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Original Article

Growth patterns and associated factors among children receiving long-term inhaled corticosteroid therapy for asthma. A hospital-based prospective observational cohort study.

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Abstract

Background

Inhaled corticosteroids (ICS) are central to persistent asthma management in children, but prolonged exposure may affect linear growth, particularly at higher doses or with repeated systemic corticosteroid use.

Objectives

To describe growth patterns and identify factors associated with reduced height velocity among children receiving long-term ICS therapy for asthma.

Methods

This prospective observational cohort study included 100 children aged 5–14 years at RSDKS Government Medical College, Ambikapur, Chhattisgarh, India. Demographic characteristics, asthma severity and control, corticosteroid exposure, adherence, and anthropometric measurements were recorded. Height, weight, and corresponding z scores were assessed at baseline, 6 months, and 12 months. Reduced height velocity was defined as below the age- and sex-specific 25th percentile. Associated factors were evaluated using logistic regression.

Results

The mean age was 9.2 ± 2.6 years, and 61.0% were boys. Mean annual height velocity was 5.3 ± 1.1 cm/year, and the mean height-for-age z score declined from −0.39 ± 0.86 at baseline to −0.48 ± 0.89 at 12 months ($p<0.001$). Reduced height velocity occurred in 19/100 (19.0%) children. Annual height velocity was 5.8 ± 0.9, 5.2 ± 0.9, and 4.3 ± 1.0 cm/year in the low-, medium-, and high-dose groups, respectively ($p<0.001$); the corresponding proportions with reduced height velocity were 7.5%, 19.0%, and 44.4% ($p=0.004$). In multivariable analysis, high-dose inhaled corticosteroid therapy (adjusted odds ratio 4.21, 95% confidence interval 1.28–13.86; $p=0.018$), two or more systemic corticosteroid courses (adjusted odds ratio 3.47, 95% confidence interval 1.05–11.50; $p=0.042$), and baseline height-for-age z score below −1 (adjusted odds ratio 3.22, 95% confidence interval 1.02–10.19; $p=0.047$) remained independently associated with reduced growth.

Conclusion

Most children maintained acceptable growth, although a clinically relevant subgroup demonstrated reduced linear growth..

Recommendations

Serial height monitoring, optimal asthma control, and use of the lowest effective ICS dose are recommended, particularly in higher-risk children.

Keywords: *asthma; children; growth velocity; height-for-age z score; inhaled corticosteroids; linear growth*
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Introduction

Asthma is among the most common chronic respiratory disorders of childhood and is characterised by variable airflow limitation, airway inflammation, recurrent symptoms, and episodic exacerbations. Inhaled corticosteroids (ICS) remain the principal controller therapy for children with persistent asthma because they reduce symptoms, improve lung function, and lower exacerbation risk [1].

Linear growth in children with asthma reflects a complex interaction between genetic potential, nutritional status, pubertal timing, chronic inflammation, disease severity, physical activity, and pharmacological treatment. Poorly controlled or severe asthma can itself delay growth through recurrent inflammation, sleep disruption, reduced appetite, and repeated systemic corticosteroid exposure. Consequently, reduced height velocity in a treated child cannot be attributed to ICS exposure alone without consideration of disease-related and constitutional factors [2].

Concerns regarding ICS-associated growth suppression have persisted because corticosteroids can influence growth hormone activity, bone formation, collagen synthesis, and adrenal function after systemic absorption. Controlled trials have demonstrated a small reduction in linear growth during the first year of daily ICS treatment. A Cochrane review reported an average reduction of approximately 0.48 cm/year in growth velocity, although the magnitude varied across corticosteroid molecules and study populations [3]. A

subsequent meta-analysis similarly found a modest decrease in annual growth and a small reduction in attained adult height after prolonged exposure [4].

The relationship between dose and growth is clinically important. Higher corticosteroid doses increase systemic exposure, but direct comparisons have been limited by differences in drug potency, inhaler devices, adherence, age, asthma severity, and duration of observation [5]. Evidence also indicates that corticosteroid molecule and delivery system can modify the growth effect, although existing head-to-head studies have not established a definitive hierarchy for routine clinical selection [6].

