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INTEGRATED STUDY MASTER'S FINAL THESIS

Literature review:
"Global Dynamics of Body Size and Proportions of the Adult Population in Recent Decades and Relationship of Body Markers to Health Risks"

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ABSTRACT (SANTRAUKA)

Background.
The prevalence of overweight and obesity has increased globally over the recent decades, yet most studies rely exclusively on body mass index, which does not capture changes in body fat distribution or overall body composition.
Objective.
The aim of this literature review was to analyse and summarise global secular changes in adult body size and shape, body proportions, and body composition, their association with health outcomes, and contributing factors to observed changes. In addition, methodological limitations of the existing evidence base were assessed.
Methods.
A combined methodological approach was used. A systematic literature search was conducted in PubMed and Google Scholar according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines, supplemented by backward citation tracking, to identify evidence on body size, body shape, and body composition. Studies reporting population-level anthropometric trends or associations between anthropometric indicators and health outcomes in adults were qualified for inclusion. At this stage, a total of 32 studies were included for qualitative synthesis. Eight supervisor-recommended references on secular trends in adult height and body proportions were integrated as contextual evidence, documented separately in Annex 2.
Results.
Adult body mass index and obesity prevalence have increased consistently across almost all populations over four decades, with the most rapid recent increases in low- and middle-income countries. A key finding is that waist circumference has increased disproportionately relative to body mass index across at least six countries on three continents, indicating a shift towards greater central adiposity. Central adiposity measures, particularly waist circumference and waist-to-height ratio, consistently outperformed body mass index in predicting cardiometabolic risk. The body mass index- mortality relationship was non-linear, with overweight associated with lower all-cause mortality and severe obesity showing significantly elevated risk. Secular trends in adult height, documented across more than 200 countries, however, it has been much less pronounced over the past few decades than concurrent increases in body mass index and waist circumference, and have occurred predominantly through gains in leg length. This indicates that the anthropometric transformation of recent decades is primarily a shift in body mass and body shape rather than body height acceleration in the traditional sense. Relative leg length emerged as an independent marker

of early-life conditions and cardiometabolic risk. Contributing factors include the nutrition transition, urbanisation, declining physical activity, and population-specific biological variation. The analysed studies show significant geographical variations, however, mostly only body mass index is considered.

Conclusion.

The global obesity epidemic is changing, with central adiposity increasing beyond what body mass index trends suggest. Incorporating waist circumference and complementary anthropometric indicators into surveillance and clinical practice is essential to more accurately capture the course of population-level metabolic risk. Future research should prioritise large-scale longitudinal studies using multiple anthropometric indicators, invest in surveillance in underrepresented regions, and standardise waist circumference measurement protocols to enable reliable global comparisons.

Santrauka

Įvadas.

Pastaraisiais dešimtmečiais visame pasaulyje išaugo antsvorio ir nutukimo paplitimas. Tačiau dauguma studijų remiasi vien kūno masės indeksu (KMI), kuris neužfiksuoja kūno riebalų pasiskirstymo ar bendros kūno sudėties pokyčių.

Tikslas.

Šios literatūros apžvalgos tikslas - išanalizuoti ir apibendrinti studijas, nagrinėjančias suaugusių asmenų kūno dydžio ir formos, kūno proporcijų bei kūno sudėties pokyčius pasauliniu mastu, ryšį su sveikatos būkle ir potencialius tokių pokyčių veiksnius. Taip pat įvertinti esamos publikacijų bazės metodologiniai apribojimai.

Metodai.

Buvo taikomi keli literatūros apžvalgos metodai. Sisteminė literatūros paieška taikyta analizuojant atlikta PubMed ir Google Scholar duomenų bazėse publikacijas pagal PRISMA (angl. *Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) 2020 m. gaires ir papildyta atgaline citavimo analize, siekiant nustatyti įrodymus apie kūno dydį, formą ir kūno sudėtį. Į analizę įtraukti tyrimai, kuriuose nagrinėjamos populiacijos lygmens kūno matmenų tendencijos arba sąsajos tarp antropometrinių rodiklių ir suaugusiųjų sveikatos būklės. Šios dalies kokybinei sintezei iš viso įtraukti 32 tyrimai. Aštuonios vadovės rekomenduotos studijos apie suaugusiųjų ūgio ir kūno proporcijų epochines tendencijas buvo integruotos kaip kontekstinė informacija ir atskirai dokumentuotos 2 priede.

Rezultatai.

Suaugusiųjų KMI ir nutukimo paplitimas per keturis dešimtmečius nuolat išaugo beveik visose populiacijose, o sparčiausiai šie rodikliai pastaruoju metu didėjo mažas ir vidutines pajamas gaunančiose šalyse. Ypač svarbu tai, kad juosmens apimtis padidėjo neproporcingai KMI atžvilgiu mažiausiai šešiose trijų skirtingų žemynų šalyse, o tai rodo globaliai didėjantį centrinio nutukimo paplitimą. Be to, centrinio nutukimo rodikliai, ypač juosmens apimtis ir juosmens bei ūgio santykis, buvo pranašesni už KMI, prognozuojant kardiometabolinę riziką. Ryšys tarp KMI ir mirtingumo rodiklių buvo netiesinis: antsvoris buvo susijęs su mažesniu bendru mirtingumu, o didelis nutukimas - su ženkliai padidėjusia mirtingumo rizika. Epochinė suaugusiųjų ūgio didėjimo tendencija, dokumentuota daugiau nei 200 šalių, tačiau pastaruoju metu ši tendencija buvo gerokai mažiau ryški nei tuo lygiagrečiai didėjantis KMI ir ypač - juosmens apimtis. Ūgio padidėjimą daugiausia lėmė kojų ilgio pokytis. Tai rodo, kad pastarųjų dešimtmečių kūno pokyčiai pirmiausia yra susiję su kūno stambumo ir formos transformacija, o ne ūgio akceleracija. Svarbu tai, kad santykinis kojų ilgis, kaip nepriklausomas žymuo, siejosi su ankstyvojo gyvenimo sąlygomis ir kardiometabolinės rizika. Potencialų apžvelgtų kūno pokyčių veiksniai apima mitybos pokyčius, urbanizaciją, mažėjantį fizinį aktyvumą ir populiacijoms būdingus biologinius skirtumus. Apžvelgtos studijos atskleidžia didelius geografinius skirtumus, bet daugiausia dėmesio skiriama tik KMI nagrinėti.

