



SURINDER NATH, MARY CHACKO

MATURATIONAL SEQUENCE IN THE ARM AND THE LEG SEGMENTS AMONG THE DANGI FEMALES OF UDAIPUR, RAJASTHAN

ABSTRACT — *The maturational sequence of growth in arm and leg segments has been studied on a sample of 238 female Dangis of Rajasthan, measured cross-sectionally, ranging in age between 8 and 18 years for ten measurements pertaining to the arm and the leg segments, besides stature and sitting height. The study clearly reveals the existence of both Cephalo-caudal and Caudo-cephalic sequence of maturation. The existence of smaller area gradients is also evidenced at different age levels within the constituent components of the arm and the leg segments. Growth has not ceased among female Dangis of Rajasthan by age 18 in majority of the measurements except foot length, upper-arm length and hand length where adult size has been achieved by age 17. The remaining measures require a certain percentage of growth yet to be achieved to reach their final size.*

KEY WORDS: *Dangi — Cephalo-caudal — Caudo-cephalic — Maturational sequence — Growth gradient.*

It has been observed that the growth trends do not exhibit wide variations except for the ones that are due to an individual's socio-economic status. Spurt in stature in general is more due to an increased rate of growth in the trunk segment in contrast to an increase in the leg segment as evidenced from the studies of Marshall (1977), Nath (1971; 1972; 1975; 1982), Nath and Jhingon (1982), Tanner (1962; 1964; 1978). However, there exists a fairly regular order in which various segmental components accelerate, for example, leg length reaches its peak first, some 6 to 9 months ahead of the trunk (sitting height). At adolescence children, especially girls, usually complain of having longer hands and feet, not realizing that their hands and feet will ultimately be smaller in proportion to the arms, legs and stature at the close of the adolescent spurt (Tanner 1978).

The organisation of growth is expressed through the presence of maturity gradients. It is generally observed that at all ages the foot is nearer its adult size than the calf, and the calf in turn is nearer than

the thigh. Tanner (1962; 1964; 1978) in his studies showed that a maturity gradient is said to operate in the leg running from an advanced maturity distally to retarded maturity proximally. This maturational sequence is more specifically termed as following a caudo-cephalic direction of maturation in the studies of Nath (1972; 1975; 1982), Nath and Jhingon (1982). A similar type of gradient is present in the arm segment as well.

The human body as a whole exhibits the existence of cephalo-caudal maturity gradient, as the head is, at all ages, ahead in maturation over the trunk, and the trunk over the legs. In the studies of Tanner (1962; 1964; 1978), Marshall (1977), Nath (1972; 1982), Nath and Jhingon (1982), Sathyavathi et al. (1981), it has been observed that within the limbs the upper segment of the arm is advanced in maturation over the upper segment of the leg and so on. There are other maturity gradients too, some covering small areas and operating for a short duration, while others covering whole systems and operating throughout the

period of growth. Due to the differential rate of segmental progression different maturity gradients, i.e. cephalo-caudal and caudo-cephalic, operate simultaneously at the same age in different segmental components, and also at different ages.

In the present report an attempt has been made to examine the maturational trends between the constituent components of the arm and the leg in specific and between main body components in general on a female sample drawn from the Udaipur district of Rajasthan.

MATERIAL AND METHODS

Data for the present study consist of 238 Dangi females, ranging in age from 8 to 18 years from the Udaipur district, Rajasthan, measured cross-sectionally for the following measures of the upper and the lower extremities—total upper extremity length, upper arm length, forearm length, hand length, total lower extremity length, thigh length, calf length and foot length. Besides measurements on the two extremities, stature and sitting height have also been obtained for each subject following the standard techniques of Martin and Saller (1959) and IBP by Weiner and Lourie (1969).

Exact age of each subject was recorded from the school records. The subjects were classed into mean age categories as 8.0, 9.0, 10.0 and so on up to 18.0 years. Age group 8.0 includes all girls who have attained 7 years and 6 months of age but are less than 8 years and 6 months (up to 8 years 5 months and 30 days) thereby giving a mean age of 8.0 years. Similarly, age group 9.0 includes all girls who have attained 8 years and 6 months of age but are less than 10 years and 6 months, and so on up to 18.0 years.

Growth gradients (percentage of the final size attained at a given age) have been calculated for each of the ten measures in order to assess the maturational sequence in the two extremities, stature and sitting height among Dangi female.

$$\text{Growth Gradient} = \frac{X_A}{M} \times 100$$

Where X_A is the mean value of the measure at age A , and M is the maximum value of that measure in the final age group (which happens to be 18 years in the present study).

