·1 on the scale. Similarly, any date between 0·2 and 0·299 should be read at 0·2. Sexes combined; aged 7–10 in January.*

The mean rate of growth of the whole sample, over the whole year, was 5·6 cm/yr. This is an average of children whose ages varied between approximately 7·25 and 10·25 at the end of the year. According to Tanner *et al.* (1966) the mean velocity over the year ending at age 7·25 years is 5·8 cm/yr. The mean velocity over the year ending at age 10·25 years is 5·21 cm/yr. Strictly speaking to allow for this change in overall velocity with age, a correction should be applied to a child's measured velocity before it is compared with the charts. For example, in the case of a child aged 10·25, 0·4 cm/yr should be added to his 'whole year' velocity to make it comparable with the charts. The proportion of this 0·4 cm which would be grown in a given season would however be unknown and, even if it were known, would be so small as to be within the limits of error of the original measurement of velocity. The age correction can therefore, for practical purposes, be ignored.

Fastest and slowest growth in individuals. Fig. 3 shows the number of boys in whom the fastest and slowest 3-monthly periods of growth ended in each month. Both cycled and observed data are represented.

The essential character of the distributions is not altered by the cycling, though some maximum and minimum rates are found in February and March. The observed data gave no information about 3-

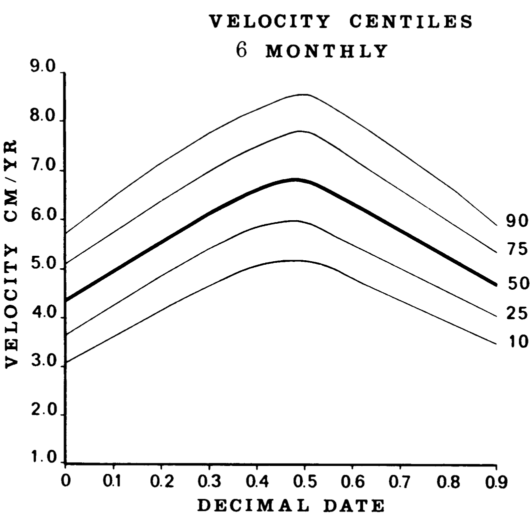

FIG. 2.—*Centiles for growth velocity over 6-monthly periods, otherwise as for Fig. 1.*

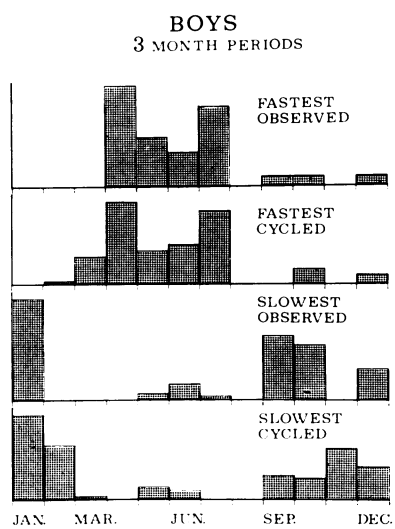

FIG. 3.—*Distribution of months in which individual boys completed their fastest and slowest periods of growth over 3 months.*

month periods ending on these months. Fig. 4 shows the corresponding data for 3-month periods in girls. The months at the end of the fastest and slowest 6-month periods of growth are shown in Fig. 5 and 6.

In the observed data, the fastest and slowest velocities over 3-monthly periods were determined for each child, regardless of the times of the year at which these velocities occurred.

The mean of the fastest rates for boys was 8·15 ± 0·14 (SD 1·31) cm/yr and for girls it was 8·39 ± 0·17 cm/yr (SD 1·41). The mean of the slowest rates was 3·10 ± 0·10 (SD 0·98) cm/yr for boys and 3·13 ± 0·14 (SD 1·13) for girls.

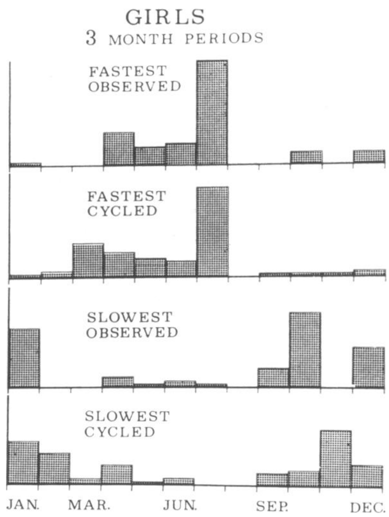

FIG. 4.—*Distribution of months in which individual girls reached their fastest and slowest periods of growth over 3 months.*

The magnitude of the seasonal variation was determined by subtracting each child's fastest rate over a 3-month period from his/her slowest. This gave a mean value of 5·06 ± 0·18 cm/yr for boys and 5·20 ± 0·20 cm/yr for girls. The difference between the two sexes was not significant ($P > 0·5$).

