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Turkish migrants adjust body height during adolescence to the host community in Germany

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Abstract

Background Investigating migration is crucial for understanding population changes and their impact on growth. Migration and its associated Social-Economic-Political-Emotional (SEPE) factors can influence height, aligning with the theory of "developmental plasticity", which suggests that environmental stimuli affect growth patterns.

Objective This study aims to analyse the impact of migration and associated stress on the growth and development of first- and second-generation migrant children in Germany.

Sample and Methods The analysis utilized the KiGGS (German Health Interview and Examination Survey for Children and Adolescents) dataset, collected by the RKI (Robert Koch-Institut, the central public health institute in Germany) between 2003 and 2006. The baseline survey included anthropometric, demographic, and social data from 8,986 males and 8,654 females, aged 0–17 years across 167 cities in Germany. Height data from first- and second-generation Turkish-origin children and their German-origin peers were analysed to assess differences in growth patterns.

Results Differences in height were observed between first- and second-generation immigrant children of Turkish origin compared to German-origin peers. Second-generation boys aged 3–10 (heightSDS=-0.29) were shorter than German-origin peers (heightSDS=0.04). First-generation boys in this group were even shorter (heightSDS=-0.19). In the 11–17 group, second-generation boys showed a heightSDS of 0.12, above their German-origin counterparts (height SDS=0.06), while first-generation boys were notably shorter (heightSDS=-0.54). For children (aged 3–10) and adolescents (aged 11–17) of both sexes, no significant differences were found between the first and second generations.

Conclusion Migration and associated environmental factors impact children's height, highlighting the complexity of generational shifts in physical growth.

Take-home message for students Migration influences children's growth, with first-generation Turkish-origin children in Germany being shorter than their German-origin peers. Second-generation children grow taller, but do not fully reach German height levels. These findings highlight the role of Social-Economic-Political-Emotional (SEPE) factors and developmental plasticity in shaping intergenerational growth patterns.

Introduction

The study of human growth patterns has long been a topic of interest in anthropology and public health. Previous research has shown that height is influenced by various factors, such as genetics, nutrition, physical activity and overall health (Deaton 2007; Stulp and Barrett 2016). Newer studies show that the impact of those factors can be seen as overestimated (Hermanussen and Wit 2017; Özer and Scheffler 2018). Over the last decade other factors, namely Social-Economic-Political-Emotional (SEPE) factors, were proven to either enhance or inhibit growth (Bogin 2021). Significant variation in adult body size across human populations is often seen as a form of adaptation to local ecological conditions, with developmental plasticity playing a key role in contributing to this variability (Wells and Johnstone 2017). To better understand the extent of this variability and the dimensions in which humans can grow, as well as the factors that affect growth, the phenomenon of migration could play a key role (Bogin and Loucky 1997). Migrants are defined as individuals who move from one place of residence to another, particularly from their birthplace to a new geographic and social environment.

Migration is influenced by "push-pull" factors (Ravenstein 1885; Hagood and Ducoff 1946) which describe the reasons why people move from one place to another. The European Psychiatric Association has categorized these factors into two primary groups: "pull" factors, such as educational, economic, or personal opportunities, and "push" factors, such as political instability, poverty, or conflict (Bhugra et al. 2014; Cadorin et al. 2024). These forces not only drive migration but can also trigger strategic growth adjustments in migrants, as they adapt to new socio-environmental conditions that influence their developmental trajectories (Bogin et al. 2018a). The term "social growth adjustment" describes the manner in which individuals modify their growth and size in response to subtle changes in their social or environmental context. This is influenced by factors such as competition, cooperation, and group dynamics. It is observed in mammals (Huchard et al. 2016) but also used in the social sciences to describe how individuals or groups adapt to social norms and community expectations (Buston and Clutton-Brock 2022). Individuals within the same social group typically have similar body heights; migrants often unconsciously adapt their height to match the average height of their host communities (Bogin et al. 2018a; Scheffler et al. 2021).

In this study, the operationalisation of generational differences is achieved through an analysis of height standard deviation scores (heightSDS) between first- and second-generation migrant children. A smaller height gap between second-generation children and the host (German-origin) group, compared to the first generation, is interpreted as evidence of such an adjustment. This phenomenon can be connected to the term "community effect in body height", which is used to describe the impact of "social interaction within a group on the growth and body height of its members" (Hermanussen and Scheffler 2019). We examine this effect by comparing heightSDS distributions across generations and age groups. If second-generation children's heights converge towards those of the German-origin group, especially during adolescence, this would support the view that social inclusion and peer alignment may contribute to growth outcomes. The impact of migration on physical characteristics varies based on age at migration (Mascie-Taylor and Little 2004). Most growth happens in early childhood, but the most critical changes occur in adolescence

shortly before final adult height is reached around 18 or 19 years of age (Cameron and Bogin 2012).

