

The rise of the couch potato: The decrease of external skeletal robustness of childhood continues in young adult women

Theresa Hamp¹  · Christiane Scheffler¹ 

¹IBB Human Biology, University of Potsdam, Potsdam, Germany

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There are not conflicts of interest.

Correspondence to:

Theresa Hamp
email: sophie.hamp.2019@gmail.com

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Abstract

Background A decrease of external skeletal robustness in children and adolescents over the last decades has been documented. This has mainly been attributed to a lack of movement during childhood and adolescence.

Objectives This paper aims to determine whether this decrease of external skeletal robustness continues into adulthood.

Sample and methods The elbow breadth, absolute and relative pelvic breadth, Frame index and the thoracic index were analysed in 1836 women between the ages of 18 and 29 years in two cohorts (birth years 1951–1994, 1995–2005). The means, standard deviations, minima and maxima as well as selected percentiles were calculated for each of the above-named measurements of both cohorts. The results were tested for significance using a Kolmogorov-Smirnov test. The samples were collected in Germany.

Results Young women born after 1995 have lower mean values ($p < 0.05$) for absolute pelvic breadth (27.3cm vs. 28.2cm), relative pelvic breadth (0.16 vs. 0.17), elbow breadth (5.9cm vs. 6.1cm), frame index (35.25 vs. 36.81), and thoracic index (67.87 vs. 69.46) than women born between 1951–1994.

Conclusions The trend toward a reduced external skeletal robustness observed in modern children and adolescents seems to continue into adulthood. The changes in the thoracic index appear to be due to the secular trend in growth.

Take-home message for students Young adults born after 1994 show lower values in skeletal measurements than young adults born earlier. The data confirm that the trend towards reduced external skeletal robustness detected in childhood continues into adulthood. This trend has been mainly linked to decreased physical activity during growth.

Introduction

Physical activity is defined as movements of the body that increase energy consumption by straining the muscles (Caspersen et al. 1985). Historically, humans have lived and worked in environments that required high levels of physical activity every day, first as hunters and gatherers and later also as farmers (Walker et al. 2003). However, with the start of industrialisation in the late 18th century, the daily levels of physical activity started to decline as machines and electricity made the work easier (Drath and Horch 2014). In the USA, the number of people using personal vehicles increased between 1970 and 2000, as did daily screen time. These trends led to an increase in daily time spent seated (Owen et al. 2010). Also globally, daily levels of physical activity decreased continuously. In 2014, based on smartphone data, the global average of daily steps was $4,961 \pm 2,684$ (SD) steps/day (Althoff et al. 2017), whereas Hadza hunter-gatherers of northern Tanzania still take an average of 18,434 steps/day for men and 10,921 steps/day for women (Wood et al. 2021). The lifestyle changes and the low levels of daily physical activity also affected children. In Germany, almost 85% of children and adolescents did not fulfil the recommended 60 minutes of physical activity per day (Krug et al. 2012). The question arises to what extent changes in lifestyle are associated with parallel trends in the human body.

In a cross-sectional study, German children aged between 6 and 10 years were examined in terms of their BMI, body fat percentage, Frame index (relative elbow breadth), total number of steps per week, time spent in sports clubs per week, time spent training and time spent watching TV per day. The Frame index was used as an indicator for skeletal robustness (Frisancho 1990). The study showed a positive correla-

tion between skeletal robustness and daily physical activity (Rietsch et al. 2013a).

The modern lifestyle of humans affects other skeletal measurements, in particular pelvic breadth in children and adolescents. A significant decrease of absolute and relative pelvic breadth, as well as the Frame index of children and young adults was found since 1980. While absolute and relative pelvic breadth, and relative elbow breadth decreased, the thoracic index did not show significant differences (Scheffler and Hermanussen 2014). Since not only height but also the thoracic index can be used as an indicator of long-term growth trends, the stability in the thoracic index during recent years suggests that the observed changes in elbow and pelvic breadth are separate phenomena that had occurred independently of the known secular trends in growth (Bodzsař and Susanne 1998; Scheffler and Hermanussen 2014).