When the maximal rate for each child was expressed as a multiple of his/her minimal rate, the mean values obtained were 3·01 ± 0·17 for boys and 3·07 ± 0·19 for girls. The difference between the sexes was not significant ($P > 0·7$).

The correlation coefficients between the fastest and slowest rates were 0·1 for boys and 0·09 for girls. These are not significant ($P > 0·1$).

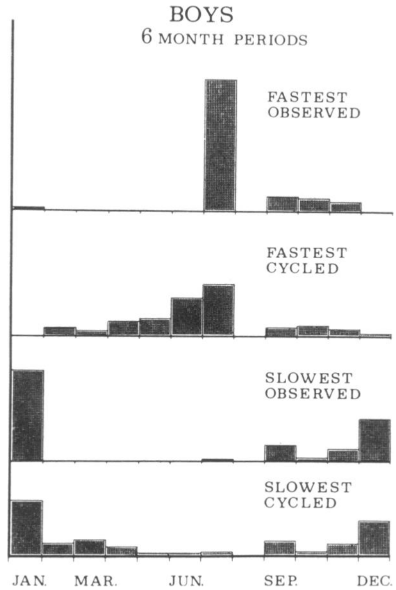

FIG. 5.—*Distribution of months in which individual boys completed their fastest and slowest periods of growth over 6 months.*

The corresponding data over 6-monthly periods are given in Table IV.

The distribution of differences (maximum minus minimum velocity) and of the quotients maximum/minimum velocity for each child over 3-month periods are shown in Fig. 7 and 8. Fig. 9 and 10 give the corresponding data for 6-month periods.

Discussion

It is clear from the data that no satisfactory assessment of the normality of a child's growth can be made over a period of 3 months. The centiles show that a growth rate of less than 2·5 cm/yr may be quite normal over 3 months ending in December or January, though it would be grossly

TABLE IV

	Boys	Girls
Mean fastest rate	6·87 ± 0·10 (SD 1·0)	7·09 ± 0·13 (SD 1·15)
Mean slowest rate	4·07 ± 0·07 (SD 0·8)	4·19 ± 0·12 (SD 1·07)
Mean (fastest/ slowest)	2·80 ± 0·11	2·90 ± 0·14
Mean (fastest/ slowest)	1·74 ± 0·04	1·79 ± 0·07
r (fastest/ slowest)	0·21 ($P < 0·05$)	0·36 ($P < 0·01$)

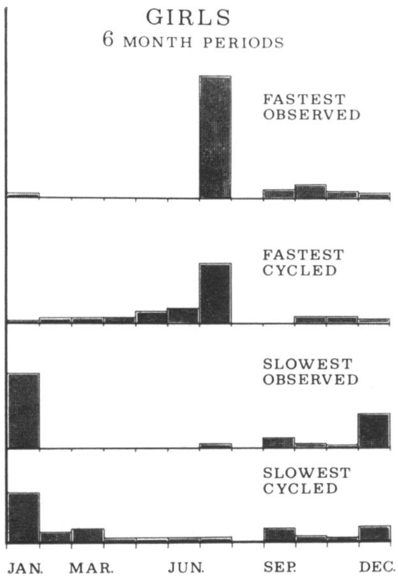

FIG. 6.—*Distribution of months in which individual girls reached their fastest and slowest periods of growth over 6 months.*

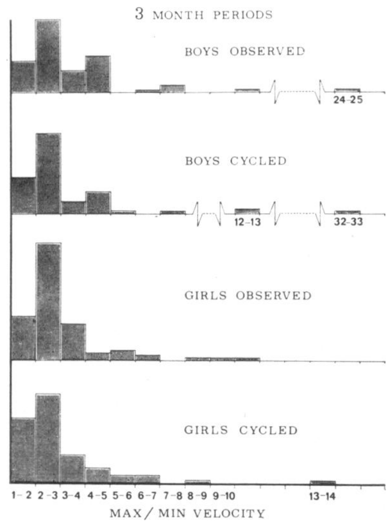

FIG. 8.—*The maximal growth velocity over 3 months divided by the minimal velocity over 3 months for the same child. The distribution of the quotients is shown. In the case of the boys the scale has been condensed to accommodate a few very high values.*