Išvada.

Pasaulinė nutukimo epidemija keičiasi. Centrinis nutukimas didėja sparčiau, nei rodo KMI tendencijos. Juosmens apimties ir papildomų antropometrinių rodiklių įtraukimas į stebėjimos sistemas ir klinikinę praktiką yra būtinas, siekiant tiksliau užfiksuoti metabolinės rizikos raidą populiacijos lygmeniu. Būsimuose tyrimuose reikėtų teikti pirmenybę didelės apimties išilginiams tyrimams, įtraukiant platesnes antropometrinių rodiklių tyrimų programas, daugiau skirti dėmesio mažiau ištirtų regionų stebėjimui ir standartizuoti juosmens apimties matavimo protokolus, kad būtų galima atlikti patikimus pasaulinių duomenų palyginimus.

KEYWORDS

Obesity
Body Mass Index
Waist Circumference
Central Adiposity
Body Proportions
Secular Trends

ABBREVIATIONS

AOR – Adjusted Odds Ratio

AUC – Area Under the Curve

BF% – Body Fat Percentage

BIA – Bioelectrical Impedance Analysis

BMI – Body Mass Index

CI – Confidence Interval

COVID-19 – Coronavirus Disease 2019

CVD – Cardiovascular Disease

DALYs – Disability-Adjusted Life Years

DXA – Dual-Energy X-ray Absorptiometry

EPIC – European Prospective Investigation into Cancer and Nutrition

HDL – High-Density Lipoprotein

HR – Hazard Ratio

IGF-1 – Insulin-like Growth Factor 1

IL-6 – Interleukin-6

MRI – Magnetic Resonance Imaging

NCD – Non-Communicable Disease

NHANES – National Health and Nutrition Examination Survey

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Q1 – Quintile 1

Q5 – Quintile 5

T2DM – Type 2 Diabetes Mellitus

TNF-α – Tumour Necrosis Factor-Alpha

VAT – Visceral Adipose Tissue

WC – Waist Circumference

WHO – World Health Organization

WHR – Waist-to-Hip Ratio

WHtR – Waist-to-Height Ratio

1. INTRODUCTION

Overweight and obesity have become a global burden over the past four decades. Their prevalence has risen markedly across nearly all countries and regions, in high-income as well as low- and middle-income settings (1,2). Countries undergoing rapid economic development and nutrition transition, characterised by shifts from traditional diets towards energy-dense processed foods and declining physical activity (3), have been particularly affected in recent decades.

Excess body weight, and particularly excess body fat, is associated with an increased risk of cardiovascular disease, type 2 diabetes, several types of cancer, and premature mortality (1,4,5). These conditions represent preventable causes of mortality globally and place a substantial burden on healthcare systems, economies, and individual quality of life, with particularly rapid growth in disease burden in low- and middle-income countries (2,6,7).

Recent evidence suggests that body fat distribution is shifting towards greater central adiposity in many populations, even beyond what overall weight gain would predict (8,9). Central adiposity, meaning the accumulation of fat in the abdominal region, is more strongly linked to metabolic disease than overall body mass, as measured by body mass index (10).

Despite this, body mass index remains the most commonly used measure in both routine clinical practice and population surveillance (10). Body mass index is calculated from weight and height alone and does not provide information about body fat distribution, body composition, or body proportions (11,12). A high body mass index does not necessarily indicate excess fat, and a normal body mass index does not rule out excess visceral fat (11). Body mass index-based monitoring alone may miss or underestimate metabolic risk, especially where central adiposity is increasing disproportionately (12).

Alternative anthropometric indicators such as waist circumference, waist-to-height ratio, and direct body composition measures can capture aspects of adiposity that body mass index misses (11,13,14). These measures are used far less frequently in large-scale surveillance, and the evidence on how they relate to long-term health outcomes across different populations has not been comprehensively synthesised (11).

No integrative review to date has brought together the evidence on global secular trends in adult body size, body proportions and body composition alongside their associations with health outcomes.

Existing reviews typically focus on a single dimension, such as body mass index trends, central adiposity, or adult height, without integrating all dimensions into a unified picture of how the human body has changed over recent decades. This gap limits the ability to assess whether current body mass index-based population surveillance systems, such as national health examination surveys (11), adequately capture the changing nature of the obesity epidemic and its health consequences.

This review aims to address this gap through a combined methodological approach to provide a more comprehensive picture of anthropometric change. A systematic search strategy was applied to identify evidence on body size, shape and composition and their relation to health risks, complemented by narrative integration of additional evidence on secular trends in adult height and body proportions.

1.1 Research Questions

a. What are the global trends in adult body mass index, body proportions, and body composition over recent decades?
b. How do body mass index, waist circumference, waist-to-hip ratio, waist-to-height ratio, body proportions, and body composition relate to health risks such as cardiovascular disease, type 2 diabetes, metabolic syndrome, cancer, morbidity, and mortality?
c. What are the major contributing factors driving changes in adult body size and body composition (environmental, behavioural, socioeconomic, and biological factors)?
d. What methodological issues affect the interpretation of trends and associations, and what gaps remain in the literature?

