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SECULAR TRENDS IN BODY HEIGHT AND BODY MASS OF SLOVENIAN YOUNG ADULTS FROM 1954 TO 2019

SEKULARNI TRENDI TELESNE VIŠINE IN TELESNE MASE PRI SLOVENSKIH MLAJŠIH ODRASLIH MED LETI 1954 DO 2019

ABSTRACT

Secular trends in body height and body mass serve as critical indicators of a population's nutrition, health, and overall well-being. This comprehensive study delves into the anthropometric data of Slovenian young adults spanning a remarkable 65-year period, comparing these findings with secular trends observed in other populations. Data acquisition was accomplished through the utilization of the SLOfit system and the integration of earlier research studies in Slovenia. Height and body mass measurements were collected employing standardized methodologies. Generalized Additive Models for Location, Scale, and Shape (GAMLSS) were harnessed to derive centile curves and establish reference values. Slovenian males consistently grew taller than females, reaching their peak in 2019. Young Slovenian adults continue to grow taller and gain more body mass, with substantial changes in recent years. The largest changes in body mass in both males and females occurred in years between 2015 and 2019, with wider spreads in mass centiles in these years compared to the beginning of the observed period. Healthcare and diet improvements likely contributed to increased body mass, yet sedentary lifestyles and altered diets may also be involved. This research enhances our understanding of environmental, and socio-economic factors in human growth, with implications for public health policies and long-term planning. While this study spans 65 years, it faces limitations in measurement consistency and demographic data. Future research should explore region-specific influences on these trends. In conclusion, monitoring secular trends in body height and body mass is crucial for evidence-based policymaking, health planning, and public health interventions, enabling the promotion of healthy lifestyles and the proactive management of emerging health challenges.

Keywords: secular trends, body height, body mass, young adults, Slovenia

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IZVLEČEK

Sekularni trendi telesne višine in telesne mase služijo kot pokazatelji prehranjenosti, zdravja in splošnega dobrega počutja prebivalstva. Ta obsežna študija se poglobljа v antropometrične podatke slovenskih mladih odraslih v 65-letnem obdobju in primerja te ugotovitve s sekularnimi trendi drugod po svetu. Podatke smo črpali iz sistema SLOfit in jih integrirali s prejšnjimi raziskavami narejenimi na Biotehnični fakulteti. Meritve višine in telesne mase so bile zbrane z uporabo standardiziranih metodologij. Splošni aditivni modeli (GAMLSS) so bili uporabljeni za izpeljavo centilnih krivulj in določitev referenčnih vrednosti. Ugotovili smo, da so slovenski moški skozi leta vedno višji in da so dosegli vrhunec rasti v letu 2019. Največje spremembe v telesni masi tako pri moških kot pri ženskah so se zgodile v letih med 2015 in 2019, z večjimi razmiki v centilih telesne mase v teh letih v primerjavi z začetkom opazovanega obdobja. Izboljšave zdravstvene oskrbe, boljše prehrane in bolj pogost sedentarni način življenja, so verjetno prispevali k povečani telesni masi slovenskih mladih odraslih. Ta raziskava izboljšuje naše razumevanje okoljskih in socialno-ekonomskih dejavnikov v človeški rasti. Čeprav ta študija traja 65 let, se sooča z omejitvami glede doslednosti meritev in demografskih podatkov. Prihodnje raziskave bi morale raziskati vplive posameznih regij na te trende. Skratka, spremljanje sekularnih trendov v telesni višini in telesni masi je ključnega pomena za oblikovanje politik, ki temeljijo na zdravstvenemu načrtovanju in javnozdravstvenih intervencijah, kar pa omogoča promocijo zdravega načina življenja in proaktivno obvladovanje nastajajočih zdravstvenih izzivov.

Ključne besede: medgeneracijske spremembe, telesna masa, telesna višina, mladi odrasli, Slovenija

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INTRODUCTION

The phenomenon of secular trends in body height and body mass are widely acknowledged as a pivotal indicator of population nutrition, health, and overall well-being (Cole, 2003). Examining these trends yields valuable insights into the evolution of human body composition at the population level (Zhang et al., 2019). The variations seen in body growth can partly be explained by differences in living conditions and the availability or allocation of resources. (Malina et al., 2011). Such disparities can be attributed to a range of factors, also including genetics (Lauby-Secretan et al., 2016) but are hugely determined by environmental conditions (Dubois et al., 2012), socioeconomic status (Öberg, 2014), health status, and the complexity of nutrition (Tanner, 1992). In this regard the steady increase in body height and body mass worldwide can be attributed to lifestyle changes and socioeconomic conditions (Kuh et al., 1991; Marmo et al., 2004; Padez, 2003; Prebeg, 1998; Rodriguez-Martinez et al., 2020a; Thomas & Frankenberg, 2002). This phenomenon, referred to as the secular trend in body height, has led to successive generations surpassing their predecessors (Malina, 1990). The pace and timing of this phenomenon exhibit considerable variation across different countries (Bentham et al., 2016). While most European populations have witnessed a noticeable surge in average body height (Carrascosa et al., 2004; Garcia & Quintana-Domeque, 2007; Roczen Kirsten, 2000), past decades' studies indicate that this upward trend has plateaued in certain countries, such as Germany (Zellner et al., 2004), Poland (Krawczynski et al., 2003) and Denmark (Schönbeck et al., 2013). This stagnation in body height increase is attributed to either a cessation in socioeconomic advancement or the population attaining their maximum genetic potential in these regions.

