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Plasticity of human growth – a systematic review on psychosocial factors influencing growth

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With 1 figure and 1 table

Abstract: *Background:* This systematic review aimed at collecting, analyzing and summarizing scientific studies focusing on psychosocial factors that influence linear growth among humans. *Methods:* The online database “PubMed” was used in order to acquire suitable scientific studies. These studies were evaluated based on clearly defined criteria that determine whether a study was to be excluded or included in the literature review. In the end, a total sum of 36 studies remained, which were carefully analyzed and used to generate an overview of the association between psychosocial factors and linear growth. *Results:* In the 36 reviewed studies, different social and psychological factors, such as socioeconomic status, parental education or emotional deprivation were set in relation to physical growth among humans. The studies were listed and summarized, depending on the investigated psychosocial factor. A clear association between psychosocial factors and growth could be observed in most of the reviewed studies. *Discussion:* Based on the results of the reviewed studies it could be concluded that the regulation of linear growth is also subject to different psychosocial factors. The way in which the developing human and the specific social environment interact seemed to have a major impact on linear growth. Status-specific stress was discussed as one possible explanation for the regulating mechanism of human linear growth.

Keywords: linear growth; final body height; regulation; psychosocial factors; social factors; psychological factors

1 Introduction

Human growth represents the increase in body height over time. The physiological process of growing forms the physical boundaries of each individual and thus contributes to the understanding of the self. But why are some people tall and others short? Human growth is known to depend on multiple genetic and environmental factors. The provision with nutrition and sanitation as well as the prevalence of disease are often considered as some of the most determining environmental factors when it comes to the plasticity of human growth (Hochberg 2011). However, an increasing amount of research points towards a more complex regulation of the final body size. Especially during postnatal growth, the time period between birth and late adolescence, the developing human is known to be extremely sensitive to its social and emotional environment (Spencer 2017). But can the social environment also affect linear growth?

The connection between the social environment and physical growth has been discussed for a long time. James Tanner coined the concept of growth as a “target seeking process” and ascribed its regulation partly to an individual’s social environment (Tanner 1963). One possible explanation for the interplay between the quality of the social environment and growth outcomes was provided in a study on growth failure among institutionalized children (Johnson & Gunnar 2011). The authors found out that psychosocial short stature was connected to abnormal levels of baseline cortisol, the hormonal response to chronic stress. The persistent increased level of stress hormones, especially corticotrophin-releasing factor (CRF), would lead to a stimulation of somatostatin production. Somatostatin is one major inhibitor of growth hormone (GH). Consequently, the constant elevation of CRF would lead to a down-regulation of GH. In addition, the increased level of baseline cortisol during chronic stress would exert significant effects on the production of IGF-1 in

the liver by reducing the responsiveness of the liver to GH (Johnson & Gunnar 2011). Taking all these findings into consideration, the authors concluded that the chronic exposure to social stress may determine the lack of growth in institutionalized children significantly (Johnson & Gunnar 2011).

The hormonal interplay between stress hormones and linear growth should not be limited to the target group of children in institutionalized settings only. Social stress factors such as competition, subordination, isolation and deprivation are frequently occurring processes in human societies (Smither 1993; Cummins 1998). Consequently, the idea that these stress factors exert similar effects on growth outcomes became plausible. This systematic review aimed at creating a collection of scientific studies, in order to answer the overall research question how psychosocial factors influence the process of physical growth in humans.

2 Methods

The following systematic review was based on a set of scientific methods defined by Petticrew & Roberts (2006). These scientific methods were used to limit systematic error and consequently biased results. They furthermore defined criteria to exclude or include literature as well as methods to research and appraise the given literature (Petticrew & Roberts 2006).

The research for the following systematic review was conducted using the online database “PubMed” (<https://www.ncbi.nlm.nih.gov/pubmed/>). This online database was easily accessible and provided a plethora of studies conducted in the field of research relevant for the research question. To access the relevant studies, the specified search entry “psychosocial factors and linear body growth humans” was used in “PubMed”.

When entering these terms in the online database, a large amount of more or less useful studies appeared. To identify those studies with a potential value for the research, a set of inclusion and exclusion criteria needed to be applied (Petticrew & Roberts 2006).

2.1 Exclusion and inclusion criteria

Most importantly, all studies included in the collection of reviewed studies needed to provide information that is useful to answer the research question. Additionally, a clarification of the population, intervention and outcomes of interest was necessary to filter for relevant results and to limit the amount of studies included in the review (Petticrew & Roberts 2006).

The interventions of the studies should primarily focus on the association between a psychosocial variable and linear growth. The psychosocial variables mainly referred to in this systematic review were socioeconomic status, education, social mobility, emotional deprivation and social iden-

tification. In addition, studies that have investigated other parameters in relation to linear growth were considered as well, in case their results revealed relevant information with regard to the influence of psychosocial factors.

The population of interest for this systematic review was limited to children and adolescents, because growth happens most intensely during the adolescent growth spurt from age twelve until sixteen years (Bogin et al. 2018a). As mentioned initially, humans in this life history stage are also highly sensitive to their social and emotional environment (Spencer 2017). Studies on adults were included in the data collection as well, if their final body height has been investigated in relation to psychosocial aspects during development. Even though infants also show a high growth velocity, studies that observe growth among infants were not collected, since an additional paper is going to focus explicitly on this age group.

