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Original Research Article

Differences in skeletal growth pattern of *yoga* practising adolescent girls: A cross-sectional study

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ABSTRACT

Background: *Yogasana* improves both mental and physical health. There is sparse systematic research on the growth of *yogasana* practising adolescents.
Objectives: This study aims to assess the differential skeletal growth pattern among pre-adolescent and adolescent girls as a result of *yoga* practice.
Methods: A cross-sectional anthropometric study was conducted on stature (height), sitting height and leg length of 757 school-going girls (4-15 years old), divided in two groups, Yoga Group (YG) (n=380) and age matched Control Group (CG) (n=377) participants participating in recreational games other than yoga. Descriptive and inferential statistical analyses were applied. Unpaired t-test was performed for assessment of level of significance and Pearson's correlation (r) test was performed to to identify the association between growth pattern of stature and leg length at specific ages.
Results: The physical growth showed an ascending trend in both Yoga group (YG)[2] participants and control group (CG)[3] . At the onset of adolescence (10–12 years) the mean stature and leg length of YG participants were retarded ($p < 0.05$). Sitting height in YG was significantly ($p < 0.05$) low only in 10-year-olds. The similar trends were observed in stature and leg length in YG participants at 10 years (5th and 10th percentile) and 12 years (90th and 95th percentile). There was strong positive relationship between stature and leg length of YG participants (10 years, $r = 0.86$, $p < 0.01$; 11 years, $r = 0.86$, $p < 0.01$; 12 years, $r = 0.72$, $p < 0.01$). The stunted growth in YG participants during adolescence may be related to retarded growth of leg length.
Conclusions: Intense *yogasana* practice with greater skeletal stress possibly hinders stature in adolescent girls from 10 to 12 years. This may compromise with the natural growth pattern, necessitating special care during *yoga* training among adolescents while selecting the type, intensity and duration of *yogasanas* practice.

1. Introduction

Yoga is a form of lifestyle that improves overall health of body and mind. *Yogasanas* are integral part of *yoga*. Modern science emphasizes its efficacy on all human organ systems viz., cardiovascular [1,2], respiratory [3,4], digestive [5], musculoskeletal [6] and nervous system [7]. Some studies have reported the effectiveness of *yoga* on physical development during adolescence, indicating improvement in physical strength and endurance [8], body weight, body composition, body circumferences [9–11] and psycho–physiological parameters viz., general wellbeing, confidence, emotional stability, motor and social skills [12]. The popularity of *yoga* has led to its mass practice among children even from the age of 4 years, whose natural growth spurt is observed during adolescence [13]. This natural growth though generally enhanced by physical training and games [14,15], can be negatively affected by faulty training [16]. This may also applies to *yogasana* practice. WHO, UNO as well as UNESCO have been emphasizing on the development of children and adolescents worldwide. About 15–25% of the final adult stature [17] and half of the total bone mass [18] is acquired during adolescence. Considering the

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[2] YG: *Yoga* Group.
[3] CG: Control Group.

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formative stage of bone growth in the vulnerable growth plate, particularly at adolescence, the mass scale *yogasana* practice among children in this crucial stage needs to be addressed appropriately through scientific studies. Though reports of athletics viz., gymnastics, swimming [19,20] and physical education training [15,21,22] on growth during adolescence exist, such studies with an emphasis on the growth pattern of *yoga* practising children are scanty.

Hence, the present study aims to report the growth trend of *yoga*-practising girls from childhood to adolescence within the existing *yoga* training system for various *yogasana* competitions.

2. Methods

2.1. Study design and participants

A cross-sectional study was conducted for three years (2016–2019). Study was approved by Institutional Ethics Committee (Reg. No. WBSU/IEC/10/03, dated: 06.06.2016) and written consent was obtained from the guardians as well as from children above 7 years who could express properly. 1000 school-going girls (4–15 years old) were screened on the basis of their physical activities. Of them, 165 participants who were either trained in various other sports or dancing regime or had been suffering from chronic diseases, inborn physical deformities, any infectious diseases or injuries, were excluded from the study. Potential participants were examined by a qualified physician (MBBS) of the health care centre of West Bengal State University (parent Institute) who conducted their clinical assessment. Of the remaining 835 girls, 415 were involved in only yoga practice for at least 6 months and 420 did not practice yoga and thus segregated as yoga group (YG) and age matched control group (CG) participants respectively. Finally, the physical growth pattern of 757 pre-adolescent (4–8 years) and adolescent girls (9–15 years) was recorded. Anthropometric and socio-demographic data could be obtained from 380 YG and 377 age matched CG participants who were available throughout the study period. A flowchart containing sampling details have been provided as supplementary data (supplementary file 1). Participants belonged to lower - middle income group (LMIG), as per modified Kuppuswamy's socio-economic scale [23]. Participants from both the groups used to play other recreational games occasionally. YG participants practised yoga in 'yoga training centres' and participated in yoga competitions (inter school/inter club/district level) in West Bengal. The yoga training protocols at various centers were uniform and in accordance with the guidelines of the competitions. The YG participants practised various yoga postures according to their age groups (Table 1).