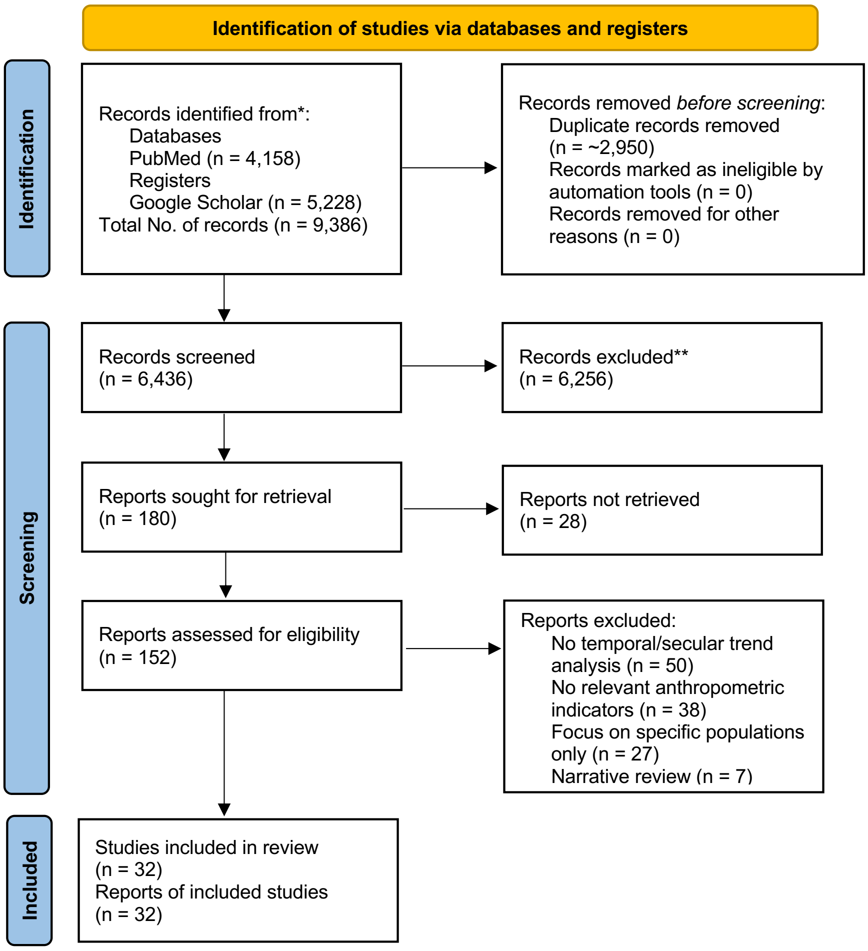
1.2 Aim and Objectives

The aim of this literature review is to provide a comprehensive synthesis of the current evidence on global trends in adult body size, body proportions, and body composition, and to evaluate their associations with major health outcomes, including cardiovascular disease, type 2 diabetes, metabolic syndrome, cancer, and mortality. Given the progressing global burden of obesity and the limitations of body mass index as a sole indicator of adiposity-related health risk, this review examines the available epidemiological literature to address the four research questions outlined in Section 1.1.

2. METHODS

This literature review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, to ensure transparency and reproducibility (15).

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only



*Multiple Google Scholar searches were conducted with different keyword combinations, resulting in considerable overlap between searches. The combined total (n = 5,228) represents the sum of all individual search results before deduplication. Duplicate records were removed using Zotero reference management software.

** Records excluded at screening were assessed based on title and abstract review against predefined inclusion and exclusion criteria. Backward citation tracking of included studies and relevant reviews identified 2 additional studies: Albrecht et al. (2015) and WHO Expert Consultation (2004).

Figure 1 PRISMA 2020 Flow Diagram (15)

2.1 Literature Search Strategy

A systematic search was performed in two electronic databases, PubMed and Google Scholar. PubMed was selected due to its broad coverage of biomedical and epidemiological peer-reviewed literature, while Google Scholar was used as a complementary source to identify additional population-based and interdisciplinary studies that may not be fully indexed in medical databases. A comprehensive Boolean search strategy was applied in PubMed, combining terms related to anthropometric measurements (e.g. body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), body composition, body proportions, height, sitting height, stature, leg length, secular trends in height), temporal developments (e.g. long-term trends, longitudinal changes), adult populations, and health-related outcomes (e.g. cardiovascular diseases (CVD), type 2 diabetes (T2DM), metabolic syndrome, cancer, morbidity, and mortality). This search yielded 4,158 records (Table 1).

Due to the limited Boolean functionality of Google Scholar, simplified keyword combinations were used. These searches focused on core concepts such as adult height, body proportions, BMI, WC, long-term trends, and population-based health outcomes. Depending on the search term, between 18 and 2,100 records were identified. As there was considerable overlap between the individual Google Scholar searches, the results were not added together but were used to identify further relevant studies.

All identified records were exported to Zotero reference management software, and duplicates were removed before screening. No start date was applied to capture all relevant studies on long-term global trends in adult body size. The search included studies published up to February 2026.

This literature review applied a combined methodological approach. A systematic search strategy was used to identify evidence on body size, body shape, and body composition (BMI, waist circumference, and related adiposity indicators), while narrative integration was applied for evidence on secular trends in adult height and body proportions, which were not covered by the primary Boolean search. This dual approach was chosen because a strict systematic methodology limited to adiposity indicators would have excluded essential evidence on height and proportion trends, while a fully narrative review would have lacked the rigour needed for the extensive BMI and waist circumference literature.