From those studies that investigated the effects of psychosocial factors on physical growth among children, adolescents or adults, only studies containing relevant outcomes with regard to the research question needed to be considered. In terms of qualitative results, both studies that did and did not find an association between psychosocial factors and physical growth had to be included in order to prevent from biased results.

In Fig. 1 the process of including and excluding studies in the data collection is visualized. As shown, each study needed to pass all three criteria (a), (b), (c) in order to be included in the systematic review. While the first level contains the search entry, the following three levels visualize the criteria used to determine the usefulness. The numbers underneath each box stand for the amount of studies included or excluded on each level. In addition to the studies provided on “PubMed” based on the search entry, the similar-results-option as well as cited sources in the reviewed studies helped to navigate towards more useful studies. Starting with a total of 737 studies, the application of exclusion- and inclusion-criteria generated a total of 36 studies used for this systematic review.

3 The systematic analysis: psychosocial factors and physical growth

In the following systematic analysis of literature, studies are presented according to their research topic. Overall, the studies are subdivided into social factors and psychological factors. While social factors such as socioeconomic status, educational level and social mobility rather focused on the individual’s position in the social hierarchy, psychological factors reflected the individual’s emotional reaction to the social environment. Even though social and psychological factors were investigated separately, they are strongly related and summarized as psychosocial factors.

Fig. 1. Visualization of the inclusion- and exclusion-criteria of literature.

3.1 Social factors

3.1.1 Socioeconomic status

Socioeconomic status is a broad social parameter describing an individual's position in a social dominance hierarchy (Cummins 2016). This parameter is determined by other factors also operating at the social dominance hierarchy level, for example wealth, education and social relations. Despite

its multifactorial background, the association between socioeconomic status (SES) and growth outcomes has been well researched. In 1975, Christiansen, Mora and Herrera explored the relation between family social characteristics and growth of young children in Colombia. The authors found clear differences in physical growth between lower and upper socioeconomic groups. While higher SES was associated with taller mean stature, lower SES was associated with a mild

deficit in height. These findings led the authors to conclude that SES is accompanied with certain types of behavior and possibilities, which in turn affect growth (Christiansen et al. 1975).

The association between SES and physical growth was also noted in the study on height and body proportions of Maya American children (Bogin et al. 2002). The authors compared body proportions of Maya children living in Guatemala with Maya American children who have recently migrated to the United States. For the Maya American children, the migration to the United States resulted in a drastic increase in general living conditions. If this improvement in living conditions would also manifest in a change in body proportions among Maya American children was the primary objective of the comparison. Comparing the two cohorts of children, the authors found out that Maya American children were on average 11.54 cm taller and 6.83 cm longer legged than the children living in Guatemala. Consequently, so the authors conclude, the change in socioeconomic conditions faced by those Maya children raised in the United States resulted in a taller stature and an increase in relative leg length. These results provide striking evidence that stature is a sensitive indicator for the quality of the environment (Bogin et al. 2002).

Another study that focuses on associations between height and socioeconomic status was conducted by Czapla and Liczbińska. In their 2014 published study, Czapla and Liczbińska examined the demographic and biological data of adult inhabitants from five provinces of the kingdom of Poland collected between 1897 and 1914. Their analysis of the historic data revealed a significant association between final body height and socioeconomic status among the different provinces. The authors concluded that the socioeconomic conditions in a certain region exert significant effects on the quality of life, which is reflected in biological variables such as height (Czapla & Liczbińska 2014).

Starting from the basic assumption that the socioeconomic and cultural contexts shape the determinants of living conditions and possibly also growth, Ngyuen et al. examined the factors associated with physical growth of children in rural and urban settings. Comparing cohorts of children from urban and rural areas in Vietnam, Ngyuen et al. found a statistically significant difference in socioeconomic parameters and body height. The authors argued that underlying factors such as parental occupation and household wealth as well as basic factors of the socioeconomic context exerted the strongest effects on child growth (Nguyen et al. 2013). Instead of pointing towards one possibility of growth regulation, Bielicki, Szczotka and Charzewski considered a variety of plausible factors. They speculated that psychosocial stimuli and parents' education might also contribute to the differences in linear growth among different socioeconomic populations (Bielicki et al. 1981).

More evidence for an association between household wealth and physical growth was revealed in a 2015 study

conducted by Krishna et al. The research team investigated the short- and long-term effects of household wealth on physical growth during childhood among eight cohorts of children from four different countries. As indicators for physical growth, Krishna et al. did not only rely on absolute height-for-age z-scores but also on the prevalence of stunting (Krishna et al. 2015).