This paper aims to determine whether the decrease in skeletal robustness that was observed in children aged 6–10 years in the years 2010 to 2012 (Rietsch et al. 2013a) continues into adulthood. We chose the year 1995 to clearly separate two cohorts of women, either born in the years before the decline in skeletal robustness was observed, or thereafter. Two cohorts of young adult women were compared with respect to their Frame Index, elbow breadth, absolute and pelvic breadth and thoracic index. The anthropometric data of the cohorts of young adult women had been gathered at different points in time. It was hypothesised that the previously described decrease of external skeletal robustness continues into adulthood and that, consequently, the percentile values of the Frame index, elbow breadth as well as absolute and relative pelvic breadth of cohort 2 would be significantly lower than the corresponding values of cohort 1.

Sample and Methods

Data sets

For this paper, data collected for the following studies at universities in Potsdam and Berlin were used: (Flügel, B., Greil, H., Sommer, K. 1986; Gierloff 2011; Greil 1988; Schilitz 2001; Trippo 2000) and the data set measured by students in practical course in Human Biology at the University of Potsdam (Table 1). The data was collected using standardised methods. It was anonymised. For cohort 1, the sample consists of multiple data sets, all of which – with the exception of (Greil 1988) – are random samples. As for the data set (Greil 1988), it consists of data that were collected and chosen such that it represents the social stratification of the population in the GDR at the time of data collection (Greil 1988). For cohort 2, the sample consists only of students and is thus not completely random. However, the women in both cohorts came from different rural and urban regions in Germany. The women were not chosen based on their origin – with the exception of (Greil 1988). Thus, both data sets are comparable.

To ensure the comparability of the results, only the data sets for which the year of birth and year of data collection as well as the

sex, body height, elbow breadth, absolute pelvic breadth, thoracic breadth and depth in cm were given, was used. Additionally, the data set was split into two cohorts. 1995 was set as the cut-off year, whereby it itself is included in the second cohort (Table 1). This cut-off year was chosen based on the following deliberations: The individuals examined in previous studies were between respectively 3 and 18 years (Scheffler and Hermanussen 2014) and 6 and 12 years old (Rietsch et al. 2013a), with the data used for this purpose being collected between 1980 and 2012. The data set used for this study contains data collected between 1980 and 2024. Since the last year of data collection is 2024 and the individuals studied are between 18 and 29 years old, this means that they were born in 1995 at the earliest. Therefore, 1995 was chosen as the date for separating the cohorts.

Hence, cohort 1 consists of 1715 women aged 18–29 years who were born between 1951 and 1994. Cohort 2 contains data from 121 women born between 1995 and 2005.

Data analysis

We analysed elbow breadth and absolute pelvic breadth. Those measurements were also put into relation with body height. For this, the Frame index $FI = \text{elbow breadth}$

Table 1 Cohorts with years of birth and the respectively used data sets. The data stem from 1836 women aged between 18 and 29 years gathered at universities in Potsdam and Berlin, Germany

Cohort	Years of birth	Data sets
1 n=1715	1951-1994	(Flügel, B., Greil, H., Sommer, K. 1986) (Gierloff 2011) (Greil 1988) Data set measured by students in practical course in Human Biology at the University of Potsdam (Data Bank Human Biology – University of Potsdam) (2018–2024) (Scheffler et al. 2014) (Schilitz 2001) (Trippo 2000)
2 n=121	1995-2005	Data set measured by students in practical course in Human Biology at the University of Potsdam (Data Bank Human Biology – University of Potsdam) (2018–2024)

(mm)*100/body height (cm) (Frisancho 1990) and the relative pelvic breadth (absolute pelvic breadth in cm/body height in cm) were calculated. Additionally, the thoracic index was determined using the formula $TI = \text{thoracic depth (cm)} * 100 / \text{thoracic breadth (cm)}$ (Knusmann 1988). Information about individual lifestyle was not available.

To evaluate the distribution of the data, the mean μ and the standard deviation σ (SD) of the aforementioned measurements as well as the respective 1σ ranges around the mean were calculated (Strick 2018; Stegen 2025). The 3rd, 5th, 50th, 95th, and 97th percentiles were calculated to investigate the outer regions of the distribution of the data. As the data distribution of the two cohorts was likely not a normal distribution, the significance levels of the results were tested using a Kolmogorov-Smirnov test using $p < 0.05$ as the significance level (Duller 2018). This test relies on calculating the maximum difference between the empirical cumulative distribution functions (ECDFs) of both samples. Therefore, it is insensitive to unequal sample sizes, which is why the two cohorts are comparable despite the difference in sample size (Schwarzenberger 2025). The statistical values were determined using R version 4.4.3. All studies were conducted under the principles of the Helsinki declaration of ethical principles for medical research involving human subjects (WMA 2013)(WMA 2013). Additional study specific permissions are mentioned in the original publications.