RESULTS AND DISCUSSION

Table 1 presents the mean values and standard deviation for all the measurements of the arm and leg segments, stature and sitting height. The mean values listed for all the eleven age groups under study, i.e. 8.0 years through 18.0 years, reveal an increasing trend of growth in the different segmental measurements of the two extremities, stature and sitting height.

Table 2 expresses total amount of growth attained, between 8.0 years and 18.0 years by the Dangi females, by the measures of the arm and leg segments, stature

TABLE 1. Mean and Standard Deviation of Ten Body Measurements among Dangi Females

Age in years	No. of subjects	Stature (cm)		Sitting height (cm)		Leg Segment				Arm Segment			
		Mean	S.D.	Mean	S.D.	T.L.E.L. (cm)	T.L. (cm)	C.L. (cm)	F.L. (cm)	T.U.E.L. (cm)	U.A.L. (cm)	F.A.L. (cm)	H.L. (cm)
						Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
8.0	21	117.3	6.6	60.7	3.9	62.2	32.6	24.3	18.1	51.9	22.3	16.4	13.2
9.0	20	124.8	6.7	63.2	4.4	68.3	34.8	26.2	19.2	54.1	23.7	17.3	14.0
10.0	24	126.8	6.9	64.3	3.5	69.3	35.7	28.2	19.5	56.2	23.9	18.4	14.2
11.0	22	129.7	6.4	65.6	4.0	71.0	36.7	29.2	20.0	58.0	24.4	18.8	14.5
12.0	22	139.1	6.6	69.8	3.2	77.7	39.0	32.8	21.2	62.1	27.1	20.2	15.6
13.0	21	141.7	4.2	70.9	4.8	79.7	40.2	33.7	21.3	63.7	28.7	20.6	16.0
14.0	26	148.4	6.4	73.4	4.3	82.8	41.6	35.1	22.1	67.0	30.6	20.9	16.5
15.0	20	151.4	4.4	75.6	4.8	83.1	42.0	35.3	22.7	68.8	30.7	21.6	16.8
16.0	20	151.9	4.4	76.0	3.4	84.2	43.0	35.6	22.8	69.1	30.9	21.9	17.2
17.0	21	152.9	5.8	76.3	2.9	85.6	43.5	35.8	23.0	69.8	31.0	22.3	17.3
18.0	21	154.0	5.8	76.4	2.5	86.4	43.6	36.1	23.0	70.3	31.0	22.4	17.3

T.U.E.L. = Total Upper Extremity Length,
U.A.L. = Upper Arm Length,
F.A.L. = Fore Arm Length,
H.L. = Hand Length.

T.L.E.L. = Total Lower Extremity Length,
T.L. = Thigh Length,
C.L. = Calf Length,
F.L. = Foot Length.

TABLE 2. Absolute Growth Achieved by the Ten Measures between 8.0 and 18.0 years

Measurements	Ultimate Gain (cm)
Stature	36.7
Sitting height	15.7
Total lower extremity length	24.2
Thigh length	11.0
Calf length	11.8
Foot length	4.9
Total upper extremity length	18.4
Upper Arm length	8.7
Forearm length	6.0
Hand length	4.1

and sitting height. It has been observed that the stature attains the maximum total gain (36.7 cm) in a period of eleven years, while hand length attains least increase (4.1 cm) during this period.

The sequence of segmental maturation among Dangi females has been studied through the maturity gradients (Table 3). The percentage of growth achieved at each age point from 8.0 years to 17.0 years, relative to their final size taken at 18.0 years, helps us to explain and understand the extent of maturity attained by the constituent components of arm and leg segments, stature and sitting height. The sequence of maturation could be evolved within the constituent components of arm and leg segments on the basis of the growth attained by them at any particular age.

In growth studies it is generally observed that growth rates vary for different children and even within the same child at different ages, because growth and differentiation do not take place at the same rate and time in the constituent components of the body. As a result of the differential rate of segmental development the overall increase in stature during adolescence is attributed to the increased rate of growth in the trunk segment in contrast to the increase in the leg segment (Marshall 1977; Tanner 1962; 1964; Nath 1971) or the head and neck segments (Nath 1972; 1975;

TABLE 3. Percentage of growth achieved by the ten measures of their final value taken at 18.0 years among Dangi females