In contrast, Asian countries continue to experience growth at varying rates (Bentham et al., 2017; Bents et al., 2018). The long-term pattern of body growth has shown an upward direction over the past two centuries (Bodzsar, 1998; Roche, 1979; Tanner, 1966; Van Wieringen, 1986), nevertheless with notable interruptions during periods of crisis in Europe, such as World War I and II (de Muinck Keizer-Schrama & Mul, 2001).

Situated at the nexus of pivotal European cultural and trade routes, Slovenia has long been a focal point of strategic interests for major European powers, resulting in a diverse genetic pool (Fertil, 2010; Reeves, 1921; Taylor & Gradišnik, 1956). The pre-WWII evidence is scarce, but the most extensive accelerated growth of young adults in Slovenia was recorded in the first two decades after the WWII (Štefančič, 2008). There was also a significant increase in body mass,

although not proportional to the increase in height (Štefančič, 2008), while the measurements, which took place between 1981/82 and 1991/92, showed a slowing down of the acceleration tendencies (Štefančič, 2008). The availability of cross-sectional data on body height and mass from individual sources over the last few decades enabled the study of secular trends concerning body height and mass across the entire adult population aged 18-74 in Slovenia (Robič Pikel et al, 2023). However, with rare exceptions (Robič Pikel, 2022), these analyses have not specifically addressed the young adult segment of this population in detail for the past century. The present study tries to close this gap by analysing pertinent data regarding the anthropometric parameters of Slovenian young adults over a period of 65 years and contrast them with the secular trends observed in other populations and age cohorts. Additionally, the study aims to ascertain alterations in the amplitude and orientation of secular trends in body height and body mass of Slovenian young adults in the age group of 18-25 years, spanning a period of 65 years.

METHODS

Data were collected within the SLOfit study of the Faculty of Sport, University of Ljubljana (No. 6-2019-539) and with regular measurements and data collection within the (data) Base of Anthropometric Measurements (BAM) (Golja & Pikel, 2021) at the Department of Biology, University of Ljubljana, approved by the Slovenian National Medical Ethics Committee (KME 104/12/10) and following the Declaration of Helsinki. In the analysis, we used anonymised data.

Participants

Body height and body mass data between 1954 and 1990 were obtained from measurements at the Biotechnical Faculty of the University of Ljubljana and collected from BAM (Golja and Robič Pikel, 2021), while the after 1990 data were obtained through the SLOfit system for population aged 18 – 25 years. The SLOfit system is a population-based national surveillance system that tracks somatic and motor development of children, youth, and adults in Slovenia on the population level (Jurak et al., 2020, 2022). All available data were merged into a single dataset and Table 1 provides sample sizes of individual measurements from 1950 to 2019.

Table 1. Sample sizes (N) and mean age of participants [years] (M) separated by sex and year of measurement.

	Male		Female			Male		Female	
Year	N	M	N	M	**Year**	N	M	N	M
1954	264	20,7	183	20,2	**1996**	5935	18,5	6428	18,5
1955	158	20,9	20	21,0	**1997**	4884	18,5	4652	18,5
1956	100	20,6	113	20,0	**1998**	5211	18,5	5054	18,5
1957	131	21,3	145	20,5	**1999**	4974	18,5	5093	18,5
1958	90	23,3	56	22,4	**2000**	5058	18,5	4672	18,5
1959	224	20,5	292	19,7	**2001**	4983	18,5	4786	18,5
1960	224	20,5	194	20,8	**2002**	5102	18,5	4867	18,5
1961	216	19,7	152	19,9	**2003**	5036	18,5	5023	18,5
1962	219	21,7	124	21,3	**2004**	4253	18,5	4202	18,5
1963	197	21,5	104	20,4	**2005**	4374	18,5	4430	18,5
1964	210	20,4	264	20,4	**2006**	5693	18,5	5818	18,5
1965	61	21,9	114	21,3	**2007**	3453	18,5	3918	18,5
1967	41	23,5	33	23,4	**2008**	3491	18,5	3462	18,5
1969	32	22,8	91	23,0	**2009**	5297	18,5	5545	18,5
1981	54	20,0	84	19,2	**2010**	4698	18,5	5534	18,5
1982	203	19,2	179	18,9	**2011**	4769	18,5	4972	18,5
1983	36	20,0	87	19,9	**2012**	5628	18,5	5562	18,5
1987	89	20,4	187	19,3	**2013**	5031	18,5	5374	18,5
1988	188	20,6	142	19,7	**2014**	5269	18,5	5041	18,5
1990	3611	18,4	5268	18,4	**2015**	6259	18,7	6543	18,7
1991	3576	18,4	5120	18,5	**2016**	6246	18,5	6105	18,5
1992	4794	18,5	6326	18,5	**2017**	6046	18,5	5995	18,5
1993	5118	18,5	6321	18,5	**2018**	5058	18,5	5291	18,5
1994	6211	18,5	7116	18,5	**2019**	2559	18,5	2670	18,5
1995	5950	18,5	6578	18,5					

Testing and measurements

A comprehensive approach was adopted to ensure the use of standardized research tools and the availability of necessary measurement equipment and personnel.

Testing and measurements at the Biotechnical Faculty

A part of the anthropometric measurements was conducted between 1954 and 1990 at the Department of Biology on an annual basis by proficient personnel. Standardized equipment and procedures were applied (Weiner & Lourie 1969, Lohman et al. 1988). Practitioners belonging to three different generations were responsible for taking measurements. Each examiner underwent direct training from their predecessor, ensuring that all measurements were consistently performed following the same procedure. During the measurements, the subjects were barefoot and dressed in light clothing. Body mass was measured with certified calibrated personal scale to the nearest 0.5 kg (a standard physician balance beam scale). Body height was measured with standardized anthropometer to the nearest 0.1 cm according to the following protocol: no shoes were worn, upright stance with subject's heels together, with subject having relaxed shoulders and back as straight as possible, and with head positioned in Frankfort plane (Kotnik & Golja, 2012).