Germany has a long-standing history of high migration rates (Green 2013), a trend that is expected to continue or even increase in the future due to factors such as climate change and political conflicts. Climate-induced migration introduces new challenges for human development, as it is often accompanied by environmental pressures such as food and water shortages, sociocultural instability, and economic and political uncertainties. These stressors can impact the development and well-being of future generations (Özer and Scheffler 2018). While migration can be categorized as voluntary or forced, Rösler et al. ((Rösler et al. 2023) found no significant differences in height development between these groups, even though psychological strain has been shown to vary. Although Rösler's study focused on internal migration within cultural groups, research such as Bakewell (Bakewell 2021) emphasized the overlapping challenges faced by migrants in both voluntary and involuntary contexts. Based on these findings, and the understanding that migration experiences exist along a continuum, this study treats migration as a unified category without distinguishing between voluntary and forced contexts. Still, it is important to note that there is also literature available stating that the acculturation experiences and the psychological stressors may differ. Udahemuka and Pernice (Udahemuka and Pernice 2010) found voluntary migrants to be more likely to adapt to the host culture, while forced migrants tend to maintain stronger ties to their culture of origin. Regarding the psychological stressors a recent review found higher rates of mental health issues among forced migrants compared to voluntary migrants; these differences are associated with additional stressors, including trauma, loss, and disrupted life trajectories, which collectively increase the psychosocial strain experienced through forced migration (Cadorin et al. 2024).

There is also evidence suggesting that growth and height patterns vary between first-generation migrants, second-generation migrants, and the host population (Greulich 1957). Such variations are often discussed as a link to improved living conditions or differences in socio-economic status (Gualdi-Russo et al. 2014).

At 1.5 million, Turkish-origin individuals make up one of the largest migrant groups in Germany (Statistisches Bundesamt 2024). Their stature is on average shorter than the average height of German-origin individuals (Fredriks et al. 2003). This is ideal for studying how changes in environment and living conditions across generations influence physical development.

We hypothesize that:

the height of second-generation migrants, if their parents migrated into a country where the average height is higher than in the country of origin, is more similar to the height of peers in the host community compared to first-generation migrants.

during adolescence (ages 11–17), as a critical phase of growth and development, Social-Economic-Political-Emotional (SEPE) factors associated with migration exert a more pronounced influence on height, potentially leading to adjustments in growth relative to non-migrant peers.

Methods

Survey methods and participants

The present analysis is based on data from the KiGGS Baseline Survey (German Health Interview and Examination

Survey for Children and Adolescents), conducted by the Robert Koch-Institut the central public health institute in Germany, between 2003 and 2006 (Robert Koch-Institut, Kamtsiuris et al. 2007, Kurth et al. 2019). The survey included 17,640 children and adolescents, of whom 8,986 were male and 8,654 female, aged between 0 and 17 years, from 167 cities and municipalities across Germany. It collected both anthropometric data and socio-demographic information through physical examinations and questionnaires. Body height was measured following internationally recognized anthropometric standards (Knußmann 1996). For all participants older than 2 years, height was measured while standing, without shoes, using a portable stadiometer (Holtain Ltd., UK). All linear measurements, including height, were taken with a precision of 0.1cm. For this study, height data from first- and second-generation Turkish-origin children and their German-origin peers were analysed to assess differences in growth patterns associated with migration. Examinations were voluntary and the baseline study was approved by the Ethics Committee of the Virchow Hospital of the Humboldt University of Berlin (Robert Koch-Institut).

Dataset

A sub dataset was created including only participants age 3 to 17. We used the following factors for the analysis: age, height, sex, migration status, place of birth of each parent, nationality of each parent. For nationality and birthplace only Turkey and Germany were used. We divided the categories "first generation", "second generation", and "host population (German origin)" based on a review of the relevant literature, ensuring that the terms aligned with commonly accepted criteria (Borrelli and Ruedin 2024). Using these terms, we identified the corresponding individuals within our sub dataset (Table 1). Specifically, "first generation (F1)" individuals were those whose parents were born abroad, "second generation (F2)" referred to those born in the host country but with at least one parent born abroad, and "host population (G)" encompassed individuals whose parents were both born in Germany. We then filtered the dataset to include only those individuals who met these criteria.