Database	Keywords	Results (n)
PubMed	“BMI” OR “body mass index” OR “waist circumference” OR “waist-to-hip ratio” OR “waist-to-height ratio” OR “body composition” OR “body proportions” OR “anthropometry” OR “height” AND trend OR change OR temporal OR secular OR longitudinal OR “time trend” AND adult OR adults OR “middle aged” AND mortality OR “cardiovascular diseases” OR CVD OR “type 2 Diabetes” OR T2DM OR “metabolic syndrome” OR morbidity OR “health risk” AND “global” OR “worldwide"	4,158
Google Scholar	BMI OR “waist circumference” AND adults AND “secular trend”	2,100
	BMI OR “waist circumference” AND adults AND “secular trend” mortality	1,390

	"body mass index" OR "waist circumference" AND adults AND "secular trend"	1,720
	"adult height" OR stature OR "body height" OR height AND "secular trends" OR "time trend" OR "long term trend" AND "body proportions" OR "sitting height" OR "leg length" AND adults AND population	18

Table 1 Search Strategy and Results

In addition to the electronic database searches, backward citation tracking (snowballing) was performed by screening the reference lists of all included studies and relevant reviews to identify further eligible studies not captured by the database searches. This process identified two additional studies that met the inclusion criteria (8,16).

Systematic reviews and meta-analyses were included both as direct sources of synthesised evidence and to contextualise findings from primary studies. Because such reviews may contain primary studies also included separately in the present review, a formal assessment of duplicate primary references embedded within these reviews was not undertaken. Findings are therefore interpreted qualitatively without assumptions of statistical independence between sources. For this reason the overall synthesis is designated as a literature review rather than a strict systematic review, in accordance with methodological guidance.

For evidence on secular trends in adult height, relative leg length, and body proportions, eight supervisor-recommended references (17–24) were integrated narratively as contextual evidence. These references were not identified through the primary Boolean search, which focused on BMI- and waist-circumference-related adiposity indicators, and were not included in the formal PRISMA flow diagram or the 32-study synthesis. They are cited in Sections 3.1.1, 3.1.4, 4.2.4, 4.3.3, 4.4.2 and 5.5, and documented separately in Annex 2.

2.2 Eligibility Criteria

2.2.1 Inclusion Criteria

- Studies including/focusing predominantly on adult populations.
- Assessment of at least one anthropometric measure (e.g. BMI, WC, WHR, WHtR, body composition, body proportions, height, sitting height).
- Examination of temporal or secular trends and/or association with health outcomes, or population-level determinants of variation in body size, proportions, or composition.
- Peer-reviewed publications including:
    - Original research articles.
    - Systematic reviews with quantitative meta-analysis.

    - Consensus statements and expert consultations.
    - Modelling studies and global burden of disease analyses.
- Publications in English.

Meta-analyses and systematic reviews with quantitative meta-analysis were included as they provide synthesised quantitative evidence from multiple primary studies, which is valuable for addressing research questions about global trends and health associations. Their methodological role is described in Section 2.1. The WHO consultation report (11) was used as a definitional source for anthropometric thresholds without being counted among the 32 included studies. Four narrative and critical reviews (3,4,12,25) were consulted as background literature to provide context for definitions of anthropometric indicators, the historical development of BMI, the nutrition transition, and the epidemiological background of obesity-related metabolic disease. These were not counted among the formally included studies but were cited where they informed the interpretation of findings.

2.2.2 Exclusion Criteria

- Studies focusing exclusively on children, adolescents, specific disease groups, or pregnant women, as well as animal studies.
- Clinical intervention studies.
- Narrative reviews without original data synthesis, case reports, editorials, or commentaries.
- Studies for which the full text was not accessible via Vilnius University VPN.
- Studies lacking trend analyses, relevant health outcomes, or analysis of population-level determinants of anthropometric variation.

2.3 Study Selection

The identified datasets were evaluated during the screening phase. First, titles and abstracts were reviewed for relevance based on predefined inclusion and exclusion criteria. Studies were excluded at this stage if they did not focus on adult populations, did not include anthropometric measurements, or did not address temporal trends or health-related outcomes, or population-level determinants of anthropometric variation. Studies considered potentially suitable were retrieved in full text and evaluated against all inclusion and exclusion criteria for final inclusion. A total of 28 articles had to be excluded at this stage because the full texts were not accessible. Access was attempted through multiple channels, including, open access journals, institutional subscriptions, the Vilnius University VPN system, interlibrary loan requests, and direct author contact. Despite these efforts, no full texts could be obtained through any available channel. The entire study selection process was documented using a PRISMA flow diagram (Figure 1).

2.4 Data Extraction

In this analysis and interpretation stage, all included studies were systematically evaluated using a standardised data extraction table. Extracted information included: author and publication year, study design, study population, geographical region, observational period, anthropometric parameters, health outcomes reported, key findings, and the corresponding research questions addressed by each study.

Due to heterogeneities among studies in terms of measurement methods, study design and outcome definition, a quantitative meta-analysis was not feasible. Therefore, findings were synthesised qualitatively. Studies were grouped thematically according: global anthropometric trends, regional patterns, associations with health risks, contributing factors and methodological considerations. The complete data extraction and synthesis table is provided in Annex 1.

2.5 Quality Assessment

Methodological quality and limitations of the included studies were evaluated through narrative assessment. Attention was paid to study design appropriateness, sample size and representativeness, measurement methods, confounding factors, and transparency in reporting. Limitations noted by study authors were extracted and synthesised to identify common methodological challenges in the literature.

Due to the descriptive and observational nature of most included studies, standardised risk-of-bias tools designed for intervention studies were not considered appropriate. Instead, qualitative considerations focused on the rigor of sampling methods, measurement protocols, statistical approaches and the recognition of study limitations.

Section 3 defines the anthropometric indicators used across the included studies and outlines the biological mechanisms that link adiposity to chronic disease, which are essential for interpreting the health associations reported in the Results.

3. THEORETICAL BACKGROUND

3.1 Anthropometric Indicators

Multiple anthropometric measures are used to assess body size, composition, proportions, and fat distribution, varying in predictive value and practicality for surveillance.