Testing and measurements within the SLOfit system

Anthropometric measurements within SLOfit system were performed between 1990 and 2019 in Slovenian high schools. All anthropometric variables were performed by Physical Education teachers, who were extensively trained in anthropometry and SLOfit measurement protocols by the Faculty of Sport. Height was measured to the nearest 0.1 cm with head positioned in Frankfort plane, while body mass was measured to the nearest 100 grams (Kovač, Marjeta, Jurak Gregor, Starc Gregor, 2017).

Statistical analyses

Centile curves and reference values were obtained using Generalised Additive Models for Location, Scale and Shape (GAMLSS) (Rigby & Stasinopoulos, 2005). Three continuous (Box-Cox Cole and Green [BCCG], Box-Cox power exponential [BCPE], Box-Cox-t [BCT], generalised inverse Gaussian) distributions were fitted to the data as appropriate, optimising the degrees of freedom (DF) for P-splines fit for all parameters of the respective distributions using Schwarz Bayesian criterion (SBC) (Schwarz, 1978). Appropriate link functions were used for the parameters. BCCG is routinely used in the Lambda Mu Sigma (LMS) method (Cole & Green, 1992). BCPE and BCT are extensions of LMS adding an extra parameter, ν, to allow modelling (positive or negative) kurtosis [with $\nu=2$ BCPE and BCCG (LMS) coincide]. The best-fitted model was selected based on SBC, observation of worm plots (Buuren & Fredriks, 2001) and comparison of estimated and empirical centiles. In all the models, $\lambda=0.5$ was used

for the power transformation of age. Separate analyses were performed for males and females. DFs (Degrees of Freedom) for P-splines fit for the extra parameter were optimised, as described previously. The analysis was performed using the R language for statistical computing (R version 3.6.3, R Foundation for Statistical Computing, Vienna, Austria); GAMLSS were fitted using R package gamlss (Stasinopoulos & Rigby, 2007).

The best-fitted models with the optimal DFs for the P-splines fit for all parameters of the respective distributions and SBC for each gender are reported in Supplemental files (see Table S1, S2, S3, S4).

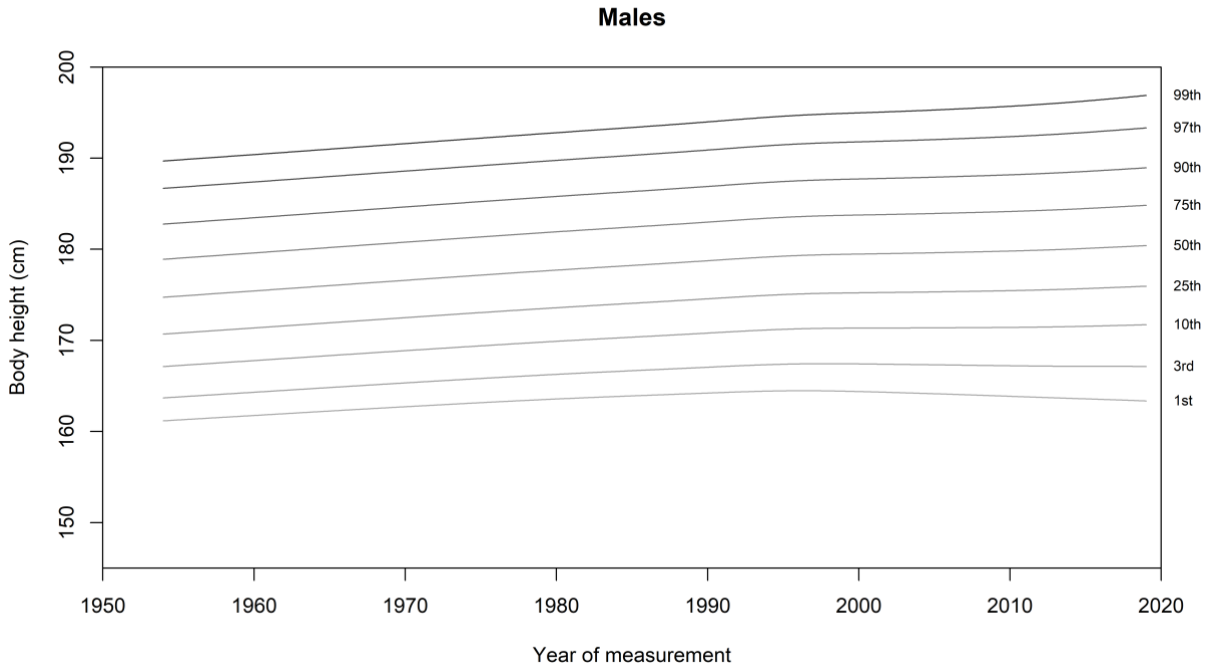
RESULTS

In present study, we examined the body height and body mass of 311634 young adults, comprising of 151304 males and 160330 females, who were measured over a period extending from year 1954 to year 2019. Given the asymmetric distribution observed in our dataset, we opted to present the central tendency and variability of our data in terms of the median (Me) and interquartile range (IQR), respectively. The median age of all participants was found to be 18.48 years. This measure of central tendency was accompanied by an IQR of ±0.53 years, indicating a relatively narrow range of age variability among participants. This pattern of age distribution was consistent across gender subgroups, with males displaying a median age of 18.47 years (IQR: ±0.53 years) and females showing a median age of 18.48 years (IQR: ±0.53 years). These findings highlight the homogeneity in the age distribution of our sample, providing a stable foundation for the subsequent analysis of body height and body mass across the study population.