Results

The means of the body height increased from cohort 1 to cohort 2 (165.8cm vs 169cm). The means of the absolute pelvic breadth (28.2cm vs 27.3cm), elbow breadth

(6.1cm vs 5.9cm), Frame index (36.81 vs 35.25) and thoracic index (69.46 vs 67.87), and relative pelvic breadth (0.17 vs.0.16) are lower ($p < 0.05$) in cohort 2 than cohort 1 (Table 2). The percentile values of cohort 1 were lower than those of cohort 2 (Table 3).

For the absolute pelvic breadth, 72.1% of the values in cohort 1 were in the 1σ range of the mean, for cohort 2, 71.9% of the values were in this range. The values of all determined percentiles of the absolute pelvic breadth in cohort 1 were above those of cohort 2 ($p < 0.05$). The difference between the values of the cohorts was smaller in the lower percentiles (3rd, 5th percentile) than in the upper percentiles (95th and 97th percentile) (Table 3).

For the relative pelvic breadth, 71.7% of the values of the values in cohort 1 were in the 1σ range around their mean, for cohort 2 this was true for 66.1% of the values. The values of the 3rd and 5th percentiles of cohort 1 were the same as the respective values of cohort 2. The 50th, 95th and 97th percentiles of cohort 1, however, were larger than those of cohort 2 ($p < 0.05$) (Table 2,3). 66.1% of the values of the elbow breadth in cohort 1 were within the 1σ range. 62% of the values in cohort 2 were in the 1σ range. The values of the 3rd, 5th, 50th, 95th, and 97th percentile of the elbow breadth in cohort 1 were above those in cohort 2 (Table 3). All differences were statistically significant (Table 2).

69.7% of the Frame indices of cohort 1 were in the 1σ range. 68.6% of the values in cohort 2 were also in that range. The values of all considered percentiles of the Frame index in cohort 2 were below the respective percentile values in cohort 1 (Table 3). The differences were statistically significant (Table 2).

68.6% of the thoracic indices in cohort 1 were within the 1σ range. For cohort 2, this was true for 65.3% of the values. The values of the 3rd, 5th, 50th and 97th percentile of

the thoracic index of cohort 1 were larger than those of cohort 2. The value of the 95th percentile of cohort 1 was somewhat smaller than that of cohort 2 ($p < 0.05$) (Table 2, 3).

Discussion

The hypothesis that the values of the elbow breadth, Frame index as well as the absolute and relative pelvic breadth of cohort 2 were significantly lower than those of cohort 1 was confirmed.

There were significant reductions of the elbow breadth, absolute pelvic breadth and Frame index between the cohorts (Tables 2, 3). It should be noted that for the absolute pelvic breadth, the differences between the values of the two cohorts were larger in the upper than in the lower percentiles (Table 3). For the relative pelvic breadth, the 3rd and 5th percentiles were similar, while the other percentiles were larger in cohort

1 than in cohort 2 (Table 3) indicating that the reduction of the pelvic breadth has a bigger effect on people with a wider pelvis than on people who already have a narrow pelvis.

Trends of declining external skeletal robustness have also been observed in other regions, e.g., for school children in Argentina (Navazo et al. 2020) and Russia (Rietsch et al. 2013b) and in Slovenian young adults (Kotnik et al. 2024).

A reduction in physical activity during childhood has been observed in the last decades (Kettner et al. 2012). Bipedal locomotion influences bone growth in both the elbow and the pelvis (Pearson and Lieberman 2004). Bone growth occurs mainly during childhood and adolescence, hence, reduced physical activity during those periods can lead to reduced growth of elbow and pelvis (Hereford et al. 2024). Over the last decades, physical activity levels have decreased in Germany (Krug et al. 2012; Rietsch et al. 2013a). Thus, the reduction of the skeletal breadths between the two cohorts can be explained by the lower level

Table 2 Means (μ), standard deviations (σ) and p-values of the absolute and relative pelvic breadth, elbow breadth, Frame index (relative elbow breadth), thoracic index (ratio of thoracic breadth and depth) and body height of different cohort of women aged 18 to 29 years. The data were collected at universities in Berlin and Potsdam, Germany