3.1.1 Indicators of Overall Body Size

Body Mass Index

BMI is calculated as body weight in kilograms divided by the square of height in metres (kg/m^2) (11). It is the most widely used anthropometric measure due to its simplicity, low cost, and a population-level representation for body fat (25). The World Health Organization (WHO) defines overweight and obesity based on BMI thresholds. For adults, overweight is defined as BMI ≥25 kg/m², and obesity as BMI ≥30 kg/m², with further classification into Class I obesity (BMI 30.0–34.9 kg/m²), Class II obesity (BMI 35.0–39.9 kg/m²), and Class III obesity (BMI ≥40 kg/m²) (11). These thresholds have since been reviewed and contextualised in the wider literature (12).

BMI itself does not differentiate between fat and lean body mass, provides no indication of fat distribution, and varies in its relationship to body composition across age, sex, and ethnic groups (12).

Height

Adult height is measured vertically from the floor to the highest point of the head in a standing position (26). This measure reflects influences from prenatal development through adolescence. Variation in adult stature across populations is shaped by population history and ecological conditions, with climate contributing additional effects (17,26). Secular trends in adult height across global populations are detailed in Section 4.2.4 of the Results, and associations with health outcomes are discussed in Section 4.3.3.

3.1.2 Body Shape

Waist Circumference

WC is typically measured horizontally at the midpoint between the iliac crest and the lowest rib (10). Commonly used WC thresholds are ≥102 cm for men and ≥88 cm for women in populations of European descent, though lower thresholds have been proposed for other ethnic groups (10). WC serves as a marker of abdominal and visceral fat distribution and is independently associated with metabolic risk beyond BMI (9,10,27).

Waist-to-Hip-Ratio

WHR is calculated as WC divided by hip circumference (10). A WHR of >0.90 for men and >0.85 for women is generally considered to indicate central obesity (10). It reflects the distribution of body fat between central (abdominal) and peripheral (hip and thigh) regions and is associated with cardiovascular risk (10).

Waist-to-Height-Ratio

WHtR is calculated as WC divided by height (14). A WHtR of ≥0.5 has been proposed as a screening threshold for increased cardiometabolic risk (13).

3.1.3 Body Composition and Body Fat Topography

Body composition refers to the distribution of the body's mass between two principal components: passive (fat) mass and active (lean) mass (11,25). Passive mass comprises subcutaneous adipose tissue, which can be assessed through skinfold measurements at specific anatomical sites such as the triceps, subscapular, suprailiac, and abdominal regions and visceral adipose tissue (VAT), quantifiable through imaging techniques such as dual-energy X-ray absorptiometry (DXA), magnetic resonance imaging (MRI), or bioelectrical impedance analysis (BIA) (10,11). Active mass comprises bones, skeletal muscles, and internal organs (11,25). Body fat topography refers to the spatial distribution of adipose tissue across the body, which varies systematically by sex, age, ethnicity, and individual characteristics (10,28,29).

However, population-level studies specifically examining secular trends in skinfold thickness or body fat topography were limited in the available literature, representing a notable gap in the current evidence base.

3.1.4 Body Proportions

Body proportions refer to the relative lengths of body segments (e.g., limb length relative to trunk length). These proportions reflect both genetic and population-based factors as well as environmental influences (26), and they vary systematically between populations (30). Secular changes are detailed in Section 4.2.4, and associations with health outcomes are discussed in Section 4.3.3.

Sitting Height

Sitting height is measured vertically from the sitting surface to the highest point of the head with the individual sitting upright. It primarily represents trunk length, including the head, neck, and torso. Compared with total standing height, sitting height provides information about body proportions, specifically the relative contribution of trunk versus leg length to total stature (26).

Leg Length

Leg length can be measured directly or estimated as standing height minus sitting height (26,30). It varies across populations in relation to population history and environmental conditions during development. Leg length is considered a more sensitive marker of early developmental and environmental conditions than trunk length, as limb growth is particularly responsive to nutritional and health-related exposures during childhood (17,21,26).

3.1.5 Selection of Anthropometric Indicators for Population Surveillance

The choice of anthropometric indicators involves a compromise between accuracy, cost, feasibility, and the outcomes of interest (10). BMI remains the most widely used measure due to its simplicity and the availability of extensive historical data (12). There is growing support for incorporating WC alongside BMI to capture additional information about abdominal fat distribution (9,10). Body proportion assessment is less common in population surveillance but can provide additional information. Variation in body proportions across populations reflects both population history and environmental influences (26), and different body segments show distinct associations with cause-specific mortality (30).

Direct body composition methods (e.g., BIA, DXA, MRI) provide the most detailed information but are less feasible for large-scale surveillance due to their cost and limited availability (10,25).

3.2 Biological Basis of Adiposity-related Health Risks

3.2.1 General vs. Central Adiposity

The location of fat storage is more relevant for metabolic risk than the amount of fat (10,28,29). Subcutaneous adipose tissue is located beneath the skin in the hips, thighs, and gluteal region, and is not strongly associated with adverse metabolic outcomes at moderate levels (10,28). VAT, on the other hand, is metabolically active and located within the abdominal cavity surrounding the internal organs. It contributes disproportionately to systemic metabolic dysfunction compared with peripheral fat deposits (10,28,29). WC therefore complements BMI for evaluating cardiometabolic risk, as discussed in Section 4.3.2 (10).

3.2.2 Visceral Fat and Metabolic Dysfunction

VAT drives metabolic dysfunction through several interconnected pathways. It releases inflammatory cytokines such as tumour necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6), which promote chronic low-grade inflammation and development of insulin resistance (28,29). Over time, insulin resistance may progress to T2DM through pancreatic beta-cell dysfunction (31). Visceral fat also causes an unfavourable lipid profile characterised by elevated triglycerides and reduced high-density lipoprotein (HDL) cholesterol, which accelerates atherosclerosis and increases cardiovascular risk (10,28). Visceral fat accumulation is associated with hypertension (32). The combination of these factors, insulin resistance, dyslipidaemia, hypertension, and central obesity, constitutes the metabolic syndrome (28,33).