Age in years	Stature	Sitting height	T.L.E.L.	T.L.	C.L.	F.L.	T.U.E.L.	U.A.L.	F.A.L.	H.L.
8.0	76.17	78.14	71.99	74.77	67.31	78.69	73.71	71.93	72.77	76.30
9.0	81.04	82.72	79.05	79.81	72.57	83.47	76.95	76.47	77.23	80.92
10.0	82.33	84.16	80.21	81.88	78.11	84.78	79.94	77.09	82.14	82.08
11.0	84.22	85.86	82.17	84.17	80.88	86.96	82.50	78.71	83.48	83.81
12.0	90.32	91.36	89.93	87.15	90.86	92.17	88.33	87.42	90.19	90.17
13.0	92.01	92.14	92.24	92.20	93.35	92.61	90.61	89.68	91.96	92.48
14.0	96.36	96.07	95.83	95.41	97.23	96.08	95.30	98.71	93.30	95.37
15.0	98.31	98.94	96.18	96.38	97.78	98.69	97.15	99.03	96.43	97.11
16.0	98.63	99.47	97.45	98.62	98.61	99.13	98.29	99.68	97.77	99.42
17.0	99.29	99.87	99.07	99.77	99.17	100.00	99.28	100.00	99.55	100.00
18.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

T.L.E.L. = Total Lower Extremity Length,
T.L. = Thigh Length,
C.L. = Calf Length,
F.L. = Foot Length.

1982; Nath and Jhingon 1982) as both the components show an increased rate of growth during the pre-adolescent spurt period.

An examination of the present data on Dangi females reveals that the stature, sitting height and the two extremities including their constituent sub-segments attain the maximum annual increase between 11.0 and 12.0 years (Table 1). The extent of the increase during this period varies between a maximum of 9.4 cm in the case of stature and a minimum of 1.0 cm in the case of hand length. The leg segment as a whole exhibits an increase of 6.7 cm in contrast to 4.1 cm increase in the arm segment.

Assessing the extent of absolute growth (Table 2) in stature, sitting height and the constituents of arm and leg segments between 8.0 and 18.0 years it may be stated here that Dangi females exhibit maximum absolute growth in stature amounting to 36.7 cm while in the case of sitting height the increase is 15.7 cm, which is less than half in comparison to stature. In the case of leg segment the total increase is over one and a half times that of the sitting height, i.e. 24.2 cm, which is significantly greater than the increase shown by the arm segment (18.4 cm). The thigh component (11.0 cm) of the leg exhibits almost a one and a half times greater increase than the upper arm (8.7 cm) component of the arm segment. While the calf component (11.8 cm) of the leg indicates a nearly double the increase in absolute size of the forearm component (6.0 cm) of the arm segment. The absolute gain achieved by the foot (4.9 cm) and the hand (4.1 cm) is more or less similar. The hand exhibits the least growth during this period among Dangi females.

Observing the maturational sequence of development of stature, sitting height and the components of arm and leg segments through the maturity gradients it may be stated here that Dangi females exhibit the existence of both the maturational directions, i.e. cephalo-caudal as well as caudo-cephalic at different age levels (Table 3).

The maturational trends for stature and its two main components, i.e. sitting height and lower extre-

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F.A.L. = Fore Arm Length,
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mity length reveal that at age 8.0 sitting height is advanced in maturity, achieving 78.14 per cent of its final size compared with lower extremity length, 71.99 per cent, and stature, 76.17 per cent, indicating the existence of cephalo-caudal direction of maturation between the two constituents of stature. This direction of maturation within the two constituents remains constant up to 17.0 years, as at all ages sitting height expresses an advanced maturation over the lower extremity length, it is only at age 13.0 that this maturational sequence is reversed to caudo-cephalic direction but this change is not very prominent as the advancement in percentage of growth shown by lower extremity over the sitting height is of a very low order, i.e. 0.10 percent.

The two extremities, i.e. the lower and the upper, show the existence of both the maturity gradients at different ages. At ages 8.0, 11.0 and 15.0 the two extremities exhibit cephalo-caudal maturational trend while at other ages the maturational trend is caudo-cephalic, indicating an advanced maturation of the leg segment over the arm-segment as a whole. At age 17.0 the leg segment has attained 99.77 per cent growth in contrast to 99.28 percent growth achieved by the arm segment. It may be mentioned here that growth in both these segments among Dangi females is not complete at age 17.0 as both the extremities require between 0.23 percent (leg) and 0.72 per cent (arm) growth yet to be achieved to reach their final size. The existence of both the gradients at different age levels between the two extremities is suggestive of the fact that the smaller area gradients as referred by Tanner (1964); Marshall (1977); Nath (1972; 1975; 1982) and Nath and Jhingon (1982) are operative between the two segments. Due to the existence of smaller area gradients the rate of development in different proportions differs and the existence of cephalo-caudal gradient in the present sample between the two extremities results from the increased rate of growth in the arm segment over the leg segment at ages 8.0, 11.0 and 15.0, while at remaining ages the leg segment grows at an increased rate.