Stunting describes the phenomenon of short height for a specific age and relies on a plethora of different factors (Green 2018). Multiple studies, which investigated the environmental causes for stunting, provided evidence for an effect of socioeconomic conditions during growth on the prevalence of stunted individuals. The results of these studies usually pointed out that stunting was associated with being raised in poor households with low income (Wamani et al. 2007; Keino et al. 2014; Green et al. 2018), belonging to socially less privileged groups (El Taguri et al. 2009; Mushtaq et al. 2011) and living in rural areas (El Taguri et al. 2009; Mushtaq et al. 2011).

As discussed in the previously mentioned studies, mechanisms that operated through SES directly on the regulation of growth might not be generalizable but rather multifactorial and highly complex (Vercelotti et al. 2014). The research team around Vercelotti explored the multidimensionality of stature variation in the past by comparing characteristics of archaeological and living populations. Their data on the archaeological populations was based on skeletons from two well-researched sites in Italy and Poland, which have been dated back to the Middle Ages. Using the relative skeleton leg length as well as stress indicators in the skeletons and characteristics of the remnants, the scientists were able to reconstruct information on the association between social status, status-specific stress level and final body height (Vercelotti et al. 2014).

Based on the analysis of social status, social stress and final body height among individuals of the archaeological populations, the authors acknowledged the association between socioeconomic variables and growth outcomes. They also predicted that the final growth result of a population depends on multiple other, highly population-specific environmental factors as well (Vercelotti et al. 2014).

More information on the variety of environmental factors influencing growth was provided in a study by Keino et al. (2014). Their meta-analysis included the results of 18 independent studies on factors for stunting among children and adolescents in Sub-Saharan Africa. In 14 out of the total 18 studies, socioeconomic variables of the family were significantly associated with stunting. Interestingly, the results of the meta-analysis also showed that lifestyle and nutritional factors were not significantly associated with prevalence of stunting but rather independent (Keino et al. 2014).

Mumm et al. widened the scope of possible associations between SES and growth even more by reviewing 2156 modern and historic growth studies. The authors aimed at generating valid claims about the influence of SES on growth among

infants and juveniles. Having analyzed the large amount of studies, Mumm et al. pointed out that a socioeconomic influence on height variability was significant. They suggested that wealthy societies would produce on average tall children and that economically unequal societies would be characterized by small and light children (Mumm et al. 2017). While another study by Mumm, Ipsen and Hermanussen supported this association at the level of whole societies, the authors found a large discrepancy between the within-population variation in height. Consequently, they concluded while socioeconomic factors may have a significant effect on average height results of whole populations, the regulation of growth on an individual level might depend on multiple other factors as well (Mumm et al. 2016).

Taking the findings of the previously reviewed studies together, it should be noted that a general association between socioeconomic status and growth outcomes could be observed. Even across various temporal and cultural contexts, taller mean stature and lower frequencies of stunting were associated with higher socioeconomic status (Christiansen 1975; Bielicki et al. 1981; Bogin et al. 2002; Wamani et al. 2007; El Taguri et al. 2009; Mushtaq et al. 2011; Nguyen et al. 2013; Czapla & Liczbińska 2014; Keino et al. 2014; Vercelotti et al. 2014; Krishna et al. 2015; Schwekendiek 2017; Green et al. 2018; Scheffler et al. 2020). Despite their agreement on a general association between socioeconomic status and growth, the authors discussed different possible explanations for this trend. These explanations included nutritional benefits, status-specific stress, context-dependent and multifactorial as well as individual approaches.

3.1.2 Parental education

Across the previously reviewed studies on SES, the level of parental education is frequently associated with growth results. Nguyen et al. (2013) and Schwekendiek (2017) found out that a higher level of maternal education would exert obvious positive effects on child growth. Similarly, the study of Bielicki et al. (1981) revealed a positive association between level of paternal education and growth results. Based on the findings of El Taguri et al. (2009), Wamani et al. (2007), Mushtaq et al. (2011) and Nguyen et al. (2013), it could be argued that a low level of maternal education implied a higher risk of stunted growth among children.

In addition to these previous studies, more evidence for an effect of parental education on physical growth of children could be found in studies focusing primarily on the effects of parental education. Basnet et al. linked maternal resources for care to child growth and found a strong association between maternal education and child outcomes, influencing height and mental well-being (Basnet et al. 2019). Similar results were found by Scheffler et al. (2018) and Koziel et al. (2019), who revealed significant positive effects of higher parental education on growth results in their analysis of height in children from India. This association between higher levels of maternal education and increased

growth could even be observed across different socio-cultural contexts (Lakshman et al. 2013).

The research team around Lakshman analyzed data of three cohorts from Sweden, the United Kingdom and rural parts of China. In all cases, they observed a positive association between level of maternal education and height values of children, even though the association seemed to be unequally strong in the different cohorts. In addition to average height values, the prevalence of stunting was supposedly affected by the mother's degree of education. In one cohort, the prevalence of stunting among children with least educated mothers was 28.3% compared to 2.5% in the group of children from highly educated mothers (Lakshman et al. 2013).

Outstanding effects of maternal education on prevalence of stunting among children were also revealed in a study conducted by Emamian et al. (2014). The authors' aim was to describe the socioeconomic inequality in stunting and its determinants using the data of 1395 children from Iran. Investigating the set of data, the authors found significant height differences between socioeconomically more privileged and less privileged groups of individuals. The different levels of education among the socioeconomic groups exerted the strongest effect on growth results and also on the prevalence of stunting (Emamian et al. 2014).