3.2.3 Pathways to Disease

The metabolic dysfunction driven by excess adiposity, and particularly visceral fat accumulation, translates into increased risk of several major chronic diseases through distinct but overlapping pathophysiological pathways. Specific quantitative evidence on these pathways is presented in Sections 4.3.1 and 4.3.2.

Cardiovascular disease.

Obesity is one of the strongest modifiable risk factors for cardiovascular morbidity and mortality. Excess adiposity contributes to atherosclerosis, heart failure, coronary heart disease, stroke, and cardiac arrhythmias (5,34,35).

Type 2 diabetes mellitus.

The relationship between adiposity and T2DM is well established and mediated through the insulin resistance pathway described above (27,31). Both general and central adiposity contribute to diabetes risk (10,27).

Cancer.

Adiposity, particularly central obesity, is linked to increased cancer risk through chronic inflammation and hyperinsulinemia associated with excess visceral fat (28).

Mortality patterns.

While higher BMI is associated with higher mortality (5), the relationship is not linear across all BMI categories, a pattern sometimes referred to as the "obesity paradox" (36). This may partly reflect the limitations of BMI as a measure of adiposity (10,12).

3.2.4 Life-Course and Population Differences

The relationship between body size, body proportions, and health outcomes is further modified by life-course factors and ethnic variation (16,26,30).

Body proportions and developmental origins.

Human body proportions are not uniform across populations but reflect a unique mix of biological, environmental, and ecological conditions (26). A comparative analysis demonstrated that population history explains a large portion of the variation in adult stature, sitting height, and lower limb length, with environmental and climatic variables contributing additional significant effects even after adjustment for population history (26). These findings indicate that the anthropometric measures used to assess health risks are themselves shaped by long-term evolutionary and developmental processes, which must be considered when interpreting population-level data (30).

Height and health outcomes.

Adult attained height reflects cumulative developmental influences from prenatal life through adolescence (26,30). Different body segments (trunk length, leg length) may relate to distinct biological pathways influencing disease risk, including differential associations with cancer and circulatory disease mortality (30).

Population-specific risk thresholds.

The health risks associated with a given level of adiposity are not equivalent across all population groups (10,16). Body composition patterns differ between ethnic groups, and standard BMI thresholds may not equally capture metabolic risk in all populations (16).

4. RESULTS

The search and selection process, documented in the PRISMA flow diagram (Figure 1, Section 2), yielded 32 studies that met all inclusion criteria. To address the research questions formulated in Section 1.1, the following sections describe these studies, present global anthropometric trends and their associations with health outcomes, summarise contributing factors, and identify methodological limitations and gaps in the literature.

4.1 Study Characteristics

The 32 included studies were published between 2000 and 2025 and varied significantly in design, geographic scope, and anthropometric focus. Annex 1 provides a detailed summary of all included studies.

Study design.

The included studies comprised nine meta-analyses or pooled analyses (2,5,13,27,36–40), two systematic reviews with meta-analysis (9,41), two global burden of disease analyses (7,35), six prospective or longitudinal cohort studies (30,34,42–45), one retrospective cohort (46), eight cross-sectional studies (8,14,47–52), one modelling study (6), one consensus statement (10), one comparative analysis (26), and one WHO expert consultation (16). Four narrative or critical reviews (3,4,12,25) were used as background literature to contextualise the findings but were not counted among the 32 included studies. Albrecht et al. (8) and WHO Expert Consultation (16) were identified through backward citation tracking.

Geographical coverage.

Fourteen studies had a global or multi-continental scope, encompassing data from over 200 countries in the largest analysis (2). One multi-country study covered the United States, England, China, and Mexico (8). The remaining regional studies covered North America (four studies; USA (34,49,51,52)), East and Southeast Asia (seven studies; Taiwan (47), China (42,50), Indonesia (48), South Korea (46), Japan (45), Asia (7)), Europe (two studies; Norway (44), 10 European countries (30)), sub-Saharan Africa (one study; Nigeria (41); additional African data were captured within the global analyses), South America (two studies; Chile (6), Brazil (14)), and multi-region (one study; Brazil and Thailand (43)). Sub-Saharan Africa and Latin America were underrepresented. The geographical distribution of the included studies is summarised in Table 2.

Region	Studies (n)
Global	14
East and Southeast Asia	7
North America	4
Europe	2
South America	2
Sub-Saharan Africa	1
Multi-region	1
Single multi-region (US, England, China, Mexico)	1

Table 2 Geographical Distribution of Included Studies

Anthropometric indicators.

Body size in this review was examined primarily in terms of overall body mass (thickness) and body shape. Direct measurements of adipose tissue topography (e.g. skinfolds at standardised anatomical sites) and complete body composition profiles were underrepresented in the formally included literature. Fat distribution is therefore assessed indirectly through waist circumference and related indices, which correlate strongly with subcutaneous and visceral fat in the trunk region but do not measure them directly. Secular trends in adult height are complemented by additional published evidence (see Section 4.2.4) (17–20).

BMI was assessed in 28 of the 32 studies and was the most used anthropometric measure.

WC was reported in 18 studies, though the majority used it in the context of risk assessment rather than trend analysis. Only eight studies reported temporal WC trends (8,9,41,44,47,49,50,52). While BMI was nearly universally reported, central adiposity measures were primarily used in the context of risk assessment rather than routine trend surveillance.

WHR was assessed in four studies (10,27,39,48), and WHtR in five (10,13,14,27,48). Height and sitting height were examined in three studies (26,30,46), and direct body composition measures, such as body fat percentage (BF%), DXA, or visceral fat mass, were reported in four studies (16,27,44,51). The distribution of anthropometric indicators across the 32 included studies is shown in Table 3.

Anthropometric Indicators	Studies (n)	% of included studies
BMI	28	87.5%
WC	18	56.3%
WHtR	5	15.6%
WHR	4	12.5%
Height/Sitting height	3	9.4%
BF%, DXA, VAT	4	12.5%

Table 3 Distribution of Anthropometric Indicators Across Included Studies (n=32)

Sample size.