Long-term follow-up studies provide reassurance that the average effect is generally small and not continuously progressive. The Childhood Asthma Management Program demonstrated that the early height deficit associated with budesonide persisted into adulthood but remained limited in magnitude [7]. Other prospective observations found that children treated with long-term budesonide achieved adult height close to their genetically predicted values [8]. These findings support continued ICS treatment when clinically indicated while emphasising dose optimisation and serial growth surveillance.

Indian prospective data examining growth trajectories during routine paediatric asthma care remain limited, particularly regarding the combined influence of ICS dose, systemic corticosteroid courses, treatment duration, baseline nutritional status, adherence, and asthma control. The present study therefore aimed to describe changes in height, weight, and age- and sex-standardised growth indices over 12 months among children receiving long-term ICS therapy. The secondary objective was to identify clinical and treatment-related factors independently associated with reduced height velocity.

Methodology

Study design

This was a hospital-based prospective observational cohort study. Children receiving long-term inhaled corticosteroid therapy for persistent asthma were assessed at enrolment and followed prospectively with anthropometric evaluations at baseline, six months, and 12 months. Treatment was not allocated by the investigators, and routine clinical management continued according to the treating paediatric team.

Study size

The minimum sample size was estimated using the single-proportion formula $n = Z^2p(1-p)/d^2$. Assuming an anticipated prevalence of reduced growth of 20%, a 95% confidence level ($Z = 1.96$), and an absolute precision of 8% ($d = 0.08$), $n = (1.96)^2 \times 0.20 \times 0.80/(0.08)^2 = 96.04$. The minimum required sample was therefore 96 children and was rounded to 100.

Study setting and period

The study was conducted in the Department of Paediatrics at Rajmata Shrimati Devendra Kumari Singhdeo (RSDKS) Government Medical College and its affiliated teaching hospital in Ambikapur, the district headquarters of Surguja in northern Chhattisgarh, India. Established as a government medical college in 2016, the institution provides undergraduate and postgraduate medical education together with tertiary-level clinical care. The affiliated hospital has approximately 650 beds, including dedicated emergency and critical-care capacity, and provides outpatient, inpatient, emergency, operative, maternal and child health, intensive care, and diagnostic services across major specialties such as general medicine, general surgery, obstetrics and gynaecology, paediatrics, orthopaedics, otorhinolaryngology, ophthalmology, psychiatry, anaesthesiology, pathology, microbiology, radiology, and related disciplines. The hospital functions as an important referral centre for Ambikapur and the wider Surguja division, including predominantly rural and tribal populations from Surguja and neighbouring districts. Recruitment was undertaken from October 2025 to March 2026, and each enrolled child was followed for 12 months.

Study population and recruitment

Children aged 5-14 years with physician-diagnosed persistent asthma who were receiving continuous inhaled corticosteroid therapy were assessed for eligibility. During recruitment, 108 children were assessed; eight were excluded, and 100 were enrolled and included in the final analysis. Complete clinical, treatment, and anthropometric data were reported as available for all participants at 12 months.

Inclusion criteria

Children aged 5-14 years with physician-diagnosed persistent asthma, continuous inhaled corticosteroid use for at least 12 months before enrolment, and a stable treatment plan for the preceding four weeks were eligible.

Exclusion criteria

Children with endocrine disorders, chronic kidney or liver disease, congenital heart disease, malabsorption, genetic syndromes, skeletal disorders, long-term systemic corticosteroid therapy for another condition, or medicines known to substantially affect growth were excluded.

Clinical and treatment assessment

Demographic characteristics, asthma duration, previous hospitalisations, systemic corticosteroid courses, ICS molecule, inhaler device, prescribed daily dose, and treatment duration were recorded. Asthma severity and control were classified using recognised guideline-based clinical criteria [1]. Daily ICS doses were categorised as low, medium, or high after conversion to age-appropriate corticosteroid dose ranges.

Adherence was assessed through caregiver interview, prescription review, and dose-counter or canister information when available. Use of at least 80% of prescribed doses was considered good adherence, consistent with commonly used adherence thresholds [10].