The physical growth pattern of 757 pre-adolescent (4–8 years) and adolescent girls (9–15 years), free from any type of physical and mental disorders was recorded. Study was approved by Institutional Ethics Committee (Reg. No. WBSU/IEC/10/03, dated: 06.06.2016) and written consent was obtained from the guardians. This study followed purposive sampling and non-randomized trial to comply the requirement of availability of this type of data, within a certain period, with appropriate number of subjects (4–8 years: lowest, n = 25; highest, n = 41; 9–12 years: lowest, n = 30; highest, n = 39; 13–15 years: lowest, n = 25; highest, n = 41).

2.2. Training procedures

The YG participants were instructed by two qualified *yoga* trainers on three alternate days per week for an hour each, at the *yoga* training centres (Table 1), each session included 5 min prayer, 20–30 min warm up with free hand exercises and rest, followed by age appropriate core *yoga* training (Table 1) interspersed with *Shavasana* and *yogic* breathing maneuvers (YBM). The younger YG participants aged 4–6 years initially practised some easy postures. Each *yogasana* posture was held for 15–30 s. Training intensity was increased progressively according to the age and proficiency level of the participants. *Yogasanas* were followed by YBM for a short period (5–10 min including rest pauses). The major time in training was devoted in practising *yogasanas* primarily for participation in various *yogasana* competitions.

2.3. Anthropometric measurements

The anthropometric measurements were performed on YG and CG participants, as recommended by International Society for the Advancement of Kinanthropometry (ISAK) [24]. All subjects completed a pre-vallidated questionnaire on age, ethnicity, dietary pattern, socio-demographic profile etc. before being subjected to anthropometric measurements viz., stature and sitting height. The leg length was derived by subtracting the sitting height from stature. The stature of parents was also measured. All the measurements were taken by a standard anthropometer

Table 1
Yogasanas and *yogic* breathing maneuvers (YBM[a]) practised by the YG[b].

Yogasana	*Pranayama or Yogic* Breathing Maneuvers (YBM)
4 to 8 years of age	
Padmasana (lotus pose), *Vajrasana* (thunderbolt or pelvic pose), *Ardha Koormasana* (half tortoise pose), *Bhujangasana* (cobra pose), *Supta Vajrasana* (sleeping thunderbolt pose), *Shalabhasana* (locust pose), *Eka Pada Shalabhasana* (half locust pose), *Eka Pada Utthanpadasana* (raised leg pose), *Eka Pada Pawanmuktasana* (one legged wind-relieving pose), *Ushtrasana* (camel pose), *Sukhasana* (easy pose), *Shavasana* (corpse pose).	*Sahaja Pranayama* (natural deep breathing, except *Kumbhaka* or breath retention).
9 to 12 years of age	
Padmasana, Vajrasana, Ushtrasana, Ardha Koormasana, Bhujangasana, Shalabhasana, Poorna Shalabhasana (full locust pose), *Utthanpadasana* (raised legs pose), *Dhanurasana* (bow pose), *Baddha Padmasana* (locked lotus pose), *Supta Vajrasana, Pawanmuktasana* (leg lock pose/wind-relieving pose), *Akarna Dhanurasana* (bow and arrow pose), *Matsyasana* (fish pose), *Paschimottanasana* (back stretching pose), *Ardha Matsyendrasana* (half spinal twist), *Yogamudrasana* (psychic union pose), *Bhadrasana* (gracious pose), *Sarvangasana* (shoulder stand pose), *Padahastasana* (hand to foot pose), *Ardha Chandrasana* (half moon pose), *Chakrasana* (wheel pose).	*Anulom Vilom* (alternate nostril breathing), *Kapalbhati (Kriya)* (frontal brain cleansing), *Bhramari* (humming bee breath).
13 to 15 years of age	
Gomukhasana (cow's face pose), *Baddha Padmasana, Ushtrasana, Supta Vajrasana, Matsyasana, Akarna Dhanurasana, Shalabhasana, Padahastasana, Ardha Chandrasana, Ardha Matsyendrasana, Yogamudrasana, Chakrasana, Ardha Chakrasana* (half wheel pose), *Poorna Chakrasana* (full wheel pose), *Paschimottanasana, Garbhasana* (foetus in the womb pose), *Bhumasana* (leg split pose), *Poorna Shalabhasana, Bakasana* (crane pose), *Sirshasana* (headstand pose).	*Anulom Vilom, Kapalbhati, Bhramari, Bhastrika* (bellows breath), *Sheetali* (cooling breath), *Seetkari* (hissing breath).