Similar to these results, Devakumar et al. (2018) studied different socioeconomic determinants of growth and concluded that the association between maternal education and child growth was strongest. Taking their results from a longitudinal study in Nepal, the authors observed that each increase in level of maternal education resulted in an increase in average height values of children and lower prevalence of stunting. Based on these findings, they suggested that maternal education would be the most influential socioeconomic determinant (Devakumar et al. 2018).

If maternal education could be considered as one of the most relevant socioeconomic determinants for physical growth, the question remains how the level of maternal education practically affects growth outcomes. Thomas, Strauss and Henriques approached this highly complex question after having found a strong effect of maternal education on child height in rural and urban settings (Thomas et al. 1990). They argued that the largest part of the effect maternal education has on growth outcomes was mediated via access to and processing of information. However, the authors did not define the exact type of information that exhibits a key effect on growth (Thomas et al. 1990). Overall, the effects of parental education on child growth appear to be strong.

3.1.3 Social mobility

Another aspect of socioeconomic status, which is often investigated separately, is an individuals' social mobility. In contrast to the stable concept of SES, social mobility includes the notion of intra- and intergenerational migration between social classes (Koziel et al. 2019). Even though

some scientists have recently focused on the effect social mobility can have on growth results, not as much evidence has yet been generated compared to the association of absolute SES and height.

The team lead by Koziel recently investigated such associations between social mobility of the father and child growth and they found a general tendency of higher status accompanied by taller stature. They also observed a strong effect of intra- and intergenerational social mobility on growth outcomes. Low-class fathers who have attained higher education raised taller sons than low-class fathers who stayed in a low class or even than upper-class fathers who lost their social advantage (Koziel et al. 2019). Furthermore, the act of migrating between social classes seemed to affect growth of socially mobile individuals as well and not only growth among their offspring. Comparably to the findings of point 4.1.2, Koziel et al. attributed the variation in height across different social classes mainly to the level of education (Koziel et al. 2019).

The effects of intra- and intergenerational social mobility on growth results were also shown in the study of Krzyżanowska & Mascie-Taylor (2011). The two authors used data from 2090 father and son pairs to investigate the extent of social mobility in relation to height trends. In their analysis, upwardly mobile fathers grew on average taller and downwardly mobile fathers remained shorter. This effect of social mobility also remained in the generation of sons, who grew taller in upwardly mobile families and who remained shorter in downwardly mobile families (Krzyżanowska & Mascie-Taylor 2011). As an explanation for the difference in height among socially mobile individuals the authors considered a selective force behind social mobility. (Krzyżanowska & Mascie-Taylor 2011).

A similar explanation for the association between social was suggested by Power et al. (2002). Focusing on the effects of changes in the social structure and height selection, the three authors found a general trend for social mobility and stature. In their cohort study, those individuals moving to a higher class were on average taller than the individuals remaining in the class, but shorter than the individuals which stayed in the higher class in the first place (Power et al. 2002).

Contrary results on the association between social mobility and growth were provided in a study by Muraro et al. (2017). The authors investigated large amounts of data from children in Brazil. Even though they found out that higher SES children also showed taller stature in adolescence and social mobility was noted across large parts of the cohort, no associations between social mobility and growth results were apparent (Muraro et al. 2017). The authors concluded that differences in height might as well be determined by environmental influences of early childhood, independently of later social influences (Muraro et al. 2017).

Despite the mixed results on the effects of social mobility on growth in the previously reviewed studies, it must be noted that all of them found a strong association between social status and growth. These results furthermore support the findings of studies mentioned under 4.2.1. However, the amount of studies on the association between social mobility and growth outcomes was very limited and rather small. More research needs to be conducted on this interaction in order to generate further results.

3.2 Psychological factors

3.2.1 Emotional deprivation

The socioeconomic environment and accompanied determinants such as household wealth and parental education seemed to exert strong effects on the regulation of growth. The review of studies investigating the associations between socioeconomic status and growth outcomes could show a general trend of higher status and taller stature, whereas it was suggested that the final growth results of a population are always dependent on context-specific variables.

As mentioned earlier, Bielicki et al. (1981) found such an association between socioeconomic status and stature, highlighting the effects of the paternal occupational-educational characteristics on growth of their children. However, the authors pointed out that the occupational-educational position of the father couldn't influence growth among children directly. Rather, the authors suggested a regulation via nutritional, health-related and psychosocial stimuli that result in status-specific stress factors (Bielicki et al. 1981).

Similar to this association between socioeconomic status, psychosocial stress factors and the regulation of growth, El Taguri et al. (2009) highlighted the importance of family and caregiver conditions for growth results. The authors investigated the risk factors for stunting in a cohort of under-five year-olds in Libya. Focusing on different influences on growth, they did not only find significant effects of parental education, but also of psychosocial stimulation as well as family and caregiver conditions to be associated with stunting. Among the psychosocial risk factors for stunting mentioned in the paper, large family size, low quantity of interactions between child and father and absence of social and medial contact were relevant. Their finding also promoted the idea that growth may not only depend on the direct effects of socioeconomic conditions provided in a household. Rather, it could be the interplay of psychosocial stress factors that depend on the families' socioeconomic status and affect the regulation of growth (El Taguri et al. 2009).