Growth measurements and outcomes

Standing height was measured without footwear using a calibrated wall-mounted stadiometer to the nearest 0.1 cm. Weight was measured in light clothing using a calibrated digital scale to the nearest 0.1 kg. Measurements were obtained at baseline, six months, and 12 months by trained personnel using the same equipment whenever feasible. Height-for-age, weight-for-age, and body mass index-for-age z scores were calculated using the World Health Organization growth reference for children aged 5–19 years [9]. Annual height velocity was calculated as the difference between baseline and 12-month height. The primary outcome was height velocity below the age- and sex-specific 25th percentile. Secondary outcomes included change in height-for-age z score, a decline of at least 0.25 in height-for-age z score, and changes in weight-related indices.

Measures to address bias

Measurement variability was reduced by using trained personnel, calibrated anthropometric equipment, and the same equipment whenever feasible across follow-up visits. Age- and sex-standardised growth indices were used to improve comparability. Potential confounding by age, sex, baseline asthma severity, asthma control, and baseline height-for-age z score was addressed in the exploratory multivariable model. Residual confounding from disease severity, pubertal stage, parental height, nutrition, and cumulative corticosteroid exposure remained possible.

Statistical analysis

Data were analysed using a standard statistical software package. Continuous variables were summarised as mean ± standard deviation and categorical variables as frequency and percentage. Repeated anthropometric measurements were compared using repeated-measures analysis of variance. Between-group comparisons used independent-samples t test or one-way analysis of variance for continuous variables and chi-square or Fisher exact test for categorical variables. Variables associated with reduced height velocity in univariable analysis were entered into an exploratory multivariable logistic regression model. Adjusted odds ratios with 95% confidence intervals were reported. A two-sided p-value below 0.05 was considered statistically significant.

Ethical considerations

The study was conducted at RSDKS Government Medical College, Ambikapur, Chhattisgarh, India, after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from the parent or legal guardian of each participating child, and age-appropriate assent was obtained from older children. Participant confidentiality was maintained throughout the study, and all information was used solely for research purposes in accordance with institutional ethical standards.

Results

Participant recruitment and follow-up

During the recruitment period, 108 children receiving long-term ICS therapy for asthma were assessed for eligibility. Eight were excluded: five did not satisfy the eligibility criteria, two had chronic conditions that could independently affect growth, and one did not complete baseline anthropometric assessment. The remaining 100 children were enrolled and included in the analysis. Complete clinical, treatment, and anthropometric data were available for all participants at 12 months. Participant flow is summarised in Figure 1.