[a] *Yogic* breathing maneuvers includes *pranayamas* and *kapalbhati* (*kriya*).
[b] YG = *Yoga* Group.

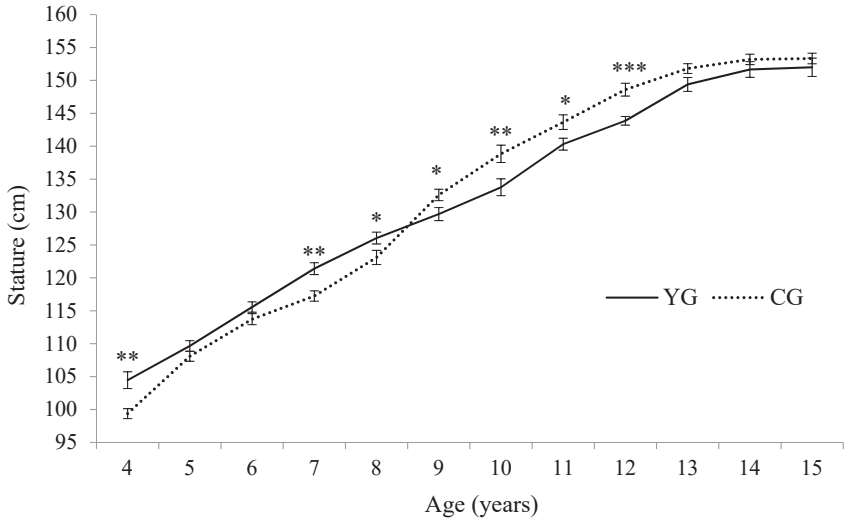

Fig. 1. Cross-sectional analyses of stature (mean ± SEM) of YG participants from 4 to 15 years show that it was higher till 8 years of age and was significantly retarded in 9–12 years, compared to CG participants. [*P* value < 0.05 (*), <0.01 (**), <0.001 (***)] (CG = Control Group participants; YG = *Yoga* Group participants).

(Span Surgical Co., Coimbatore, India). These assessments were performed on YG participants who had undergone the *yoga* practice for at least 6 months and thus were selected for the cross-sectional study.

2.4. Statistical analyses

The results were reported in terms of mean, standard deviation (±SD) and standard error of mean (±SEM). The percentiles (5th, 10th, 25th, 50th, 75th, 90th and 95th) were calculated to study the age-specific growth pattern in both YG and CG participants using Microsoft Office Excel 2007. Unpaired t-test (two tailed) was used to compare means of various parameters in different ages between YG and CG particiapnts using the GraphPad QuickCalcs Software [25]. Pearson's correlation (*r*) test was used to identify the association of growth pattern of different body segments of YG participants with stature from 9 to 12 years of age.

3. Results

The stature, leg length and sitting height were analyzed and compared between YG (n = 380) and CG (n = 377) participants. Each age category was considered in integral number of years till 11 months.

3.1. Stature (standing height)

The increase in stature of both YG and CG participants during pre-adolescence (4–8 years) followed natural growth pattern (Fig. 1). Overall, a significantly higher ($p < 0.05$) mean stature was observed in YG participants compared to age matched CG participants during pre-adolescence.

At 9 years, with the approach of adolescence, the trend reversed, where YG participants showed significantly ($p < 0.05$) lower mean stature compared to CG participants. This difference continued till 15 years though the changes were not significant in all ages. Between 10 to 12 years of age the stature of YG participants was significantly ($p < 0.05$) lower than CG participants.