Family conflict, according to Montgomery et al. (1997), could be considered as such a psychosocial stress factor. In their study, data from over 6500 British children were analyzed in order to find out if family conflict can be associated

with slow growth. Interestingly, the analysis showed that almost one third of those children who experienced family conflict were in the bottom fifth of the height distribution at seven years. Also, these children were less likely to be among the tallest individuals of the cohort (Montgomery et al. 1997). As concluding remarks, the authors suggested that environmental factors such as the exposure to family conflict might slow growth especially until the age of 7 years and affect psychological development (Montgomery et al. 1997).

In his 2017 published study, Schwekendiek compared growth patterns of Korean orphans raised in affluent societies with children living in Korea. In addition to a strong association between the social environment and growth, Schwekendiek found a stagnating trend among Korean orphans raised in affluent societies at around 160 cm. This trend, so the author, might be caused by psychosocial stress factors in the host country. Especially the accumulation to the new environment and possible discrimination were considered as potent stressors. In contrast to the environmental enrichment effects on growth, psychosocial stress factors might be responsible for limiting the final average growth results (Schwekendiek 2017).

This previously suggested effect of psychosocial stress factors on growth outcomes also was the central aspect of investigation in a study conducted by Miller et al. (2015). The authors analyzed data from 60 children, which have shown a history of institutional care or emotional neglect in their familiar environment. Comparing the set of data to a control cohort, the authors revealed that growth is most severely impaired in the group of children with institutional history. Also, children with a history of institutional care showed the lowest IGF-1 and IGFBP-3 levels (Miller et al. 2015). The authors suggested that the different time and severity of psychosocial stress in neglected and institutionalized children resulted in different regulations of growth. However, the effect of psychosocial stress on physical growth was apparent in both groups (Miller et al. 2015).

More research on the regulation of growth among institutionalized children was conducted by Johnson & Gunnar (2011). The two authors explored growth patterns of adoptees from an institutional environment as well as possible stress factors and endocrine processes associated with being raised in institutional care settings. Their analysis revealed relevant insights into the causes for growth failure among institutionalized children, which is also often considered as psychosocial short stature (Johnson & Gunnar 2011).

According to Johnson and Gunnar, institutionalized children would experience a significant growth suppression caused by adverse conditions in their environment. On an endocrine level, the two authors suggested abnormalities in the GH-IGF-1 and HPA axes to be the cause for growth suppression. The high amount of psychosocial stress from the institutional environment could reduce the production of

growth factors and consequently reduce growth (Johnson & Gunnar 2011). When the child was adopted into a more caring and nurturing environment, the improvement in environmental quality would usually lead to a catch-up in growth. Also, the functions of GH-IGF-1 and HPA axes were shown to increase their activity to a normal level after adoption.

The results of a study conducted by Kroupina et al. (2015) pointed towards a comparable association between psychosocial factors and growth. They analyzed data from orphans raised in institutional care and focus specifically on predictors of their developmental status. Kroupina et al. found out that stunting, in other words short stature as a result of compromised growth, would be a useful indicator for the negative impact of psychosocial stress factors in the institutional environment (Kroupina et al. 2015).

The children in the study cohort were on average developmentally compromised, in terms of poor emotional-behavioral regulation and degree of stunting. As a cause for this developmental impairment, Kroupina et al. discussed the typical features of institutional care settings, which were considered as a “neglect of a child’s basic needs” (Kroupina et al. 2015). The large group size and low number of caregivers per group would deprive children of adequate stimulation. In addition, the environmental instability would complicate stable long-term relationships, which are highly relevant for child development. While nutrition- and health-related aspects of institutional environments could possibly also influence growth rates of institutionalized children, the authors highlighted the relevance of an adequate emotional stimulation and environmental safety for development and growth throughout infancy, childhood and adolescence (Kroupina et al. 2015).

Johnson et al. (2010) also investigated the relationship between the caregiving environment and growth among children. To compare the growth outcomes of children living under different environmental conditions, Johnson et al. worked with a cohort of 136 institutionalized children. These children were either assigned to foster care or remained in institutional care for the period of the study (Johnson et al. 2010).

The analysis of average height scores reveals that children raised in institutional care showed suppressed growth results. While children who remained in institutional care show no improvements in growth after twelve months, a significantly different trend could be observed for those children placed in foster care. 100% of children assigned to foster care experienced catch-up in height and were consequently in the normal range of height for age. This catch-up growth was mainly caused by components of the caregiving environment, such as sensitivity, acceptance, respect and warmth, according to the authors (Johnson et al. 2010).

Another example of adverse social contexts are families in which children are abused or neglected. Oliván et al. (2002) investigated the effects of environmental adversity

and environmental improvements on growth results of pre-school children. In their study, the authors focused on physically neglected and emotionally abused children who were placed from their familiar environment to foster care. After one year of environmental, nutritional and psychological enrichment in foster care, the children showed untypically high growth velocities and consequently a significant normalization of height-for-age scores (Oliván et al. 2002).