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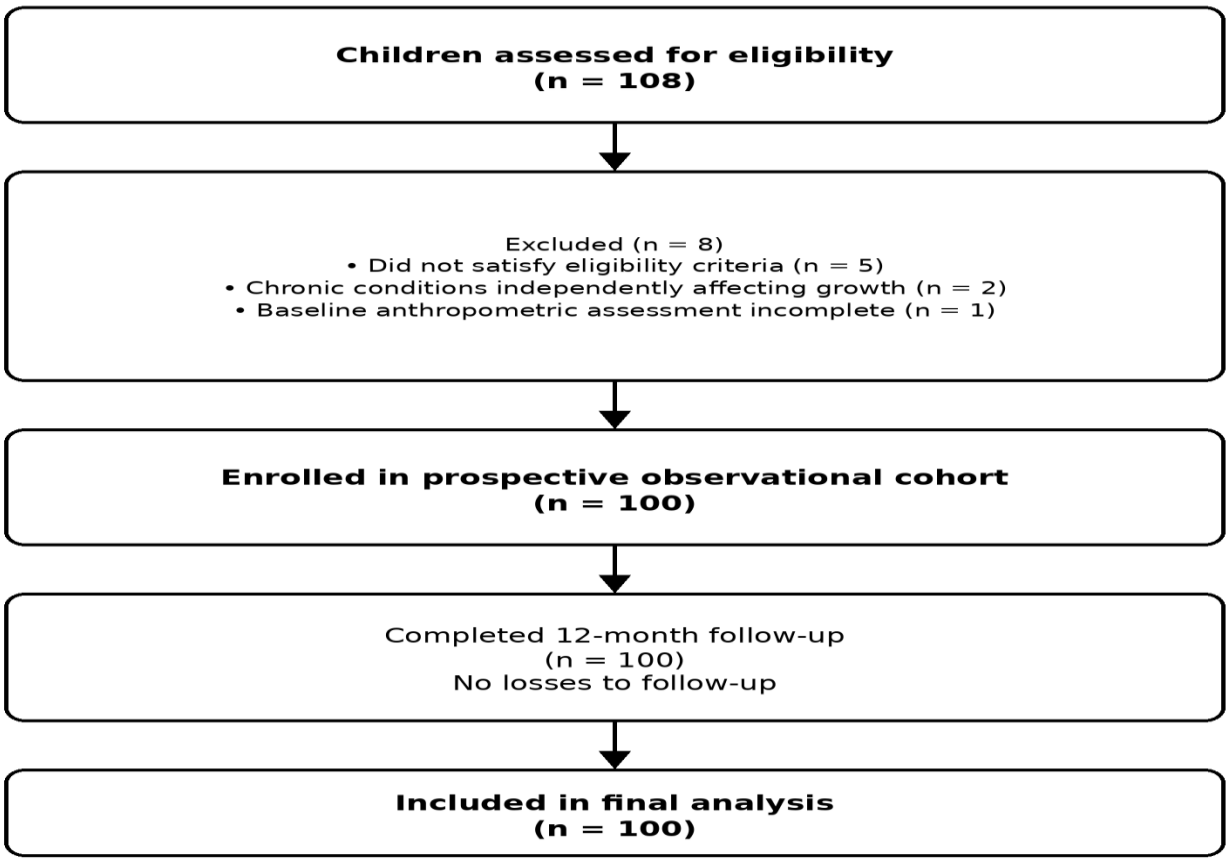

Figure 1. Participant flow through eligibility assessment, enrolment, follow-up, and analysis

Baseline demographic and clinical characteristics

The mean age was 9.2 ± 2.6 years, with a range of 5–14 years. Sixty-one (61.0%) participants were boys. The mean duration of asthma was 4.1 ± 2.0 years, and the mean duration of ICS exposure before enrolment was 2.6 ± 1.3 years. Moderate persistent asthma was the most frequent severity category, affecting 48 (48.0%) children. At baseline, 56 (56.0%) had well-controlled asthma, whereas 44 (44.0%) had partly controlled or uncontrolled disease.

Forty (40.0%) children received low-dose ICS, 42 (42.0%) received medium-dose therapy, and 18 (18.0%) received high-dose therapy. Budesonide was used by 45 (45.0%) children, fluticasone by 38 (38.0%), and beclomethasone by 17 (17.0%). Good adherence was documented in 68 (68.0%) participants. The mean baseline height-for-age z score was −0.39 ± 0.86; 18 children had a value between −2 and −1, while seven had a value below −2. Baseline characteristics are presented in Table 1.

Table 1. ***Baseline demographic, clinical, and treatment characteristics***

Characteristic	Value
Age, years	9.2 ± 2.6
Age 5–7 years	28 (28.0%)
Age 8–10 years	36 (36.0%)
Age 11–14 years	36 (36.0%)
Boys	61 (61.0%)
Girls	39 (39.0%)
Duration of asthma, years	4.1 ± 2.0
Duration of inhaled corticosteroid therapy, years	2.6 ± 1.3
Mild persistent asthma	34 (34.0%)
Moderate persistent asthma	48 (48.0%)
Severe persistent asthma	18 (18.0%)
Well-controlled asthma	56 (56.0%)
Partly controlled asthma	29 (29.0%)
Uncontrolled asthma	15 (15.0%)
Low-dose inhaled corticosteroid therapy	40 (40.0%)
Medium-dose inhaled corticosteroid therapy	42 (42.0%)
High-dose inhaled corticosteroid therapy	18 (18.0%)
Good treatment adherence	68 (68.0%)
Two or more systemic corticosteroid courses during the preceding year	19 (19.0%)
Hospitalisation for asthma during the preceding year	14 (14.0%)
Baseline height, cm	131.8 ± 15.1
Baseline weight, kg	29.2 ± 10.3
Baseline height-for-age z score	−0.39 ± 0.86
Baseline weight-for-age z score	−0.31 ± 0.92
Baseline body mass index z score	−0.12 ± 0.81

Data are presented as mean ± standard deviation or number (percentage).