Height was transformed into z-scores (heightSDS), considering sex and age as categorizing factors, using the working dataset as a reference.

We divided the sub dataset into 8 groups based on sex, migration status, and age. The two age groups used in the analysis were 3–10 and 11–17 years, since early adolescence starts at approximately 10 years of age (Sawyer et al. 2018; Bogin et al. 2018b). The group sizes were as follows: Turkish-origin boys aged 3–10 (n=199) and 11–17 (n=137), German-origin boys aged 3–10 (n=2,813) and 11–17 (n=2,422), Turkish-origin girls aged 3–10 (n=170) and 11–17 (n=102), and German-origin girls aged 3–10 (n=2,783) and 11–17 (n=2,320). The heightSDS was tested for normality using the Shapiro-Wilk test and Anderson-Darling test. Dunn's post hoc test with Holm correction was conducted to identify pairwise differences between groups following a Kruskal-Wallis test for significance, as this method controls for type I error in multiple comparisons. Confidence intervals were calculated to provide a measure of precision for the estimated differences between groups, adding further context to the statistical significance of the pairwise comparisons. To identify significant differences between the variances, an F-test was performed (Table 2).

The statistical analyses were conducted using the R programming language within the R Studio environment (RStudio Team 2024).

To identify the specific groups that differ, we examined the categorization by age groups (children, aged 3–10 years, or adolescents, aged 11–17 years, taking into account adolescence as a critical period for individual height development, sex (male or female) and migration status (yes or no)). Additionally, we examined three distinct categories to refine our analysis: first-generation Turkish origin (F1), second-generation Turkish origin (F2), and host population (G) (Table 1).

Results

The German-origin group consistently displays the highest heightSDS scores (heightSDS mean), clustering around positive values, indicating generally taller stature compared to both first- and second-generation Turkish-origin children and adolescents. Meanwhile, first-generation children and adolescents have the lowest average height scores, indicating shorter stature overall (Table 1, Figure 1). For females aged 3–10 and 11–17, there were no significant differences between the first and second generations or between the second generation and German-origin individuals, but a significant difference was found between the first generation and German-origin individuals (Table 2).

In the age group 11–17, first-generation Turkish-origin boys have the shortest height distribution, followed by first-generation girls (Table 1). The second generation of both sexes shows a smaller difference to the German-origin group (Table 2), as indicated by the non-significant F2-G comparisons. This trend highlights a significant difference between first-generation and German-origin individuals, with second-generation individuals showing a clear improvement in height. Notably, this trend is also observed in females aged 3–10, where second-generation individuals show a reduced difference to the German-origin group. However, for males aged 3–10, this pattern is less evident. The confidence interval analysis (Table 1) confirms that, for both males and females across age groups, second-generation individuals remain shorter than their German-origin peers, except for second-generation males aged 11–17 (n=17) with a mean heightSDS score of 0.12. In the age group 310 the standard deviation of the heightSDS scores varies, with the second-generation migrants showing higher variability in both males and females, while in the 11–17 age group, the variability in the second generation is lower, suggesting a trend towards homogenization in the second generation ($F=289$, $p<0.001$).

Discussion

We expected to see a difference in height between first generation (F1) migrants, second generation (F2) migrants, and the host population (G). Our first hypothesis stated that the height of second-generation migrants (F2) whose parents migrated into a country with a higher average height than their country of origin would be more similar to the height of peers in the host community. It was anticipated that the first generation would show the greatest difference in height compared to those of the host population, since the population in Turkey is on average shorter in height than the German population (Özer and Scheffler 2018). The second hypothesis suggested that during adolescence (ages 11–17), Social-Economic-Political-Emotional (SEPE) factors associated with migration would exert a more pronounced influence on height, leading to adjustments in growth

relative to non-migrant peers. Additionally, the second generation was expected to align more closely with the host population individuals, particularly in the 11–17 age group following the adolescent growth spurt due to strategic growth adjustments (Hermanussen and Scheffler 2019).