This catch-up in height would mainly be caused by the nurturing conditions in foster care and the environmental improvements compared to their abusive families. Since growth failure seemed to be reversible under conditions of psychological and nutritional enrichment, the authors considered the environmental adversity in the families as the cause for limited growth in the first place. They consequently stressed the quality of the social environment and concluded that during childhood, growth would be highly influenced by nutrition, environmental conditions and emotional factors (Oliván et al. 2002).

The combination of nutritional and psychosocial effects on growth results raises the question, whether these factors must operate simultaneously or rather individually. Starting from this research question, a group of scientists around Worku et al. (2018) focused on the relationship between malnutrition, psychosocial factors and developmental outcomes. Their aim was to “ascertain the association of developmental outcomes and psychosocial factors after controlling for nutritional indices” (Worku et al. 2018).

The authors investigated this association between developmental outcomes and psychosocial factors in a cohort of 819 Ethiopian children living in extreme poverty and compared the results with a reference group. The analysis revealed that among the children raised in extreme poverty, 39% were stunted and 16% underweight. Signs of stunting and malnutrition were absent in the less poor reference group. In addition to the nutrition-based differences between the two cohorts, the group of children in extreme poverty showed an extreme lack of psychosocial stimuli such as play activities and materials, mother-child interaction or child-child interaction (Worku et al. 2018).

The lack of psychosocial stimuli was associated with compromised developmental outcomes of children living in extreme poverty. The authors concluded that psychosocial, socioeconomic and nutritional factors might exert their effects on the regulation of growth independently and in total contribute to the inequality of children living in adverse conditions, for example extreme poverty (Worku et al. 2018).

Across the previously reviewed studies, a strong association between psychosocial factors and growth results became apparent. As several studies could show, children living in adverse social conditions, such as institutional care or abusive families suffer from compromised growth, which is caught up after environmental enrichment. These stud-

ies revealed that psychosocial stimuli could affect growth in children negatively or result in a normalization of height scores.

3.2.2 Social identification

In general, the feeling of social identification is known to be highly influential under consideration of a positive youth development (Telzer et al. 2018). Does the effect of social identification account for growth as well? Compared to the amount of studies focusing on the negative aspect of psychosocial stimuli, not as much studies could be found that investigate a stimulation of growth based on psychosocial effects. One striking example that reveals such a positive association is a literature review focusing on growth among migrants conducted by Bogin et al. (2018a). The authors analyzed height distributions of modern and historic migrant populations and find out that “migrant children and adolescents of lower social status rapidly adjust in height towards average height of their hosts” (Bogin et al. 2018a). Furthermore, the authors suggested that the concept of social connectedness might exert significant effects on the regulation of growth among migrants (Bogin et al. 2018a).

Similarly, Özer and Scheffler investigated the association of social integration and body height among offspring of Turkish migrants in Germany. The results revealed that social integration and the feeling of cultural belonging were both positively associated with taller stature. According to Özer and Scheffler, the perception of belonging and social dominance would often be associated with lower stress-levels and could result in an increase in growth hormones and longitudinal growth. Consequently, the authors characterized the complex association between psychosocial factors and growth as a “network of indirect and direct connections between stress, well-being, social status and IGF-1 level”, which influences longitudinal growth and final body height (Özer & Scheffler 2018).

4 Discussion

Based on the findings of the previously reviewed studies it can be concluded that physical growth in humans strongly depends on a variety of environmental factors, such as social and psychological factors. An individual's position in the social hierarchy as well as the emotional stimulation from the social environment impact growth significantly.

It has been shown that higher socioeconomic status, a higher level of parental education and the increase in social position are associated with a stimulation of growth (Bogin et al. 2002; Krishna et al. 2015; Koziel et al. 2019). On the other hand, lower socioeconomic status, lower levels of parental education and downward social mobility seemed to be associated with compromised growth results (Bielicki et al. 1981; Mumm et al. 2017; Green et al. 2018). Possible

explanations for this association provided by the authors vary. While some authors explained the association of status and growth with nutritional benefits of higher social classes (Christiansen 1975; Bielicki et al. 1981; Mushtaq et al. 2011; Nguyen et al. 2013), other authors investigated the effects of nutritional supplementation on growth and did not find an association (Keino et al. 2014; Scheffler et al. 2020). Additionally, some authors considered status-specific psychosocial stress to be the cause for different expressions of growth (Krishna et al. 2015; Schwegendiek 2017). This idea would attribute social factors, such as the socioeconomic status, parental education or the chances of social mobility, with a psychosocial dimension.