The smaller area gradients become more conspicuous when the constituent components of the arm and the leg segments are dealt with individually. The three components of the arm segment, i.e. the upper arm, the forearm and the hand, show that the hand length is advanced in maturity over the forearm at all ages excepting at 10.0 and 12.0 years, indicating a clearcut caudo-cephalic mode of maturation. The variation observed in the pattern of maturity at ages 10 and 12 is so minute that it amounts to 0.06 per cent and 0.02 per cent respectively. Therefore, it could safely be stated that in general the two components follow only a caudo-cephalic mode of maturation. The forearm length exhibits an advanced maturation over upper-arm length between 8.0 and 13.0 years indicating the existence of caudo-cephalic direction of maturation. This gradient is reversed to cephalo-caudal beyond the age of 13 years and operates till 17.0 years, as the upper arm length shows an advanced maturation over the forearm length between 14.0 and 17.0 years.

When compared to the upper arm length in terms

of maturity level hand length shows a similar trend as in the case of forearm and upper arm. The most interesting point noticed among Dangi females is that both the hand and the upper arm constituents of the arm segment attain complete maturation at age 17.0 while the forearm component requires 0.45 percent growth yet to be achieved at this age to reach its final size. It is indicative of the fact that the growth in the arm segment among Dangi females beyond the age of 17 is only due to the forearm component.

The constituent components of the leg segment, i.e. thigh length, calf length and the foot length, also exhibit a similar trend as observed in the case of the arm segment. Foot length achieves 78.69 per cent growth at age 8.0 as against thigh length (74.77 per cent) and calf length (67.31 per cent) and remains ahead in maturation over calf length and all ages exhibiting a caudo-cephalic maturational trend, except at ages 13.0 and 14.0 where calf length exhibits an advanced maturation over foot length, by achieving 0.74 per cent and 1.15 per cent more growth respectively, thereby reversing the maturity gradient to cephalo-caudal mode at these ages. This situation is similar to that observed between the hand and the forearm components of the arm segment at ages 10.0 and 12.0 with a varied intensity of growth. The thigh length in turn exhibits an advanced maturation over the calf length between 8.0 and 11.0 years following a cephalo-caudal maturity gradient which is reversed to caudo-cephalic mode of maturation between 12.0 and 15.0 years. At ages 16.0 and 17.0 the maturational trend between these two leg components is again reverted to cephalo-caudal gradient. This situation very explicitly demonstrates the existence of smaller area gradients within the leg segment. It may further be stated here that the foot length attains adult size at age 17 but the other components of the leg segment, i.e. the thigh length and the calf length, require 0.23 per cent and 0.73 per cent growth yet to be achieved to reach their final size respectively. This situation clearly demonstrates the fact that the lack of 0.93 per cent growth in the leg segment among Dangi females at age 17.0 is mainly due to the lack of growth exhibited by the thigh (0.23 per cent) and the calf (0.73 per cent) components.

If one compares the homologous components of the arm and the leg segments (hand-foot; forearm-calf and upper arm-thigh) it may be observed that the foot is advanced in maturation over the hand from 8.0 to 15.0 years following a caudo-cephalic maturation but at age 16.0 the gradient is reversed to cephalo-caudal direction. However, both the components achieve 100 per cent growth at age 17. The forearm component of the arm segment exhibits an advanced maturation over the calf component of the leg segment between 8.0 and 11.0 years, indicating the cephalo-caudal mode of maturation, which is reversed to caudo-cephalic between 12.0 and 16.0 years while at age 17 the forearm again supersedes the calf, reverting the gradient to cephalo-caudal direction. At this age the forearm requires 0.45 per cent growth yet to be achieved to reach its final size as against the calf, which requires 0.73 per cent growth to reach its final size.

The thigh component of the leg segment exhibits an advanced maturation over the upper arm component of the arm segment between 8.0 and 11.0 years following caudo-cephalic direction of maturation. The maturity gradient between these two components shows a reversion at age 12 to the cephalo-caudal direction and its immediate retrieval to caudo-cephalic direction is evidenced at age 13, whereafter till 17 years the two components follow cephalo-caudal mode of maturation. The upper arm reaches its final size at age 17 while the thigh component requires 0.23 per cent growth to reach its final size.

It may therefore be concluded that among Dangi females the two extremities by and large follow both the maturity directions as well as the smaller area gradients in their developmental sequence but at the component level the existence of smaller area gradients becomes more conspicuous, showing more frequent reversion and retrieval of the maturity gradients.

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Dr. Surinder Nath
Department of Anthropology
University of Delhi
Delhi—110 007
INDIA