Figures 1-4 present the centile curves for body height and body mass at the 1st (C1), 3rd (C3), 10th (C10), 25th, 50th, 75th, 90th, 97th, and 99th (C99) centiles. Corresponding score values for each of these centiles can be found in the Supplemental files (refer to Table S1, S2, S3, and S4).

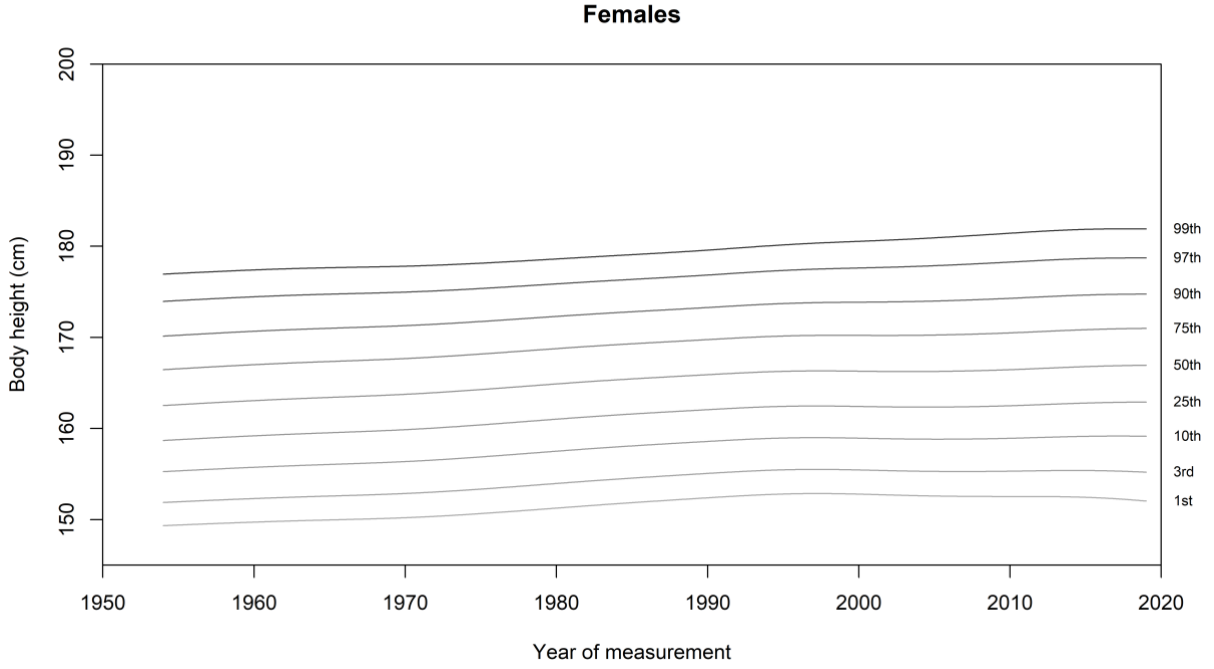
The results showed that Slovenian males measured in 1954 were the shortest, while those measured in 2019 were the tallest over the 65-year period that we observed (see Table S1). Figure 1 demonstrates that males' height has almost consistently increased during the observed period. The growth rate slowed down slightly after 1995 and at the end of the observed period, in years between 2015 and 2019 a stagnation or even slight decrease is noticed in lower centiles (C3, C1), e.g. C1 decreased from 164.5 cm in 1995 to 163.4 cm in 2019 (Table S1).

Figure 1. Body height centile curves for the 1st, 3rd, 10th, 25th, 50th, 75th, 90th, 97th, and 99th centile for males from 1950 to 2019.