Changes in growth parameters during follow-up

Mean height increased from 131.8 ± 15.1 cm at baseline to 134.4 ± 15.2 cm at six months and 137.1 ± 15.3 cm at 12 months. The mean absolute increase in height was 5.3 ± 1.1 cm. Despite this increase, the mean height-for-age z score declined from −0.39 ± 0.86 to −0.48 ± 0.89, corresponding to a mean change of −0.09 ± 0.22 ($p<0.001$). Mean body weight increased from 29.2 ± 10.3 kg to 32.1 ± 10.8 kg. Weight-for-age and body mass index z scores did not change significantly, indicating that the principal alteration involved linear growth (Table 2).

Table 2. ***Changes in anthropometric parameters over 12 months***

Growth parameter	Baseline	Six months	12 months	p-value
Height, cm	131.8 ± 15.1	134.4 ± 15.2	137.1 ± 15.3	<0.001
Height-for-age z score	−0.39 ± 0.86	−0.43 ± 0.87	−0.48 ± 0.89	<0.001
Weight, kg	29.2 ± 10.3	30.6 ± 10.5	32.1 ± 10.8	<0.001
Weight-for-age z score	−0.31 ± 0.92	−0.30 ± 0.91	−0.28 ± 0.93	0.214
Body mass index, kg/m²	16.4 ± 2.5	16.5 ± 2.5	16.7 ± 2.6	0.032

Growth parameter	Baseline	Six months	12 months	p-value
Body mass index z score	−0.12 ± 0.81	−0.09 ± 0.82	−0.06 ± 0.84	0.176

Data are presented as mean ± standard deviation. P-values represent within-participant changes across the three assessments.

Pattern of linear growth

The mean annual height velocity was 5.3 ± 1.1 cm/year. Sixty-two (62.0%) children maintained an expected age- and sex-specific height velocity, 19 (19.0%) had a height velocity below the 25th percentile, and 19 (19.0%) had a value between the 25th and 50th percentiles. A reduction of at least 0.25 in height-for-age z score occurred in 17 (17.0%) children. Eight children who were not stunted at baseline entered the height-for-age z-score category below −2 during follow-up. No participant had a decline exceeding 1.0 z score.

Mean height velocity did not differ significantly between boys and girls (5.2 ± 1.1 versus 5.4 ± 1.0 cm/year; p=0.348). No significant difference was detected among the three age groups after growth was expressed using age- and sex-standardised measures (p=0.281).

Growth according to inhaled corticosteroid dose

Annual height velocity differed across ICS dose categories. Children receiving low-dose therapy had a mean velocity of 5.8 ± 0.9 cm/year, compared with 5.2 ± 0.9 cm/year in the medium-dose group and 4.3 ± 1.0 cm/year in the high-dose group (p<0.001). The mean change in height-for-age z score was −0.02 ± 0.17, −0.09 ± 0.20, and −0.25 ± 0.24, respectively. Height velocity below the 25th percentile occurred in 3 (7.5%), 8 (19.0%), and 8 (44.4%) children in the low-, medium-, and high-dose groups (p=0.004). Post-hoc comparisons showed significantly lower height velocity in the high-dose group than in both other groups (Table 3).