The exposure to stress factors seems to depend to a large extent on the position in the social hierarchy. People attributed with social parameters that determine high social rank in dominance hierarchies, for example socioeconomic status and education, showed on average lower stress levels than people of lower social status (Vercelotti et al. 2014; Spencer 2017). Relating the social stress factors of the dominance hierarchy in human society to growth parameters, it could be revealed that stress can interfere with growth via increased levels of cortisol, glucocorticoids and other stress hormones, which reduce the amount of growth factors (Spencer 2017). People who rank lower in the status hierarchy would consequently show higher stress levels and a higher amount of stress hormones that compromise final growth results (Johnson & Gunnar 2011). However, it has also been found out that the stability of the social environment determines whether a social encounter induces or reduces the stress response (Knight et al. 2017). Social mobility could be considered as such an instance of socially instable circumstances. While upward social mobility was associated with taller stature, downward social mobility was associated with shorter stature (Krzyżanowska & Mascie-Taylor 2011; Koziel et al. 2019).

In addition to social stress factors, the emotional stimulation from the social environment was shown to be another significant determinant for growth. As the results of various studies revealed, inadequate psychosocial stimulation could lead to compromised growth of children raised in institutional environments (Johnson et al. 2010; Johnson & Gunnar 2011; Kroupina et al. 2015; Miller et al. 2015) or raised under adverse conditions in their families (Montgomery 1997; El-Taguri et al. 2007; Casale 2014; Schwegendiek 2017). Özer and Scheffler and Bogin, Hermanussen and Scheffler could furthermore observe a positive influence on growth due to positive psychosocial stimulation, such as the feeling of social belonging among migrants (Özer & Scheffler 2018).

Since especially children and adolescents rely on their social environment during development (Spencer 2017), institutional care settings were considered to lack psy-

chosocial stimulation and “neglect a child’s basic needs” (Kroupina et al. 2015). The emotional neglect experienced by children in institutional care or abusive families is a form of social deprivation and would consequently exert stress on the individual (Spencer 2017). This form of stress experienced by children in institutional environments would lead to a suppression of growth hormone and consequently to growth failure (Kroupina et al. 2015). Comparably to the role of psychosocial stress for compromised growth in institutionalized children, Özer & Scheffler (2018) observe the feeling of integration among migrants and concluded that a lower level of social belonging is associated with higher stress and shorter stature.

Taking all these findings together, it could be concluded that the quality of the environment, in terms of its socioeconomic opportunities and psychosocial stimulation, is critical for human growth.

Social interaction with other humans might induce status-specific and psychosocial stress. The resulting interplay between stress hormones and growth hormones could be one of the most determining variables in the regulation of linear growth. Still, growth should be considered as a multifactorial process depending on a variety of context-specific and individual factors, which still need to be explored in more detail.

5 Limitations

The aim of this systematic review was to provide a variety of perspectives from the scientific discourse on the regulation of growth in order to answer the research question, how psychosocial factors influence the process of physical growth in humans. Based on Petticrew and Roberts’ guidelines for scientific reviews, 36 studies on different aspects of the association between psychosocial factors and physical growth were included in the data collection. The studies included in this review were conducted in different temporal, geographical and cultural contexts and their results pointed towards a strong effect of psychosocial factors on physical growth.

However, the amount of reviewed studies was fairly small compared to the amount of data from other systematic reviews. The limitation of the data collection was mainly caused by temporal restrictions that accompanied the format of the bachelor thesis. Consequently, this systematic review cannot meet the requirements to provide a complete overview for the association between psychosocial factors and physical growth. The results of this systematic review should be seen as one fraction of explanations from the scientific discourse on the regulation of growth, which can be considered proof for the multidimensionality and complexity of the regulation of human growth.

6 Results – Overview

Table 1. Overview of the studies included in the review and comments.

Study	Topic	Comments
Basnet et al. (2019)	3.1.2. <i>Parental education</i>	- link between maternal resources for care such as education and child growth and mental well being
Bielicki et al. (1981)	3.1.2. <i>Parental education</i>	- positive association between level of parental education and growth results
	3.2.1. <i>Emotional deprivation</i>	- authors suggested a regulation of growth via (...) psychosocial stimuli and stress factors
Bogin et al. (2002)	3.1.1. <i>Socioeconomic status</i>	- improvement in living conditions associated with increase in height among cohort of Maya Americans - stature as an indicator for the quality of the environment
Bogin et al. (2018b)	3.2.2. <i>Social identification</i>	- migrant children and adolescents of lower SES would rapidly adjust in height towards average height of their hosts - concept of social connectedness might be relevant for regulation
Czapla & Liczbińska (2014)	3.1.1. <i>Socioeconomic status</i>	- association between final body height and SES - socioeconomic conditions would exert effects on the quality of life, reflected in biological variables (height)
Christiansen et al. (1975)	3.1.1. <i>Socioeconomic status</i>	- clear differences in physical growth between lower and upper socioeconomic groups - SES would be associated with certain types of behavior and possibilities which affect growth
Devakumar et al. (2018)	3.1.2. <i>Parental education</i>	- increase in level of maternal education resulted in an increase in average height values of children and lower prevalence of stunting
El Taguri et al. (2009)	3.1.1. <i>Socioeconomic status</i>	- stunting was associated with belonging to socially less privileged groups and living in rural areas
	3.1.2. <i>Parental education</i>	- low level of maternal education implied a higher risk for stunted growth among children
	3.2.1. <i>Emotional deprivation</i>	- highlight the importance of family and caregiver conditions for growth results among children
Emamian et al. (2014)	3.1.2. <i>Parental education</i>	- outstanding effects of maternal education on the prevalence of stunting among children
Green et al. (2018)	3.1.1. <i>Socioeconomic status</i>	- stunting was associated with being raised in poor households
Johnson et al. (2010)	3.2.1. <i>Emotional deprivation</i>	- children raised in institutional care would show suppressed growth results - catch-up among children from deprived environment was observed after placed in a more caring environment
Johnson & Gunnar (2011)	3.2.1. <i>Emotional deprivation</i>	- institutionalized children would experience a significant growth suppression caused by adverse conditions in their environment
Keino et al. (2014)	3.1.1. <i>Socioeconomic status</i>	- stunting was associated with being raised in poor households - lifestyle and nutritional factors not significantly associated with stunting
Koziel et al. (2019)	3.1.1. <i>Socioeconomic status</i>	- general tendency of higher status and taller stature
	3.1.2. <i>Parental education</i>	- positive effects of higher parental education on growth results
	3.1.3. <i>Social mobility</i>	- strong effect of intra- and intergenerational social mobility on growth outcomes
Krishna et al. (2015)	3.1.1. <i>Socioeconomic status</i>	- short- and long-term effects of household wealth
Kroupina et al. (2015)	3.2.1. <i>Emotional deprivation</i>	- association between psychosocial stress and growth - stunting as an indicator for the negative impact of psychosocial stress among institutionalized children