The percentile scores were assessed for further analysis of the relationship between stunted growth and *yogasana* practice near adolescence (Figs. 2 and 3). This growth retardation of YG participants (Fig. 1) has also been observed in percentile growth curve, where the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentile scores of stature have been plotted (Fig. 2). Although stature of YG participants (4–15 years) gradually increased, fluctuations in some ages were observed from 5th through 95th percentile curves. The effect

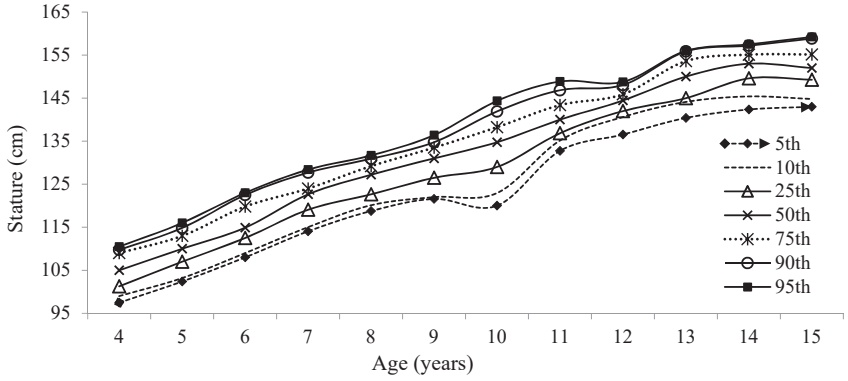

Fig. 2. Stature (cm) of YG participants from 4 to 15 years of age has been plotted in 5th, 10th, 25th, 50th, 75th, 90th and 95th percentile scores. It indicates that the stature of YG participants steadily increased except during 10 years (5th and 10th percentile) and 12 years (90th and 95th percentile). (YG = *Yoga* Group participants).

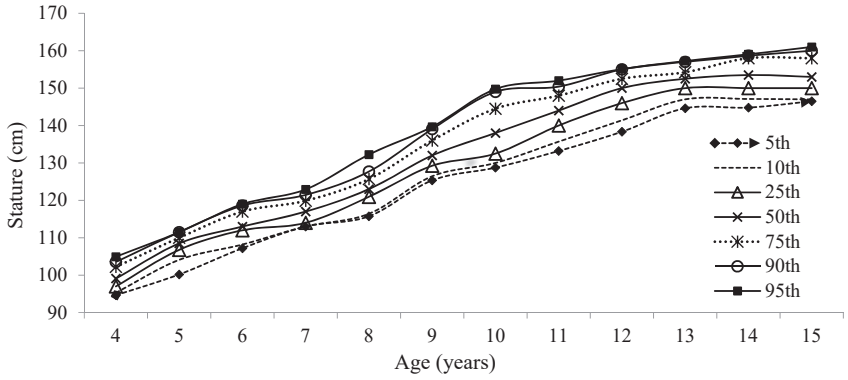

Fig. 3. Stature (cm) of CG participants from 4 to 15 years of age has been plotted in 5th, 10th, 25th, 50th, 75th, 90th and 95th percentile scores. It indicates that the stature of CG participants increased steadily from 10 to 15 years of age during adolescence (from 5th to 95th percentile) without retardation. (CG = Control Group participants).

(stunting) was more prominent at 10 years of age in 5th percentile and the increment in stature was low in 10th percentile. Again, the same stature retardation was observed at 12 years in 90th and 95th percentile (Fig. 2). On the contrary, similar retardation in stature was not observed among CG participants of corresponding ages (Fig. 3).

The parental stature of study subjects was also considered to nullify the influence of genetic variability in gaining the stature but no significant difference was observed between the parents from both groups of similar socio-economic-ethnic status and dietary pattern.

3.2. Leg length

The increase in leg length was attained significantly ($p < 0.01$) at an earlier age (4–8 years) by YG participants compared to CG participants. It then retarded in YG participants and failed to be at par with the growth of CG participants in later part of adolescence period (13–15 years) (Fig. 4). The mean leg length increased in both YG and CG participants according to age (4–14 years) but at the onset of growth spurt (10 years), the mean leg length of YG participants was significantly ($p < 0.05$) lower compared to CG participants. At 12 years, the retardation (6.22%) in mean leg length in YG participants was more prominent and highly significant ($p < 0.001$).