	Cohort 1 (1951–1994) n=1715		Cohort 2 (1995–2005) n=121		p-value (K-S-Test)
	μ	σ	μ	σ	
Absolute pelvic breadth (cm)	28.20	2.20	27.30	1.80	< 0.001
Relative pelvic breadth	0.17	0.01	0.16	0.01	< 0.001
Elbow breadth (cm)	6.10	0.40	5.90	0.40	< 0.001
Frame index (relative elbow breadth)	36.81	2.18	35.25	2.11	< 0.001
Thoracic index (relative thoracic breadth and depth)	69.46	6.50	67.87	6.87	0.001
Body height (cm)	165.80	6.20	169.00	7.20	0.018

The significance level was chosen at $p < 0.05$. Significant values are marked in bold.

of physical activity during childhood and adolescence. This means that the reduced bone growth observed by (Scheffler and Hermanussen 2014) cannot be caught up on during adolescence.

A reduction in thoracic index and an increase in body height are indicative of a secular trend in growth (Bodzsaf and Susanne 1998). In women, the thoracic

indices of cohort 2 were in general smaller than those of cohort 1, while the body height increased from cohort 1 to cohort 2 (Tables 2, 3). Hence, a secular trend in growth could have influenced the observed changes in anthropometric measurements in women.

(Bronner 2001) stated that calcium is necessary for bones to be developed. Hence, a

Table 3 Percentile values of the absolute and relative pelvic breadth, elbow breadth, Frame index (relative elbow breadth), thoracic index (ratio of thoracic breadth and depth) and body height. (1836 women aged 18 to 29 years, the data were collected at universities in Potsdam and Berlin, Germany)

Measurement	Percentile	Cohort 1 (1951–1994) n=1715	Cohort 2 (1995–2005) n=121
Absolute pelvic breadth (cm)	P3	24.50	24.20
	P5	24.90	24.60
	P50	28.00	27.20
	P95	32.00	30.10
	P97	32.70	30.70
Relative pelvic breadth	P3	0.15	0.15
	P5	0.15	0.15
	P50	0.17	0.16
	P95	0.19	0.18
	P97	0.20	0.18
Elbow breadth (cm)	P3	5.40	5.20
	P5	5.50	5.30
	P50	6.10	6.00
	P95	6.70	6.60
	P97	6.80	6.60
Frame index	P3	32.78	31.58
	P5	33.17	32.03
	P50	36.85	34.94
	P95	40.30	39.41
	P97	40.80	39.84
Thoracic index	P3	57.74	56.59
	P5	58.94	57.65
	P50	69.34	67.23
	P95	80.45	80.69
	P97	82.21	81.41
Body height	P3	153.88	155.36
	P5	155.17	156.40
	P50	165.80	168.00
	P95	175.83	180.00
	P97	177.20	181.64

lack of calcium could hinder bone growth (Bronner 2001). But there is no data on the nutrition of the people considered in this paper, but it is unlikely that the calcium intake in modern German children may be insufficient (Flynn et al. 2009).

Human bones adapt to physical strain. Mechanical strain primarily affects the skeleton during adolescence (Pearson and Lieberman 2004). Most of the bone mass is accumulated during adolescence, maximum bone mass is reached around 20 years of age. Thereafter, bone mass remains relatively constant until roughly 50 years of age (Hereford et al. 2024). Bipedal locomotion places characteristic stress on the skeleton: The elbow bears weight during the arm swing and the pelvis transfers the body weight unto the lower extremities (Kang et al. 2023; DeSilva and Rosenberg 2017). Low levels of physical activity during childhood and adolescence thus, influence the human skeleton. The reduction in external skeletal robustness reflects phenotypic plasticity under altered lifestyle in a changing everyday environment. It remains to be elucidated whether these changes should be considered pathology.

Limitations

As only complete data sets were used, the sample size was small. The data represent a cross-section, not a longitudinal section of the population. Hence, no statements can be made on the previous development of the individuals studied. Additionally, cohort 2 only contains data from students, hence, the data was not collected completely at random and thus, may not be unbiased (Kubben et al. 2019).

Conclusion

The trend toward a reduced external skeletal robustness, as reflected in a reduction

of elbow breadth and pelvic breadth in modern children and adolescents, seems to continue into adulthood. These changes appear to be explicable in part by low levels of physical activity during childhood and adolescence and in part by a secular trend in growth. In contrast to earlier studies, there were also changes in the thoracic index. The study emphasizes how quickly the human phenotype adapts to changing environmental conditions.

Disclaimer

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