The included studies varied widely in sample size, ranging from 839 participants in a comparative anthropometric analysis (26) to pooled analyses encompassing over 19 million adults (2). The large-scale meta-analyses and global trend analyses collectively covered tens of millions of participants, providing population-level evidence.

Observational periods.

The temporal coverage of the included studies spanned from the 1970s to the 2020s, with most trend analyses covering at least two decades. The longest observation period covered 1975 to 2014 (2), providing approximately 40 years of trend data.

4.2 Global and Regional Trends

What are the global trends in adult BMI, body proportions, and body composition over recent decades?

4.2.1 Universal BMI Increase

Multiple large-scale analyses documented consistent increases in adult BMI across the globe over the past four decades. The largest analysis, covering 19.2 million adults across 200 countries, found that age-standardised mean BMI increased by approximately 1.50 to 1.69 kg/m² globally between 1975 and 2014. This increase represented a rightward shift in the entire BMI distribution, affecting individuals across the BMI spectrum, not only those at the upper end of the distribution (2).

The global increase in mean BMI between 1975 and 2016 is illustrated in Figures 2 and 3 for men and women, respectively. Mean BMI increased substantially across nearly all world regions in both sexes, with particularly pronounced rises in North America, Western Asia and North Africa, Southern Europe, and parts of Latin America and Oceania.

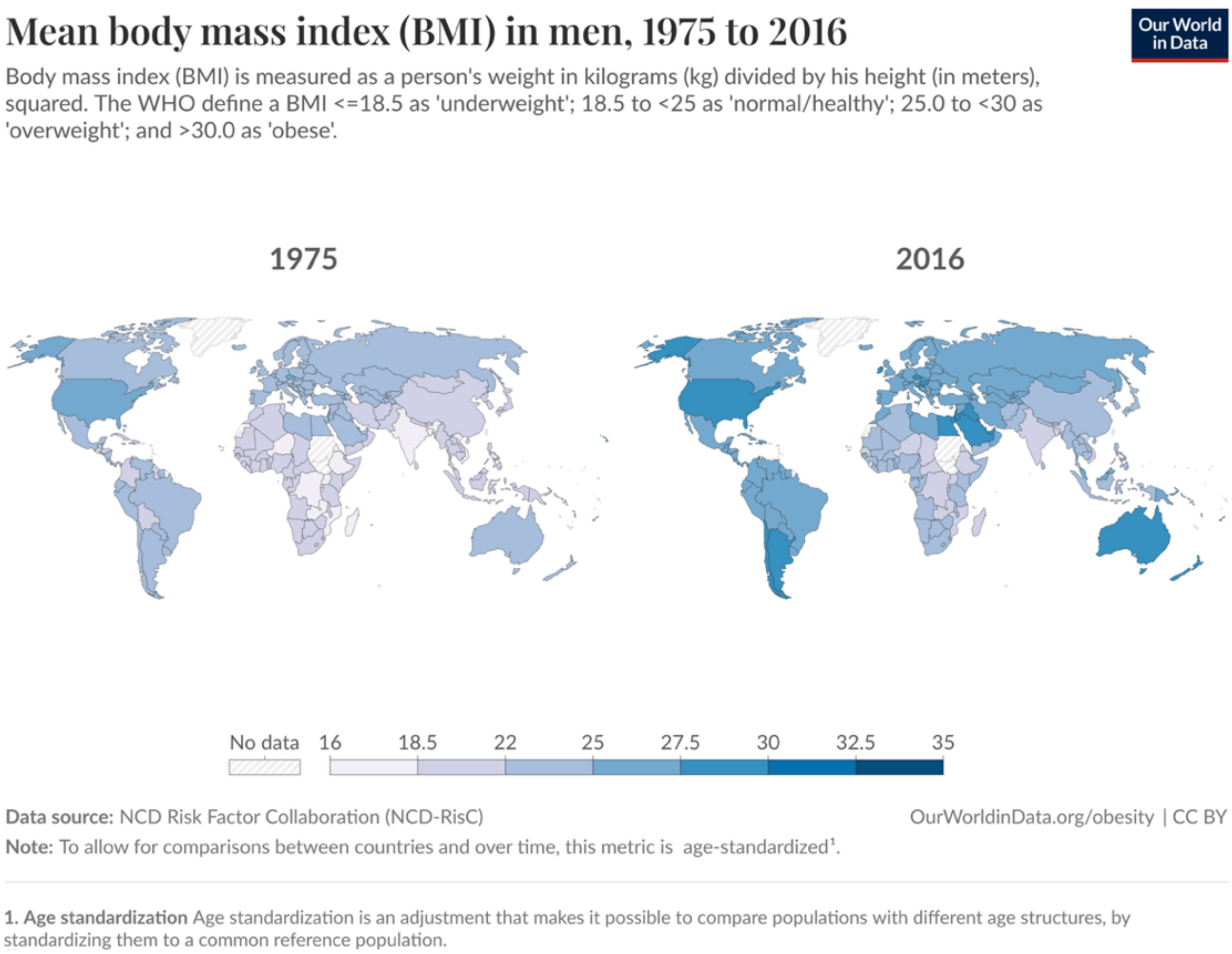


Figure 2 Mean body mass index (BMI) in adult men, 1975 and 2016. Age-standardised values. Data source: NCD Risk Factor Collaboration (NCD-RisC). Reproduced from Our World in Data (53) under Creative Commons Attribution License CC BY 4.0.