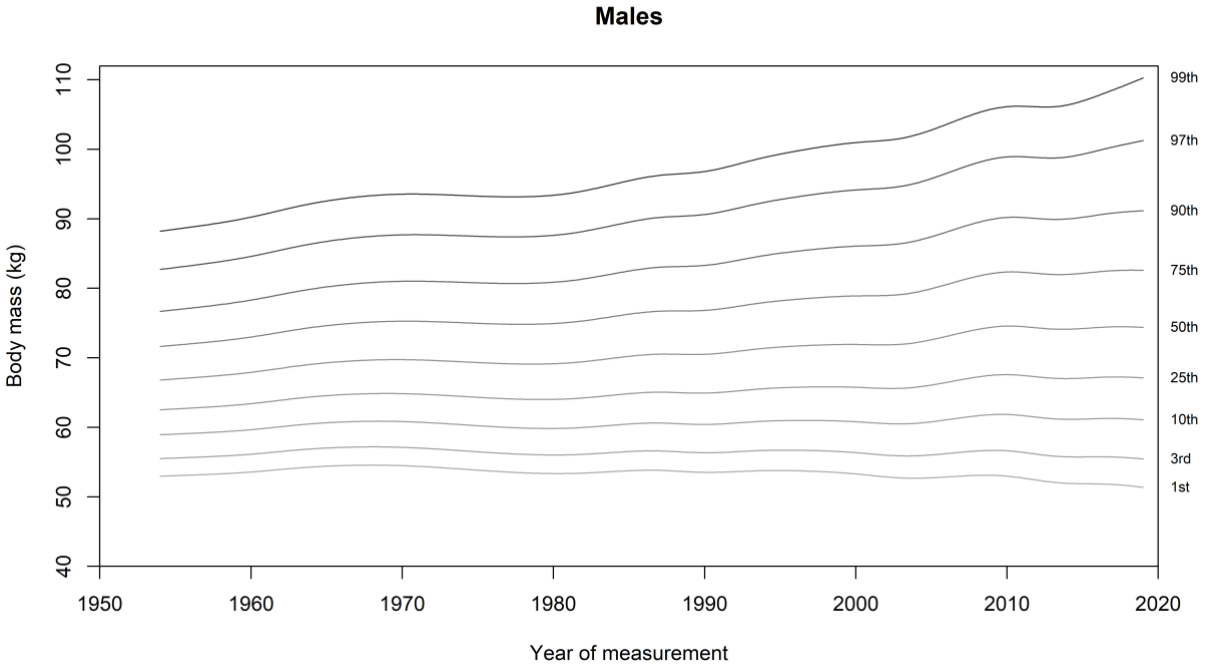
Similar to males, our analysis revealed that females measured in Slovenia in 1954 were the shortest, while those measured in 2019 were the tallest over the 65-year period that we observed. Figure 2 illustrates that females' body height has consistently increased each year. Although all the centile curves display a similar pattern of a mostly consistent growth through the observed period, growth was more pronounced before 1995, then it slowed down. At the end of the observed period a stagnation or even slight decrease may be noticed for the lower centiles. E.g. C1 decreased from 152.8 cm in 2000 to 152.0 cm in 2019 (Table S2). If one observes body height centile curves for males, there is a plateauing trend below the 50th centile, whereas young adult males' body height ranging above 50th centile exhibits continued growth.

Figure 2. Body height centile curves for the 1st, 3rd, 10th, 25th, 50th, 75th, 90th, 97th, and 99th centile for females from 1950 to 2019.



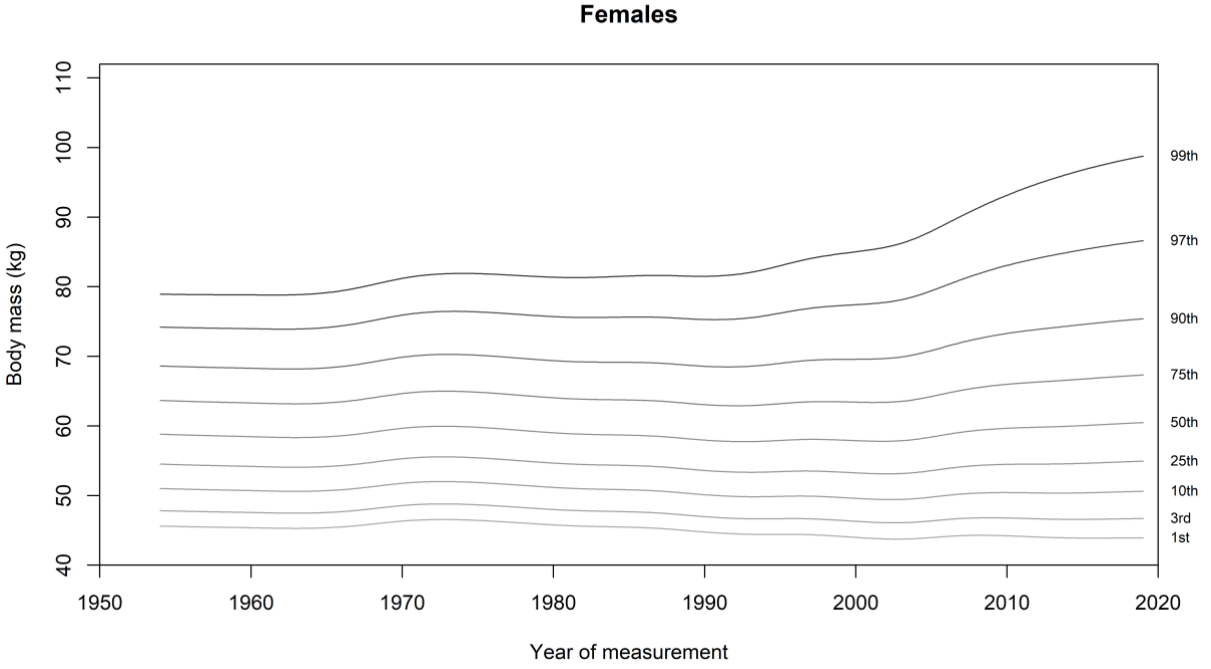
In Slovenia, changes in male body mass are less consistent than in body height (Figure 3). In the median and higher quantiles, body mass generally increases, but not so linearly as in body height. In the lower centiles, a stagnation may be noticed around C10. In the lowest centiles, C1 and C3, after the slight initial growth, the trend reverses to slightly declining. Therefore, variability in body mass steadily increase throughout the observed period, e.g. the difference between C1 and C99 increased from 35.2 kg in 1954 to 58.9 kg in 2019 (Table S3).

Figure 3. Body mass centile curves for the 1st, 3rd, 10th, 25th, 50th, 75th, 90th, 97th, and 99th centile for males from 1950 to 2019.



In female body mass, most of the centile curves are nearly flat from year 1954 through around 2005, when they started to increase in median and upper centiles and stay flat or even decrease in the lower centiles (Figure 4). Therefore, variability in body mass increased rapidly after 2005, e.g. the difference between C1 and C99 increased from 33.3 kg in 1954 to 54.9 kg in 2019 (Table S4)

Figure 4. Body mass centile curves for the 1st, 3rd, 10th, 25th, 50th, 75th, 90th, 97th, and 99th centile for females from 1950 to 2019.