Thus, percentile curves of both stature and leg length of YG participants (Figs. 2 and 5) from 4–15 years of age showed similar pattern. Leg length retardation was observed at the initial phase of adolescence in YG participants at 10 years of age, in the 5th and 10th percentile and again at 12 years in the 5th, 10th, 90th and 95th percentile (Fig. 5). Additionally, the increment in leg length in YG participants was stagnant around 14 years of age in 5th, 75th and 90th percentile.

At 10 and 12 years of age, the retarded growth in leg length was reflected both in the mean as well as in the lower (5th – 10th) and higher (90th – 95th) percentile growth curves. Such retardation was not observed among their counterparts in CG in any of the mean or percentile scores (Figs. 4 and 5).

3.3. Sitting height

Increase in sitting height in YG participants at the onset of adolescence significantly retarded ($p < 0.05$) at 10 years (Fig. 6).

Retarded growth in sitting height in YG participants was observed only in 5th percentile at 10 years, compared to CG participants (Fig. 7).

Thus, the significant growth retardation in sitting height of YG participants was observed only at 10 years of age. This was observed both in the mean value and the lower percentile score (5th). Thereafter no growth retardation was found in any age, unlike stature and leg length.

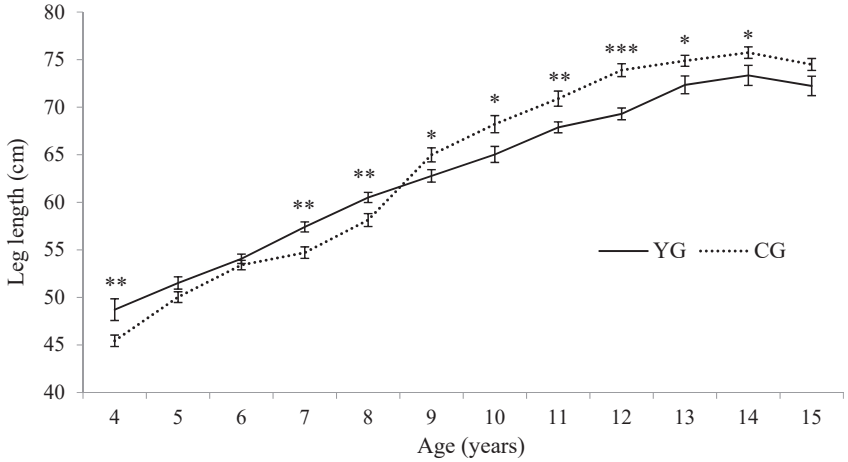

Fig. 4. Cross-sectional analyses of leg length (mean ± SEM) of YG participants from 4 to 15 years show that it was higher till 8 years of age and was significantly retarded in 9–14 years, compared to CG participants. [p value < 0.05 (*), <0.01 (**), <0.001 (***)] (CG = Control Group participants; YG = *Yoga* Group participants).

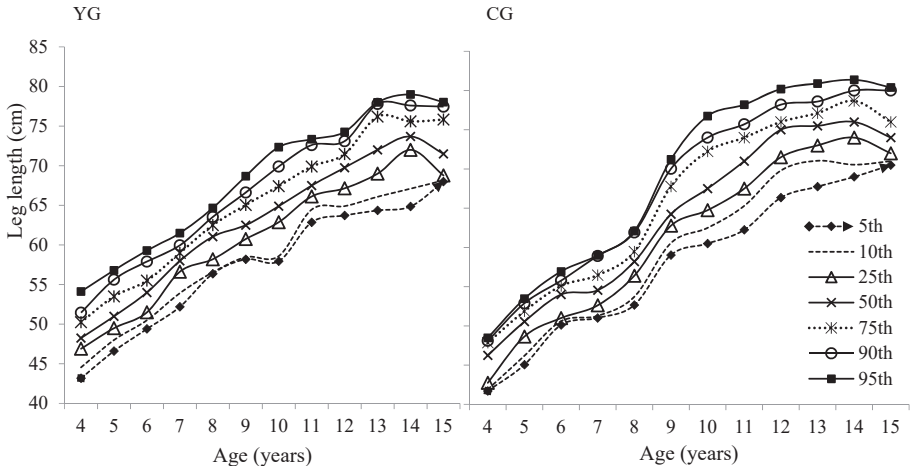

Fig. 5. Comparative analyses of leg length (cm) percentile (5th to 95th percentile scores) between YG and CG from 4 to 15 years of age indicate that leg length of YG participants was retarded at 10 years (5th and 10th percentile) and at 12 years of age (90th and 95th percentile) whereas that of CG participants increased during adolescence (from 5th to 95th percentile). (CG = Control Group participants; YG = *Yoga* Group participants).