Table 3. ***Growth parameters according to inhaled corticosteroid dose***

Growth outcome	Low dose (n=40)	Medium dose (n=42)	High dose (n=18)	p-value
Annual height velocity, cm/year	5.8 ± 0.9	5.2 ± 0.9	4.3 ± 1.0	<0.001
Change in height-for-age z score	−0.02 ± 0.17	−0.09 ± 0.20	−0.25 ± 0.24	<0.001
Height velocity below the 25th percentile	3 (7.5%)	8 (19.0%)	8 (44.4%)	0.004
Reduction in height-for-age z score ≥0.25	3 (7.5%)	6 (14.3%)	8 (44.4%)	0.002
Change in weight-for-age z score	0.05 ± 0.19	0.03 ± 0.21	0.01 ± 0.23	0.781
Change in body mass index z score	0.07 ± 0.22	0.06 ± 0.24	0.04 ± 0.25	0.892

Data are presented as mean ± standard deviation or number (percentage).

Factors associated with reduced height velocity

Reduced height velocity was observed in 8 of 18 children receiving high-dose ICS and 11 of 82 receiving low- or medium-dose therapy (44.4% versus 13.4%; p=0.006). It was also more frequent among children who had received at least two systemic corticosteroid courses during the preceding year (42.1% versus 13.6%; p=0.008), among those with partly controlled or uncontrolled asthma (29.5% versus 10.7%; p=0.022), and among children with a baseline height-for-age z score below −1 (36.0% versus 13.3%; p=0.019). ICS exposure exceeding three years was associated with reduced growth in unadjusted analysis. Sex, inhaler device, corticosteroid molecule, and treatment adherence were not significantly associated with the primary outcome (Table 4).

Table 4. ***Factors associated with height velocity below the 25th percentile***

Factor	Reduced height velocity, n/N (%)	Odds ratio (95% CI)	p-value
High-dose inhaled corticosteroid therapy	8/18 (44.4%)	5.16 (1.67–15.92)	0.006
Low- or medium-dose therapy	11/82 (13.4%)	Reference	—
Two or more systemic corticosteroid courses	8/19 (42.1%)	4.63 (1.52–14.05)	0.008
Fewer than two systemic corticosteroid courses	11/81 (13.6%)	Reference	—

Factor	Reduced height velocity, n/N (%)	Odds ratio (95% CI)	p-value
Partly controlled or uncontrolled asthma	13/44 (29.5%)	3.49 (1.20–10.15)	0.022
Well-controlled asthma	6/56 (10.7%)	Reference	—
Baseline height-for-age z score below −1	9/25 (36.0%)	3.66 (1.27–10.49)	0.019
Baseline height-for-age z score ≥−1	10/75 (13.3%)	Reference	—
Inhaled corticosteroid exposure >3 years	10/30 (33.3%)	3.39 (1.21–9.47)	0.025
Inhaled corticosteroid exposure ≤3 years	9/70 (12.9%)	Reference	—

CI: confidence interval.

Multivariable analysis and asthma control

After adjustment for age, sex, baseline asthma severity, asthma control, and baseline height-for-age z score, high-dose ICS therapy remained independently associated with reduced height velocity (adjusted odds ratio 4.21; 95% confidence interval 1.28–13.86; p=0.018). Two or more systemic corticosteroid courses were also independently associated with reduced growth (adjusted odds ratio 3.47; 95% confidence interval 1.05–11.50; p=0.042), as was a baseline height-for-age z score below −1 (adjusted odds ratio 3.22; 95% confidence interval 1.02–10.19; p=0.047). Suboptimal asthma control showed an increased adjusted odds but did not retain statistical significance (adjusted odds ratio 2.57; 95% confidence interval 0.82–8.06; p=0.105).

At 12 months, 72 (72.0%) children had well-controlled asthma, 21 (21.0%) had partly controlled asthma, and 7 (7.0%) remained uncontrolled. Children with sustained well-controlled asthma had greater mean height velocity than those with persistent partly controlled or uncontrolled disease (5.5 ± 1.0 versus 4.7 ± 1.1 cm/year; p=0.002). No clinically meaningful differences in weight-for-age or body mass index z-score changes were observed across asthma-control categories.