We can see a generational trend of increasing height among children of Turkish origin in Germany, with the second generation being generally taller than the first (Figure 1). The fact that the second generation is on average taller than the first generation and more similar to those of German-origin supports our first hypothesis, as well as the theory of the community effect (Hermanussen and Scheffler 2019) and the idea that environmental circumstances, for example Social- Economic-Political-Emotional (SEPE) factors can play an important role in height development (Bogin 2021). It is important to note that the general conditions such as schooling, access to healthcare, etc. presumably differ little between the individuals within this study. International research shows that improvements in environmental conditions, such as those experienced by migrant children in the host country, can lead to increased stature in the second generation (Bogin and Varela-Silva 2010). These studies emphasize the importance of improved living conditions and social resources, further supporting the role of SEPE factors in physical growth and the relevance of the community effect in explaining generational height increases among migrants.

Migrant children often face unique psychological stressors related to acculturation and socio-economic pressures, which can impact physical growth (Gualdi-Russo et al. 2014; Rösler et al. 2023). Studies have indicated that stress, resulting from the need to adjust to a new environment, can enhance growth rather than restrict it, particularly in the context of social adaptation (Özer

Table 1 Descriptive statistics of height standard deviation scores (heightSDS) for a subsample of 10,946 children and adolescents aged 3–17 years in Germany, categorized by sex (male, female) and migration categories (F1=first generation, F2=second generation, G=host population), confidence interval (CI) for the standard deviation. Also including number of children/adolescents (n) and standard deviation (SD). This subsample represents a subset of the total KiGGS sample of 17,640 individuals (8,986 males and 8,654 females) and includes only individuals identified as being of Turkish or German origin. (Data from the KiGGS Baseline Survey, conducted by the Robert Koch-Institut between 2003 and 2006. Kamtsiuris et al. 2007; Kurth et al. 2019)

		n	mean height SDS	SD	CI lower	CI upper
3–10 years						
Male	F1	167	-0.19	0.91	0.82	1.02
	F2	32	-0.29	1.16	0.77	1.54
	G	2813	0.04	1	0.98	1.02
Female	F1	133	-0.4	0.99	0.88	1.13
	F2	37	-0.2	0.94	0.77	1.23
	G	2783	0.04	1	0.98	1.03
11–17 years						
Male	F1	120	-0.54	1.12	0.99	1.28
	F2	17	0.12	1.05	0.79	1.61
	G	2422	0.06	0.98	0.95	1.01
Female	F1	95	-0.51	0.9	0.78	1.04
	F2	7	-0.03	0.19	0.12	0.41
	G	2320	0.08	1.01	0.98	1.04

and Scheffler 2018). There is also evidence that a sense of belonging to society, which can be associated with the community effect, plays a major role regarding physical growth and height adaption (Esser 2016). This is true for Maya immigrant children in the United States, where second-generation children are on average taller than the first generation, highlighting the importance of improved environmental and socio-economic conditions (Bogin et al. 2002). No significant differences emerged between the first and second-generation groups, except for the male 11–17 group, implying that while generational changes may exist, they are not yet statistically evident. The fact that second-generation children, despite being born in Germany, still show some lag in height compared to German-origin peers implies that these factors may persist across generations and continue to influence growth outcomes.

As our study does not include comparative data from non-migrant Turkish populations, our ability to evaluate the effects of migration as a sole factor is restricted. A study by Baran et al. (Baran et al. 2024) provides comparative insights. The authors found no statistically significant differences in height between Turkish immigrants in Germany and the Netherlands and non-migrants in Turkey, particularly among males. The authors argue that migration alone does not automatically lead to increased height or convergence with host population norms, and that factors such as integration and educational attainment are key mediators of growth outcomes. These findings suggest that the height increase observed in our second-generation sample may be due to local conditions or cohort effects.

Both boys and girls followed a similar pattern, with second-generation Turkish-origin children being generally shorter than their German-origin peers in both the 3–10 and 11–17 age groups, except for the 11–17-year-old males. Within a social group individuals perceive their environment, their cultural surrounding as well as their own

Table 2 Post-hoc pairwise comparisons using Dunn's test with Holm correction for the differences in height between first-generation (F1), second-generation (F2), and German-origin (G) children, in the age groups 3–10 and 11–17 years for both females and males. Significance thresholds of the F-value are indicated by p-values, with p<0.05 and p<0.0001 indicating significant findings. In addition to p-values, effect sizes (r) are reported to indicate the magnitude of group differences. (Data from the KiGGS Baseline Survey, conducted by the Robert Koch-Institut between 2003 and 2006, Kamtsiuris et al. 2007; Kurth et al. 2019)