3.4. Relation between stature and leg length

At the onset of adolescence (10 years) during the growth spurt (Figs. 1, 4 and 6), the stature, leg length and sitting height of YG participants were found to be significantly ($p < 0.01$, $p < 0.05$ and $p < 0.05$) retarded. The sitting height of YG participants was observed to be at par with that of CG participants from 11 years but the growth of stature and leg length was almost similar in pattern and remained retarded till 15 years of age, compared to CG participants.

Stunted growth in stature and leg length was observed in 5th and 10th percentile at 10 years and also in the 90th and 95th percentile at 12 years of age (Figs. 2 and 5). There was also strong positive correlation between stature and leg length in YG participants (at 9 years: $r = 0.81$, $p < 0.01$; at 10 years: $r = 0.86$, $p < 0.01$; at 11 years: $r = 0.86$, $p < 0.01$ and at 12 years: $r = 0.72$, $p < 0.01$). This indicated that the stunted stature was related to the retarded growth of leg.

4. Discussion

Physical growth is related to the overall stature change during adolescence. This is due to increased length and strength of weight bearing long bones and spine [26,27] which are reflected in leg length and sitting height respectively [28]. So, in the present study stature, leg length and sitting height were used as assessment criteria.

The study data indicate retardation in usual growth spurt in YG participants, compared to CG participants, as reflected in stature, leg length and sitting height at the onset of adolescence (10 years). Significant stunting in mean stature and leg length of YG participants was observed from 10 to 12 years of age though it did not persist with similar magnitude in later adolescence period. Similar pattern of stunted growth has also been observed among YG participants at the same age in percentile growth curves of stature and leg length at lower (5th and 10th) as well as higher (90th and 95th) percentile scores. Stunting was not observed in CG participants in any percentile categories at these ages (10–12 years) in stature and leg length. Theintz et al. [20] and Malina et al. [29] reported that change in stature was predominantly due to change in the leg length, which was seen in certain age (12 years) among gymnasts. A study on children of same age group has reported this [30]. Same was observed in *yoga* training in this study, the study data indicate that the changes in stature and leg length are highly correlated but sitting height (spine) does not follow this trend. Again, contrary to sitting height, leg length has remained low in YG participants up to 15 years of age. So, predominant factor for stunted stature in YG participant is retarded leg length.

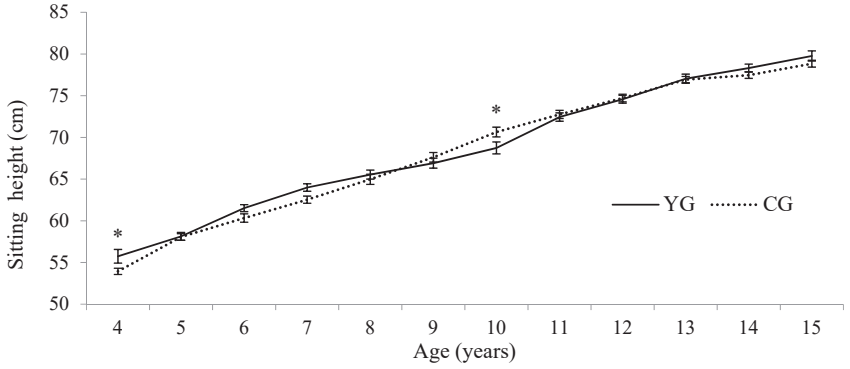

Fig. 6. Cross-sectional analyses of sitting height (mean ± SEM) of YG participants from 4 to 15 years show that it was significantly retarded at 10 years of age, compared to CG participants. [*P* value < 0.05 (*)] (CG = Control Group participants; YG = *Yoga* Group participants).