Table 1. continued.

Study	Topic	Comments
Krzyżanowska & Mascie-Taylor (2011)	3.1.3. <i>Social mobility</i>	- effect of social mobility among father and son pairs on trends in final body height
Lakshman et al. (2013)	3.1.2. <i>Parental education</i>	- association between higher levels of maternal education and increased growth across different socio-cultural contexts
Miller et al. (2015)	3.2.1. <i>Emotional deprivation</i>	- children in institutional care show low level in growth hormones and psychosocial stress is considered as one possible contributing factor for regulation of growth
Montgomery et al. (1997)	3.2.1. <i>Emotional deprivation</i>	- family conflict is considered as one stress factor that could impact growth
Mumm et al. (2016)	3.1.1. <i>Socioeconomic status</i>	- socioeconomic may have a significant effect on average height results of whole populations, regulation of growth on the individual level might depend on other factors as well
Mumm et al. (2017)	3.1.1. <i>Socioeconomic status</i>	- socioeconomic influence on height variability was significant on the level of whole societies
Muraro et al. (2017)	3.1.1. <i>Socioeconomic status</i>	- higher SES children also showed taller stature
	3.1.3. <i>Social mobility</i>	- no association between social mobility and stature observed
Mushtaq et al. (2011)	3.1.1. <i>Socioeconomic status</i>	- stunting was associated with belonging to socially less privileged groups and living in rural areas
	3.1.2. <i>Parental education</i>	- low level of maternal education implied a higher risk for stunted growth among children
Nguyen et al. (2013)	3.1.1. <i>Socioeconomic status</i>	- analysis of factors associated with rural and urban settings and growth in Vietnam - significant difference among groups in terms of SES and growth
	3.1.2. <i>Parental education</i>	- higher level of maternal education would exert positive effects on child growth
Oliván (2003)	3.2.1. <i>Emotional deprivation</i>	- children in abusive or neglecting families showed suppressed growth - catch up and higher growth velocities after placement in foster care
Özer & Scheffler (2018)	3.2.2. <i>Social identification</i>	- social integration and the feeling of belonging were positively associated with taller stature among migrant population
Power (2002)	3.1.3. <i>Social mobility</i>	- general trend for upward social mobility and taller stature
Scheffler et al. (2020)	3.1.1. <i>Socioeconomic status</i>	- association between SES and stature
Scheffler et al. (2018)	3.1.2. <i>Parental education</i>	- positive effects of higher parental education on growth results
Schwekendiek (2017)	3.1.1. <i>Socioeconomic status</i>	- higher level of maternal education would exert positive effects on child growth
	3.2.1. <i>Emotional deprivation</i>	- psychosocial stress factors could be responsible for limiting the final average growth results of orphans
Telzer et al. (2018)	3.2.2. <i>Social identification</i>	- the feeling of social identification is known to be highly influential under consideration of a positive youth development
Thomas et al. (1990)	3.1.2. <i>Parental education</i>	- strong effect of maternal education on child height in rural and urban settings
Vercellotti et al. (2014)	3.1.1. <i>Socioeconomic status</i>	- regulation of growth is multifactorial and complex - analysis of archaeological populations showed association between social status, status specific stress signals and final body height
Wamani et al. (2007)	3.1.1. <i>Socioeconomic status</i>	- stunting was associated with being raised in poor households
	3.1.2. <i>Parental education</i>	- low level of maternal education implied a higher risk for stunted growth among children
Worku et al. (2018)	3.2.1. <i>Emotional deprivation</i>	- psychosocial, socioeconomic and nutritional factors might exert their effects on the regulation of growth independently

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