DISCUSSION

The aim of the present study was to collect relevant data on the body height and body mass of young adults in Slovenia over the past 65 years and determine changes in the magnitude and direction of secular trends in body height and mass among young adults aged 18 to 25 years in Slovenia. The study showed that both male and female body height has increased over the observed period, which is in accordance with previous reports (Robič Pikel, 2021; Robič Pikel et al., 2023). The centile curves for body height showed a consistent growth across the observed years, with highest variability from 2015 to 2019, as compared to the beginning of the observed period. However, there was a slight decrease in body height for males and females ranking in the first centile in the recent years.

Young male adults ranking from the 75th to 99th centiles are still growing, which is suggesting that the growth patterns of males may vary, with those in the higher centiles demonstrating increased height potential.

Females body height followed a similar pattern as males', i.e. constant growth throughout the observed period, with slight stagnation or decline in lower centiles. However, the growth tempo was somewhat slower in females than in males, e.g. the median growth increased by 4.4 cm in

the observed period, while the males' median increased by 5.7 cm. Also, differently as in males, all the centiles in females have the highest growth tempo between 1975 and 1990, while in males the highest tempo was near the beginning of observed period and it slowed down significantly after year 2000, except for the highest centile, where it increased again after 2010. The extended growth almost to the end of the observed period of C99 is also present in females but seems to stop after 2015. Furthermorev, it is worth mentioning that the timing and pace of growth also vary between individuals and can be influenced by various environmental factors such as physical activity levels, stress, and overall health status (Silventoinen, 2003). Therefore, the variability in body height among males and females in different centiles may be the result of a complex interplay between genetics, hormonal, and environmental factors (Hills & Byrne, 2010).

Both male and female body mass has generally increased over the observed period of 65 years. This increase was more pronounced in the upper centiles and less in lower, e.g. the C99 increased by 25% in both males in females. Increase in body mass slowed down in the lower centiles, and more so in males than females, and even experience negative growth of around 3% in both genders in C1. Although the general trend of body mass was increasing, this growth was not linear: the highest increase in both genders occurred in years between 2005 and 2010. In females between 1975 and 1990, and in males in the 1980s, a significant decrease of body mass was observed with wider spreads in body mass centiles between year 2005 and 2010, as compared to the beginning of the observed period. Young males up to the 90th centile have plateaued in body mass, while young adult males in the 99th centile continue to gain body mass. It is imperative to interpret these observations with the understanding that they represent cross-sectional data from different cohorts at various time points, not longitudinal trends within the same individuals.

Young females up to the 75th centile have plateaued, whereas those in the 90th and 99th centiles are still gaining body mass. However, a decline in body mass was seen in the 50th and 99th centile groups between year 1975 and 1990, which could potentially be attributed to the influence of the sample, as it may have been unrepresentative during that time period. The increase in body mass may reflect changes in lifestyle and diet over time, which could have contributed to the observed changes in body mass.

The major finding of the study is that in the period of the past 65 years, both sexes of young adults showed an overall increase in body dimensions, which is in line with the findings from

other researchers (Kalka, Pastuszak, & Buśko, 2019; Mintem, Gigante, & Horta, 2015; Pikel et al., 2023). The body height of students over the period of the past 50 years at the University of Technology Warsaw increased by 8.06 cm, while at Józef Piłsudski University of Physical Education in Warsaw, it increased by 6.90 cm (Kalka et al., 2019). A similar 7.8 cm increase in body height was observed in 19-year-old Polish military recruits from year 1965 to 2010 (Kołodziej et al., 2015), attributed to cultural changes and improved financial status. According to these authors, the results reflected cultural changes and improvement in the financial status of the population, which contributed to more efficient use of the genetically determined growth potential. Furthermore, a study published in The Lancet in 2016 analysed population-based data from 186 countries and reported that the global age-standardized mean body mass index (BMI) increased significantly from 1975 to 2014, with men's average BMI increasing from 21.7 kg/m² to 24.2 kg/m² and women's from 22.1 kg/m² to 24.4 kg/m² (Collaboration, 2016b). The same study reported that the most pronounced increases in body height and body mass across Europe were identified between the 1970s and the 1980s, observing generally parallel upward trends in both height and body mass between genders, however, with more moderate rises in the following decades (Collaboration, 2016b). However, this pattern does not extend uniformly back in time. Specifically, analysis of body height of young adults (approximately 23 years old) born in Great Britain from the early 20th century up to 1958 (Kuh et al., 1991), with a sample size of 50,000, revealed a secular increase in body height at a rate of 1.09 cm per decade for men and 0.36 cm per decade for women. This indicates discernible differences in the magnitude of height increase per decade between genders. While the overarching trend in height and body mass has been upward for both genders, the absolute values of these increases are not identical, underscoring gender-specific variations in growth patterns over the decades. In general, both males and females have experienced increases in height and body mass in Europe over the past few decades, but the trends seem to differ between genders. Studies have consistently shown that males are taller and heavier than females on average, but some of the studies report that the rate of change in height and body mass has been similar between the genders (Collaboration, 2016a). This, however, was certainly not the case, for example, in the Slovenian (Robič Pikel et al., 2023); the present study), Czech (Kopecký et al., 2016), or British (Kuh et al., 1991) populations.