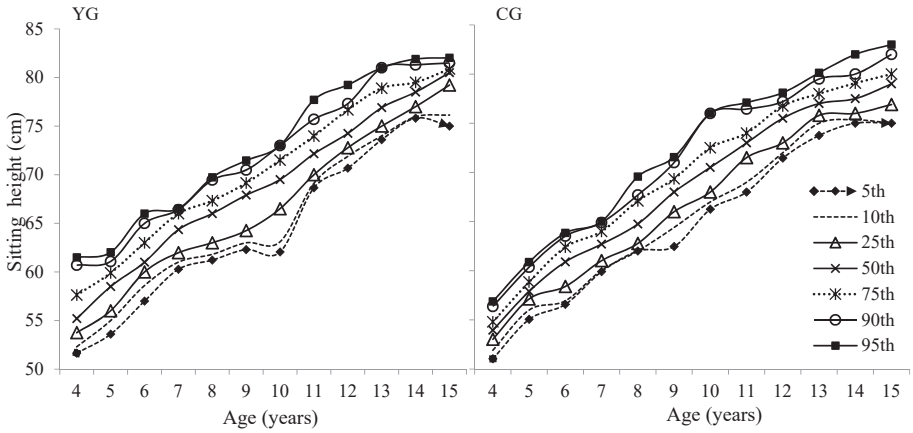

Fig. 7. Comparative analyses of sitting height (cm) percentile (5th to 95th percentile scores) between YG participants and CG participants from 4 to 15 years of age indicate that sitting heights of YG participants were retarded at 10 years in 5th percentile whereas that of CG participants increased steadily at 10 years in all percentiles. (CG = Control Group participants; YG = *Yoga* Group participants).

4.1. Factors affecting growth in general and possibility of their role

Various factors like genetic endowment, environmental situations [13,31,32], socio-economic conditions [33], nutritional status [34,35], dietary pattern [13,36,37] and heavy exercise training [16,20,38] may influence the change in stature, which again may have individual variation [39].

4.1.1. Nutrition

As growth is influence by nutritional status, the calorie intake of the participants were assessed through oral questionnaire by 24 h dietary recall method for 3 alternate days [40–42]. The diet data indicated that both YG and CG participants were undernourished according to Indian Council of Medical Research recommendation, 2010 (our unpublished observation) [43]. If undernutrition is the sole reason of stunted growth in YG participants, then it should have been reflected in sitting height from 13 to 15 years of age as well. But this was not observed indicating that undernutrition may not have interfered in the natural growth spurt.

4.1.2. Intensity of training

The YG participants have shown growth retardation mostly in this age range from 10 to 12 years. It has been reported that high intensity training and undernutrition cause stunted growth among female gymnasts, primarily due to high nutritional demand [37,44]. It has been postulated that negative energy balance or undernutrition in female gymnasts is linked with reduced growth along with the possible role of high cortisol, anti-insulin effect of elevated growth hormone (GH) and low T_3 [29,45]. Undernutrition along with intensive physical training reduces serum insulin-like growth factor-I (IGF-I) [45,46], which itself is an indicator of growth hormone (GH) insensitivity among female gymnasts [29]. Ray et al., in 2011 [47] have reported that *yoga* practices are low to moderate intensity level exercise in terms of oxygen consumption and energy expenditure. So in this study all the factors related to intensive physical training with high metabolic demand as happens in gymnasts should be excluded as cause for retarded growth.

4.1.3. Oestrogen

The average age of menarche in Indian girls is about 13 years of age [48]. Influence of oestrogen may not be contributory to the stunting of growth of our subjects as menarche initiated after 12 years in 90% of the girls (our unpublished observation), yet significant stunting has not been observed from 13 years of age in YG participants in this study.

4.1.4. Ethnicity

The interplay of ethnic factor in the findings of this study may be ruled out as the stature of YG participants of 10–12 years is significantly lower not only than that of CG participants but also lower to that of the adolescent girls of corresponding ages of Bengalee peri-urban socio-economic background as reported by Banerjee et al. [49].

Moreover, most of the above mentioned factors can be evened out as CG participants bears similar factors except *yoga* training. So these factors can be nullified and one can focus only in the training activity among study participants and it is likely that differences in physical growth of YG and CG participants during childhood and adolescence might have been due to *yoga* training.

4.1.5. Musculoskeletal stress

It is possible that training related excess musculoskeletal stress may compromise growth of the adolescent girls [20,50]. This is reflected in 90th and 95th percentile of the present study population among YG participants, implying the effect on majority of the practitioners. Since musculoskeletal stress is possible to occur only during *yogasana* component of a *yoga* practice session, hereafter the discussion on study results will be focussed with respect to *yogasana* only.