Discussion

Key findings

The principal finding was that most children maintained broadly satisfactory linear growth during 12 months of observation, but a clinically important subgroup showed growth deceleration. Mean annual height velocity was 5.3 ± 1.1 cm/year, while 19/100 (19.0%) children had height velocity below the age- and sex-specific 25th percentile and 17/100 (17.0%) had a decline of at least 0.25 in height-for-age z score. Mean height-for-age z score decreased from −0.39 ± 0.86 to −0.48 ± 0.89 (mean change −0.09 ± 0.22; p<0.001), whereas weight-for-age and body mass index z scores did not change significantly. This pattern suggests that the detected alteration was predominantly in linear growth rather than a manifestation of generalized weight loss or worsening nutritional status. The coexistence of a small average change with a larger effect in a minority also indicates that mean cohort values can conceal children who develop clinically relevant growth slowing.

Growth trajectory and inhaled corticosteroid exposure

A clear dose-related gradient was observed. Mean height velocity was 5.8 ± 0.9 cm/year with low-dose therapy, 5.2 ± 0.9 cm/year with medium-dose therapy, and 4.3 ± 1.0 cm/year with high-dose therapy (p<0.001). Likewise, reduced height velocity occurred in 7.5%, 19.0%, and 44.4% of these groups, respectively (p=0.004). After adjustment, high-dose inhaled corticosteroid therapy remained independently associated with reduced height velocity (adjusted odds ratio 4.21, 95% confidence interval 1.28–13.86; p=0.018). These findings support a dose-response relationship in which greater inhaled corticosteroid exposure may increase systemic glucocorticoid activity and transiently influence growth-related pathways, including growth hormone activity, bone formation, and collagen synthesis [2,5]. They are consistent with the Cochrane review by Zhang et al., which reported an average reduction of approximately 0.48 cm/year during the first year of inhaled corticosteroid treatment, and with the meta-analysis by Loke et al., which also found a modest reduction in growth velocity [3,4]. Nevertheless, because this was an observational study, confounding by indication remains possible: children prescribed high doses may have had more severe disease or greater cumulative steroid exposure, both of which can adversely influence growth.

The magnitude of the cohort-level change should therefore be interpreted in the context of long-term evidence. In the Childhood Asthma Management Program, budesonide produced an early height deficit that remained detectable in adulthood but was limited in magnitude [7,11]. Agertoft and Pedersen similarly reported adult height close to genetically predicted values among children treated with long-term budesonide [8]. The present 12-month findings cannot determine final adult height, but they fit the broader evidence that growth effects are usually modest at the population level and are most relevant when exposure is greater or additional risk factors are present. Thus, the observed growth signal should prompt dose review and surveillance rather than inappropriate withdrawal of effective controller therapy.

Corticosteroid molecule, dose, and delivery considerations

No significant association between corticosteroid molecule or inhaler device and reduced height velocity was detected in this cohort. This should not be interpreted as proof of equivalence because the study was not powered for head-to-head comparisons and dose categories included different molecules and delivery systems. Previous trials comparing fluticasone with beclomethasone or budesonide have reported regimen-specific differences in growth velocity [12,13], while a Cochrane review concluded that comparative evidence is insufficient to select one inhaled corticosteroid solely on the basis of growth effects [6]. Differences in potency, lung deposition, oropharyngeal deposition, systemic bioavailability, inhaler technique, and adherence may all modify systemic exposure. Consequently, drug selection should remain individualized, with emphasis on correct device use and the lowest dose that maintains asthma control.

Systemic corticosteroid exposure and asthma control

Repeated systemic corticosteroid exposure was another important determinant. Reduced height velocity occurred in 42.1% of children who had received two or more systemic corticosteroid courses compared with 13.6% of those receiving fewer courses (p=0.008), and the association persisted after adjustment (adjusted odds ratio 3.47, 95% confidence interval 1.05–11.50; p=0.042). This finding is biologically plausible because systemic corticosteroids produce substantially greater whole-body glucocorticoid exposure and can suppress growth-related endocrine and skeletal pathways [14]. Baseline height-for-age z score below −1 also independently predicted reduced growth (36.0% versus 13.3%; adjusted odds ratio 3.22, 95% confidence interval 1.02–10.19; p=0.047), suggesting that children who enter treatment with a lower growth trajectory may have less physiological reserve or may already reflect constitutional, nutritional, disease-related, or prior treatment influences. Because parental height, pubertal stage, and detailed nutritional measures were not recorded, these mechanisms cannot be separated in the present study.