Moreover, females from Central-Southeast Europe, including Slovenia, Montenegro, Serbia, and Slovakia, are among the top 10 tallest female populations globally, with Slovenian females notably ranked ninth in height (Popović, 2018). Likewise, four nations stemming from the

former Yugoslav republics- Montenegro, Bosnia and Herzegovina, Croatia, and Serbia- are recognized among the top 10 countries with the tallest male populations globally (Popović, 2018). Additionally, Albanians, hailing from the same Balkan region, are noted for their body height, ranking among the world's tallest men (Popović, 2018). While physical height is largely heritable (Silventoinen et al., 2021), there may be region-specific factors influencing height trends, above all, the environmental factors, which include the daily diet, the exposure to various infections, as well as the socio-economic status, especially during childhood (Popović, 2018; Subramanian et al., 2011). Understanding these factors can be important for informing public health policies and interventions aimed at promoting healthy growth and development in populations across the globe.

Data in present research does not suggest, that Slovenian young adults already reached the overall plateau in both, body height and body mass. Identifying the exact reasons is challenging, as several possible explanations could account for this phenomenon. One possible explanation is that the changes in lifestyle and nutrition patterns (Silventoinen, 2003) in Slovenia have contributed to the continuous increase in body height and body mass among young adults. For instance, potential improvements in healthcare and nutrition may have positively influenced the growth and development of young adults, resulting in continuous increases in body height and body mass over time. Changes in dietary habits, food availability, improvements in living standards, and economic growth, could have contributed to increases in body mass (Lobstein et al., 2015). In addition, sedentary lifestyles, caused by technological advancements and changes in work and lifestyle, can lead to body mass gain due to decreased physical activity (Owen et al., 2010). Prolonged sitting and low activity levels can reduce energy expenditure, increase calorie intake, and cause a positive energy balance, leading to body mass gain. Muscle atrophy and reduced metabolic rate can also result from prolonged sitting, making it more challenging to maintain a healthy body mass (Lee et al., 2012).

The identification of causes for the observed trends of body height and body mass of young adults is beyond this study, but the identified trends could in the future be compared with other socio-demographic and economic trends that could explain the growth trends of small populations as the Slovenian one. Namely, the population living in Slovenia experienced very turbulent and diverse changes. The 1970s witnessed transformative urbanization and industrialization processes that altered people's dietary habits and physical activity levels. During this era, there was a substantial increase in worker migration from Bosnia, Serbia, and Montenegro, with the migration numbers doubling between 1971 and 1981. The migration

number for Bosnians was even more pronounced, with their numbers tripling in the 1990s (Josipovič, 2023; Ravbar, 1990). The transition to a more sedentary lifestyle, coupled with the influx of young workers from the tallest ethnic groups in the Balkans, raises the question of whether these numbers were substantial enough to impact the population's average height in Slovenia (Grasgruber et al., 2022). These workers, who permanently settled and established their families in Slovenia, potentially contributed to demographic changes, yet the extent of their influence on height averages remains a matter for further investigation. Second, the studies of serious economic crisis in former Yugoslavia in the 1980s (Brown, 1997) that reduced access to food, and the inflow of western high-caloric and processed food in the 1990s after the disintegration of former Yugoslavia could also provide more insights in the causes for the trends in body height and body mass we observed in our analysis.

Our study provides valuable information for health professionals and policymakers from different areas, who are interested in understanding the effects of biological changes on potential future risks and opportunities. Anthropologists have long been interested in understanding the complex interplay of genetics, nutrition, environmental conditions, and social, economic, and cultural factors that contribute to human conditions.

Strengths and limitations

We acknowledge several strengths and limitations that must be considered when interpreting our findings. The main strength of this paper lies in the extensive time interval examined, covering 65 years of body mass and body height measurements in Slovenian young adults. However, during the early decades, the reporting of body height and mass relied on rather small samples. It was only from 1990 onwards, that large datasets were used. Furthermore, the anthropometric variables used in the present study were not measured with the same equipment over the years. Since the analysed data did not include specific demographic information such as education level, income, and occupation, and the absence of information on nutritional and movement behaviour or physical fitness, make interpreting of the results more challenging.

CONCLUSION

Present study explored changes in body height and body mass among young adults in Slovenia over 65 years. Results showed increased body height and body mass, reflecting the impact of improved healthcare and nutrition, but also lower physical activity on growth and development. While the exact reasons for this phenomenon remain unclear, it has occurred due to complex

and multifactorial interactions. The study contributes to the future research that could focus on how region-specific factors may have influenced the trends in body mass and body height, resulting in the population of Slovenia being among the 10 tallest nations in the World (Rodriguez-Martinez et al., 2020). In its essence, data on secular trends in body height are a valuable tool for evidence-based policymaking and can guide interventions aimed at improving nutrition, health, and overall well-being of the Slovenian population. Policymakers can use the data to inform and shape nutritional policies, because understanding how average body height and body mass change over time can provide insights into the effectiveness of nutritional programs and policies aimed at improving the overall health and well-being. Secular trends may also reflect broader health trends within a population, which can inform the designing of public health interventions based on this data, targeting specific age groups or demographics that may be experiencing challenges related to nutrition, health, or socio-economic factors. Changes in body height and body mass may be associated with socioeconomic factors, and this data can be used to monitor and address socioeconomic disparities that may contribute to variations in body height and body mass outcomes, helping to design more equitable policies. Our findings could also be valuable for long-term health planning. This includes anticipating health needs, allocating resources, and developing strategies to address potential health challenges that may emerge in the future. Lastly, comparative analysis of secular trends in body height and body mass across different populations can provide valuable insights into global health patterns. This information can be used to learn from the experiences of other countries and adapt strategies that have been successful in improving future health risks and opportunities.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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APPENDICIES

Supplemental Table S1. Average height of included males for first and last centile (C1, C99), decile (D1, D9), quartile (Q1, Q3) and Median (Me).