		F1–G			F1–F2			F2–G		
	age group (years)	F	p	r	F	p	r	F	p	r
Male	3–10	-2.98	<0.05	0.05	0.37	0.71	0.01	1.73	0.17	0.04
	11–17	-5.98	<0.0001	-0.12	-2.29	<0.05	-0.05	-0.14	0.89	<0.01
Female	3–10	-4.79	<0.0001	-0.09	-1.05	0.30	-0.02	1.39	0.33	0.03
	11–17	-5.96	<0.0001	-0.12	-1.34	0.36	- 0.03	0.26	0.79	0.01
		F1-G			F1-F2			F2-G		
	age group (years)	F	p	r	F	p	r	F	p	r
Male	3–10	-2.98	<0.05	0.05	0.37	0.71	0.01	1.73	0.17	0.04
	11–17	-5.98	<0.0001	-0.12	-2.29	<0.05	-0.05	-0.14	0.89	<0.01
Female	3–10	-4.79	<0.0001	-0.09	-1.05	0.30	-0.02	1.39	0.33	0.03
	11–17	-5.96	<0.0001	-0.12	-1.34	0.36	- 0.03	0.26	0.79	0.01

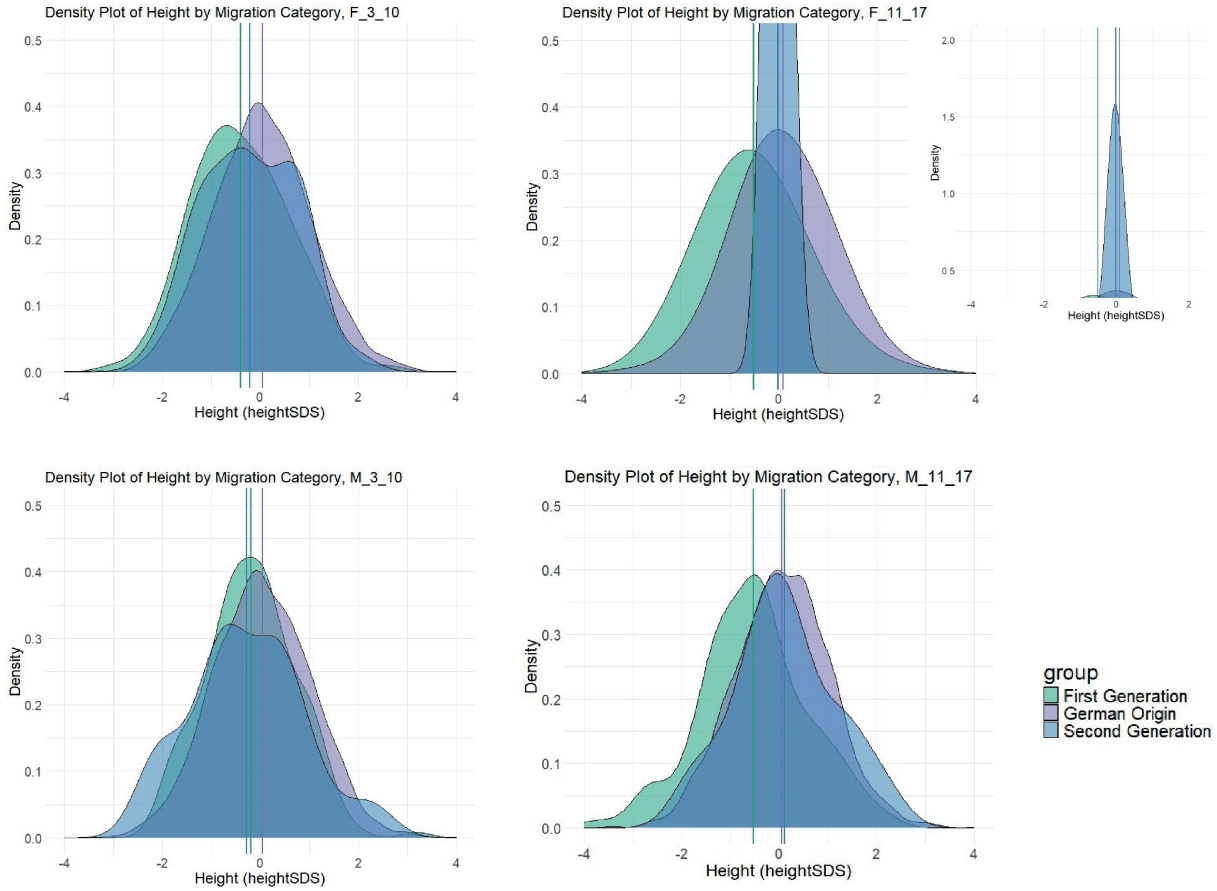

Figure 1 Density plots of height standard deviation score (heightSDS) of Turkish and German children grouped by age (3–10 and 11–17) and sex (F=female, M=male) of different migration categories coded by colour (Green=First Generation, Blue=Second Generation, Violet=German Origin). Vertical lines indicate mean of heightSDS of each sub group.