4.2. Sequence of growth of body parts and mechanism of bone growth during adolescence

Generally during early physical development the musculoskeletal growth initiates in extremities (head, hands and feet), followed by the arms and legs and finally the torso and shoulders [51]. Adolescent growth spurt starts at an average age of 10 years for girls and 12 years for boys [52]. The longitudinal bone growth in children and adolescents depends on endochondral ossification at epiphyseal growth plate. The rate and extent of bone growth is determined by this process [53] as well as the fusion of the growth plate that occurs at the end of adolescence period [54]. Tension, compression, mechanical forces etc [55] play a vital role in achievement of the final stature of an adult. Soft epiphyseal tissue injury hints as an offshoot of damage by forceful compression or stress due to exaggerated turn and twist in long bones causing

growth plate injury and early fusion [37,50,56,57]. So, any unusual pressure on the growth plate may affect the bone growth itself.

4.3. Yogasana training affecting growth among adolescents and required preventive measures

The impact of mechanical forces exerted during *yogasana* practice for 6 months or more while preparing for *yogasana* competitions, on the growing soft epiphyseal growth plate in crucial adolescence period may be responsible for the retarded growth in stature and leg length in YG participants, which may have scope for rectification. The hormesis effect may play its role where physical training with moderate intensity produces a spurt of positive effect which declines with even slight increase in intensity, creating the undesirable opposite result [58]. The basic rule of *yogasana* practice is to perform it slowly without any jerky movement while coming to a static position [59]. Although subjects had been practising *yoga* under continuous guidance of experienced *yoga* instructors, yet it is unlikely for children of those ages particularly from as low as 4 years to follow the strict regime as per *yoga* texts. So there always remains the possibility of jerky/ballistic movements. Further, with the progress of training through years, the complicated *yoga* postures as introduced with increased duration of practice in their training possibly aggravate the retardation of bone growth. Due to their fidgeting nature, they get crazy to venture out more difficult and complicated *yogasana* postures. Sometimes those postures are being introduced earlier in their training period or they themselves overexert with impatience to perform better or to attain a specific posture. Thus, basic tenet of *yoga* practice is slow but steady movement, which perhaps gets violated. This is the fundamental problem of introducing *yoga* to children. On one hand, they have supple body to practise and at the same time they are more vulnerable to musculoskeletal stress which may hinder their growth. *Yoga* trainers, coaches need to be alert about this aspect.

4.4. Comparison of growth of the study population with other studies

The growth pattern of YG and CG participants in present study is consistent with the growth pattern of Indian girls as observed in the study of Agarwal et al. [60] and Khadilkar et al. [61]. Similar growth trend has not been observed among YG participants during adolescence (10–12 years). The mean stature of YG participants has stunted at 10–12 years of age whereas the same increased steadily in CG participants and Indian girls of other generic studies [60,61]. So, it may be hypothesized that YG participants were more exposed to the possibilities of being shorter at adolescence.

Overall *yogasana* practice may cause stunted growth among those individuals who are largely within 5th percentile (10 years) as well as 90th and 95th percentile (12 years). Thus, vulnerability of potential harmful effect of intense, uncontrolled *yogasana* practice exists in major section of adolescent girls if attention is not given to follow the basic rules of *yogasana* practice. As gymnastics with its postural changes is to a certain extent similar to the physical changes in *yogasanas* and systematic studies on *yoga* in this aspect do not exist, a comparison with training scenario in gymnastics is made. Training organization viz., International Federation of Gymnastics has raised lower age limit of participation in competition to avoid involvement of intensive training during the crucial age of growth of adolescents [62]. The sequence and load of training varies among individuals with increasing age [29,38]. Caution required about warming up time, improper training types, teaching skill, extent of stretching in postures and abrupt introduction of new postures (*yogasanas*). Further longitudinal in-depth studies are required in this regard.

5. Conclusion

Intense *yogasana* practice with greater skeletal stress among adolescent girls may compromise their natural growth pattern particularly at 10 to 12 years of age. This calls for care regarding the type, intensity and duration of *yogasana* training when incorporated at the crucial age of growth among adolescents. Considering the magnitude of vulnerability in case of injuries and deformities in lower extremities among adolescent girls, one may practise *yogasana* using the other options of upper extremities of the body with due caution.

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Conflict of Interest

None.

Author contributions

Ray US conceived the work area, Ray US, Ghosh P and Mandal D designed research; Mandal D conducted research; Mandal D, Ray US and Ghosh P analyzed data and manuscript; Ghosh P had primary responsibility for final content. All authors read and approved the final manuscript.

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Appendix A. Supplementary data

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