Year	C1	D1	Q1	Me	Q3	D9	C99
1954	161.2	167.1	170.7	174.7	178.9	182.8	189.7
1955	161.3	167.2	170.8	174.9	179.0	182.9	189.8
1960	161.8	167.8	171.4	175.4	179.6	183.5	190.4
1965	162.2	168.3	171.9	176.0	180.2	184.1	191.0
1970	162.7	168.9	172.5	176.6	180.8	184.6	191.6
1975	163.2	169.4	173.1	177.2	181.4	185.2	192.2
1980	163.6	169.9	173.6	177.7	181.9	185.8	192.8
1985	163.9	170.4	174.1	178.2	182.4	186.3	193.4
1990	164.2	170.8	174.6	178.7	183.0	186.9	194.0
1995	164.5	171.2	175.0	179.2	183.5	187.4	194.6
2000	164.4	171.3	175.2	179.5	183.8	187.7	195.0
2005	164.1	171.4	175.3	179.6	183.9	187.9	195.3
2010	163.9	171.4	175.5	179.8	184.1	188.2	195.7
2015	163.6	171.5	175.7	180.1	184.5	188.5	196.3
2019	163.4	171.7	175.9	180.4	184.8	188.9	196.9

Supplemental Table S2. Average height of included females for first and last centile (C1, C99), decile (D1, D9), quartile (Q1, Q3) and Median (Me).

Year	C1	D1	Q1	Me	Q3	D9	C99
1954	149.3	155.3	158.7	162.5	166.5	170.1	176.9
1955	149.4	155.3	158.8	162.6	166.6	170.2	177.0
1960	149.7	155.7	159.2	163.1	167.0	170.7	177.4
1965	150.0	156.1	159.5	163.4	167.4	171.0	177.6
1970	150.2	156.4	159.9	163.8	167.7	171.3	177.8
1975	150.7	156.9	160.4	164.3	168.2	171.7	178.1
1980	151.3	157.5	161.0	164.9	168.8	172.3	178.6
1985	151.9	158.1	161.6	165.4	169.3	172.8	179.1
1990	152.4	158.6	162.1	165.9	169.8	173.3	179.6
1995	152.8	159.0	162.4	166.3	170.1	173.7	180.1
2000	152.8	158.9	162.4	166.3	170.2	173.9	180.5
2005	152.6	158.8	162.3	166.3	170.3	174.0	180.9
2010	152.5	158.9	162.5	166.5	170.5	174.3	181.4
2015	152.4	159.1	162.8	166.8	170.8	174.6	181.9
2019	152.0	159.1	162.9	166.9	171.0	174.8	181.9

Supplemental Table S3. Average body mass of included males for first and last centile (C1, C99), decile (D1, D9), quartile (Q1, Q3) and Median (Me).

Year	C1	D1	Q1	Me	Q3	D9	C99
1954	53.0	58.9	62.5	66.8	71.6	76.7	88.2
1955	53.0	59.0	62.6	67.0	71.8	76.9	88.5
1960	53.6	59.7	63.4	67.9	73.0	78.3	90.2
1965	54.4	60.7	64.6	69.3	74.6	80.2	92.6
1970	54.5	60.8	64.8	69.7	75.3	81.0	93.5
1975	53.8	60.2	64.3	69.3	75.0	80.8	93.3
1980	53.3	59.8	64.0	69.1	74.9	80.9	93.4
1985	53.8	60.5	64.8	70.2	76.3	82.5	95.5
1990	53.5	60.4	64.9	70.5	76.8	83.3	96.8
1995	53.8	61.0	65.7	71.6	78.2	85.1	99.3
2000	53.3	60.8	65.8	71.9	78.9	86.1	101.0
2005	52.7	60.8	66.1	72.6	80.0	87.4	102.8
2010	53.0	61.8	67.6	74.6	82.3	90.2	106.1
2015	51.9	61.2	67.1	74.2	82.2	90.2	107.0
2019	51.4	61.1	67.1	74.4	82.6	91.2	110.3

Supplemental Table S4. Average body mass of included females for first and last centile (C1, C99), decile (D1, D9), quartile (Q1, Q3) and Median (Me).

Year	C1	D1	Q1	Me	Q3	D9	C99
1954	45.6	51.0	54.5	58.8	63.7	68.6	78.9
1955	45.6	51.0	54.4	58.7	63.6	68.5	78.9
1960	45.4	50.7	54.2	58.5	63.3	68.3	78.8
1965	45.4	50.7	54.2	58.4	63.3	68.4	79.2
1970	46.3	51.8	55.3	59.7	64.7	69.9	81.2
1975	46.4	51.9	55.4	59.8	64.9	70.2	81.9
1980	45.8	51.2	54.7	59.0	64.0	69.4	81.4
1985	45.5	50.8	54.3	58.7	63.7	69.1	81.5
1990	44.8	50.1	53.6	58.0	63.1	68.6	81.5
1995	44.4	49.9	53.4	57.9	63.2	69.0	83.0
2000	44.0	49.6	53.3	57.9	63.4	69.6	85.0
2005	44.0	49.8	53.6	58.4	64.2	70.8	88.0
2010	44.2	50.4	54.5	59.7	66.0	73.3	93.2
2015	43.9	50.4	54.6	60.1	66.7	74.6	96.8
2019	43.9	50.6	54.9	60.5	67.3	75.4	98.8