Clinical implications

Asthma control also contributed to interpretation of the growth findings. Children with sustained well-controlled asthma had greater mean height velocity than those with persistent partly controlled or uncontrolled disease (5.5 ± 1.0 versus 4.7 ± 1.1 cm/year; p=0.002). Partly controlled or uncontrolled asthma was associated with reduced growth in univariable analysis (29.5% versus 10.7%; p=0.022), although the adjusted association was attenuated and no longer statistically significant (adjusted odds ratio 2.57, 95% confidence interval 0.82–8.06; p=0.105). This attenuation may reflect overlap between poor control, asthma severity, high-dose inhaled therapy, and systemic corticosteroid use, together with limited statistical power. Previous evidence indicates that asthma itself may impair growth through chronic inflammation, sleep disturbance, reduced appetite, and recurrent exacerbations [2]. Treatment adherence was not significantly associated with the primary outcome, but adherence assessment relied on caregiver interview, prescription review, and available dose-counter information; misclassification may therefore have weakened a true association [10]. Clinically, serial height measurement should be interpreted alongside disease control, exacerbation burden, cumulative corticosteroid exposure, pubertal stage, parental height, and nutrition. A sustained downward growth trajectory should prompt reassessment of asthma control, dose, device technique, adherence, comorbidities, and non-asthma causes of growth impairment.

Generalizability

These findings are most applicable to children with persistent asthma receiving long-term inhaled corticosteroid therapy in hospital-based settings similar to the study centre. Extrapolation to untreated asthma, healthy children, other age groups, or settings with substantially different treatment patterns should be cautious because the study was single-centre and did not include a control group.

Conclusion

Most children receiving long-term inhaled corticosteroid therapy maintained satisfactory growth over 12 months; however, nearly one-fifth demonstrated height velocity below the age- and sex-specific 25th percentile. High-dose inhaled corticosteroid use, repeated systemic corticosteroid courses, and a baseline height-for-age z score below −1 independently identified children at increased risk. The small decline in mean height-for-age z score should be balanced against the substantial clinical benefits of effective asthma control. Paediatric asthma care should include accurate serial height measurement, assessment of cumulative corticosteroid exposure, review of inhaler technique and adherence, and stepwise dose reduction to the lowest effective regimen whenever stable control is achieved. Children with persistent growth deceleration require clinical evaluation.

Limitations

This single-centre study had a modest sample size and lacked an untreated asthma group or healthy control group. Pubertal stage, parental target height, dietary intake, vitamin D status, and objective electronic adherence were not measured. Corticosteroid dose categories combined different molecules and devices. Residual confounding from asthma severity and systemic corticosteroid exposure remains possible, and the 12-month duration does not determine final adult height.

Recommendations

Routine paediatric asthma follow-up should include accurate serial height measurement and review of growth trajectory. Children receiving high-dose inhaled

corticosteroids, those requiring repeated systemic corticosteroid courses, and those with a lower baseline height-for-age z score merit closer surveillance. Asthma control, inhaler technique, adherence, cumulative corticosteroid exposure, nutrition, and alternative causes of growth deceleration should be reassessed when height velocity declines. When stable asthma control is achieved, therapy should be stepped down to the lowest effective corticosteroid dose in accordance with clinical guidance.

List of abbreviations

CI: confidence interval; ICS: inhaled corticosteroid(s); WHO: World Health Organization.

Source of funding

The study received no funding from any public, commercial, or not-for-profit funding agency.

Conflict of interest

The authors declare no conflict of interest.

Informed consent

Written informed consent was obtained from the parent or legal guardian of every participating child before enrolment; age-appropriate assent was also obtained from older children.

Author contributions

AKG contributed to the conception and design of the study, clinical assessment, data collection, interpretation of findings, literature review, and preparation of the manuscript. AS contributed to study methodology, clinical supervision, data interpretation, and critical revision of the manuscript. ST contributed to laboratory-related inputs, data organisation, interpretation of findings, literature review, and critical review of the manuscript. All authors reviewed and approved the final version of the manuscript.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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