social status and this perception reflects and interacts with the degree of emotional well-being (Hermanussen et al. 2022). Adolescence is a vulnerable age for emotional and social signals from the environment (Lamblin et al. 2017). Adolescent individuals may be self-sufficient in physical terms but socially and emotionally highly dependent on peers (Bogin et al. 2018b) and strongly anticipate their future social role. These findings support our second hypothesis, as they highlight the critical influence of SEPE factors during adolescence on growth and height outcomes. This suggests that children from migrant families may experience an increase in height across generations due to strategic growth adjustments (Buston and Clutton-Brock 2022); despite this increase, second-generation children have not entirely closed the height gap with German-origin children, but they result in them reaching closer to the height norms of their German-origin peers.

In contrast for males aged 11–17 years in the second generation, the average heightSDS suggested they were slightly taller than the mean. The observed pattern supports the theory of developmental plasticity, where environmental factors such as socioeconomic conditions can influence growth outcomes across generations (Fredriks et al. 2003; Hochberg 2011).

Although the second generation appears taller than the first, the fact that they are still shorter than German-origin children suggests potential barriers to full adaptive growth, even after one generation of integration. This could be due to the perception of persistent disparities in access to resources or other structural inequali-

ties affecting the families of migrant origin. Although the wide confidence interval of the standard deviation around this result warrants caution when interpreting this finding. This greater variability in height outcomes could be due to heterogeneous conditions in upbringing, different levels of assimilation, or varying socioeconomic circumstances. However, it most likely reflects the smaller sample size (n=17) of second-generation males, which introduces uncertainty in the estimate.

The confidence intervals for the standard deviations reveal the degree of uncertainty in the estimation of the SD within each group. While general trends in height distribution are apparent, the confidence intervals suggest that the variability, especially in smaller groups like the second-generation males, should be interpreted with caution.

The observed differences in the standard deviation of the z-scores across age groups suggest a dynamic pattern of physical development among second-generation migrants. The lower variability in the older age group (11–17 years), particularly among girls, points towards a trend of homogenization in the second generation. The homogenization effect aligns with findings in migration studies, where second-generation migrants often show physical growth trajectories more in line with the host population as they mature (Bogin et al. 2018a; Scheffler et al. 2021).

Although our results align with both hypotheses, it is important to approach these results cautiously. The smaller sample sizes, particularly for the second-generation groups, represent a limitation of our study, as they likely increased variability and reduced the statistical power of our analyses. As a result, there is a potential risk of biases that could lead to either over- or underestimation of the differences. In this study, all measurements were conducted using standardized protocols and calibrated equipment to ensure consistency. However, discrepancies in technique or equipment calibration, especially across different locations or time points, could have introduced minor measurement errors. Nevertheless, given the standardized approach, we believe that the effects of such discrepancies are minimal and are unlikely to account for the broader generational trends observed.

Further research is needed to explore the underlying causes of these differences, particularly in relation to socio-economic, political, and emotional conditions. These findings emphasize that generational shifts in physical growth are complex and influenced by multiple factors, and that larger, more detailed studies are needed to explore the exact mechanisms driving these trends.

Conclusion

This study shows that while second-generation children show some adaptive growth compared to the first generation, they have not yet completely reached the height levels of their German-origin peers. This suggests that generational improvements in height are occurring, however, there are still some factors, maybe related to persistent disparities, that continue to affect growth outcomes across generations. The observed generational shifts align with the theory of developmental plasticity, where environmental factors such as access to nutrition, healthcare, and other resources influence growth patterns as well as supporting the hypothesis that environmental, Social-Economic-Political-Emotional factors and the community effect have a crucial role in height development. With rising migration due to climate change and

political instability, it is crucial to understand how these dynamics impact growth in future generations, especially in the public health sector (Mascie-Taylor and Little 2004).

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