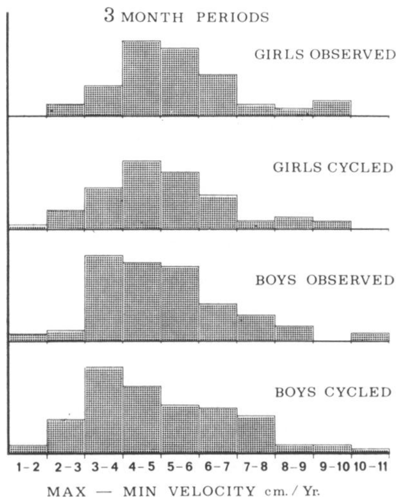

FIG. 7.—*Distribution of differences between maximal and minimal velocities of individual children over periods of 3 months.*

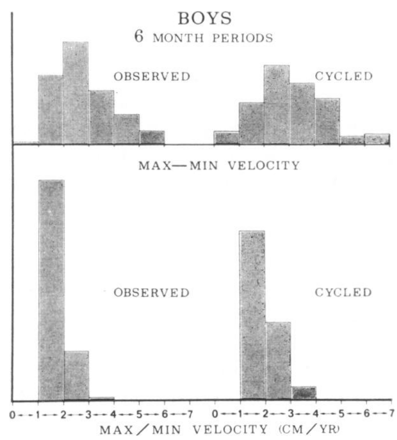

FIG. 9.—*Distribution of differences between maximal and minimal velocities and the quotient maximal velocity divided by minimal velocity over periods of 6 months in boys.*

abnormal if it persisted for the whole year. One would suspect abnormality if a rate of less than 4·0 cm were observed over 3 months ending between March and July.

Nearly all children complete their 3 months of minimal growth between September and February, but there is no way of telling when an individual child does so unless he is measured every month. The patient who is measured twice, with an interval of 3 months during the autumn or winter, may or may not have been growing at his minimal rate. The minimal rate may be less than 1 cm/yr, as estimated from the mean and standard deviation of this sample. This would represent growth of 0·25 cm in the 3 months. As measurement of stature by skilled observers with the best equipment

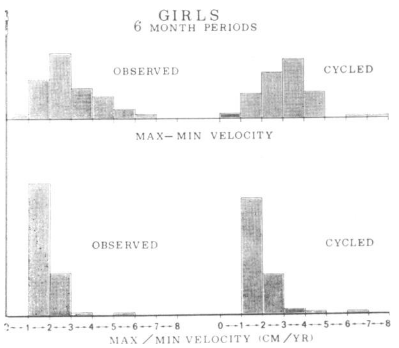

FIG. 10.—*Distribution of differences between maximal and mimimal velocities and the quotient maximal velocity divided by minimal velocity over periods of 6 months in girls.*

has an error of up to 0·3 cm, a child growing at a rate of about 1 cm/yr might not show any detectable increase in stature. Therefore, a child who apparently does not grow at all over a period of 3 months, particularly in the autumn and winter, is not necessarily abnormal. Naturally such a child would have to reach a high growth rate in another season in order to maintain a satisfactory average over the year. However, the data show that it is not uncommon for the maximal 3-monthly rate to be four times the minimum, and it may even be greater than this. The few children in whom the maximal rate was more than 8 times the minimim are those whose measured minimal rate was very small indeed and who, in fact, may not have grown at all in their slowest season.

When there is an interval of 6 months between measurements, a child growing at his slowest rate should be growing at not less than 2 cm/yr. This is most likely to occur in the 6-month periods ending between September and March. The fastest rate, in the individual, may be three or four times as great as the slowest. The 6 months of maximal growth may end between March and July (most frequently in July). As it is very unusual for a child to experience his/her minimal rate at this time of year, a very low rate suggests abnormality.

A rate of 10 cm/yr over 3 months or 9 cm/yr over 6 months is the approximate upper limit of normal for a preadolescent child who is growing at his maximal rate over the period in question.

A satisfactory assessment of a child's growth can be made only if he is observed for a full year. Very slow growth over the autumn and winter may be normal, while in spring and summer higher growth rates are to be expected than those given in the 'whole year' standards of Tanner *et al.* (1966).

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Appendix

Relation between Decimal Dates and Months

January	0·000–0·082	July	0·496–0·578
February	0·085–0·159	August	0·581–0·663
March	0·162–0·244	September	0·666–0·745
April	0·247–0·326	October	0·748–0·830
May	0·329–0·411	November	0·833–0·912
June	0·414–0·493	December	0·915–0·997

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