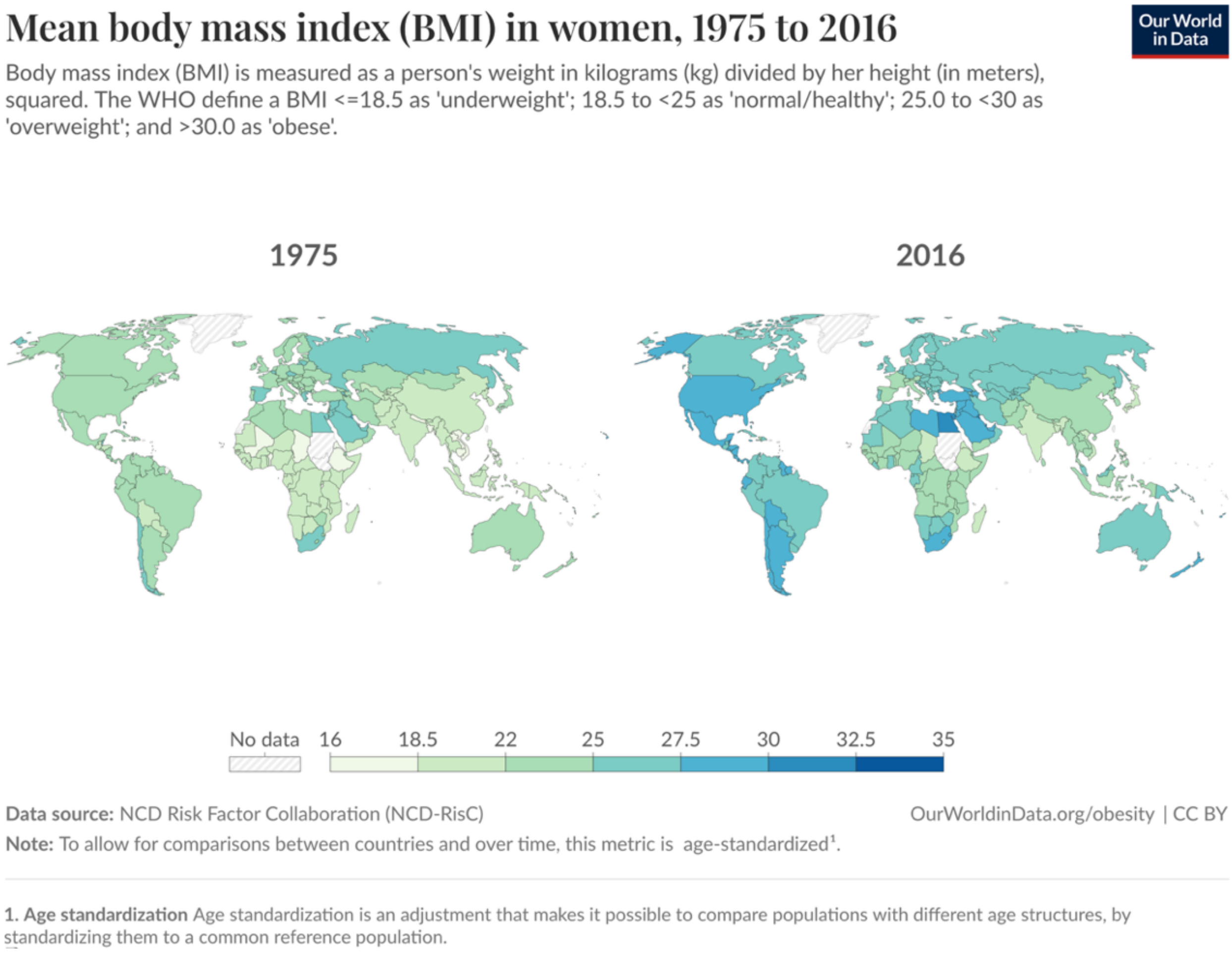


Figure 3 Mean body mass index (BMI) in adult women, 1975 and 2016. Age-standardised values. Data source: NCD Risk Factor Collaboration (NCD-RisC). Reproduced from Our World in Data (53) under Creative Commons Attribution License CC BY 4.0.

Consistent with these findings, analyses of the period between 1980 and 2008 reported that mean BMI increased by approximately 0.4 to 0.5 kg/m² per decade globally, with particularly high levels in Western high-income countries and Pacific Island nations. By 2008, no evidence of a sustained plateau or reversal in BMI trends was observed at the global level (37). A complementary analysis of the same period found that age-standardised obesity prevalence more than doubled in several regions, with women consistently showing higher obesity prevalence than men, and no country achieving a sustained decline during the study period (38).

More recent evidence indicates that female BMI has stabilised in several high-income Western countries over the past 10–15 years, while male BMI has continued to rise (51,52).

4.2.2 Disproportionate Central Adiposity

A key finding from several studies is that WC has increased faster than would be expected from BMI changes alone. Waist circumference functions as a prototype indicator of central adiposity: it is not a direct measurement of adipose tissue but correlates strongly with both subcutaneous and visceral fat in the abdominal region. This disproportionate increase in central adiposity was observed across different populations and geographic settings.

In the United States, WC increased independently of BMI changes between 1988 and 2006, showing a population-level shift towards greater central adiposity (49). A similar finding was reported among Chinese adults between 1993 and 2009, where WC increased relative to BMI, particularly among younger adults (50). Abdominal obesity prevalence increased from 27% to 47% between 1993 and 2016 in Taiwan, while general obesity rose only from 16% to 20% during the same period (47), further illustrating the disproportionate rise in central adiposity.

A global meta-analysis of 13.2 million adults confirmed that central obesity prevalence has increased from 31.3% (1985–1999) to 48.3% (2010–2014) across all income levels, with the rise exceeding that of general obesity in many populations (9). These observations were confirmed internationally, with WC increasing disproportionately relative to BMI across the United States, England, China, and Mexico, with the most pronounced shifts observed in younger women aged 20 to 29 years (8). This is clinically important, as central adiposity is more strongly associated with metabolic risk than overall adiposity as measured by BMI alone (10).

4.2.3 Trends in Body Composition

A small number of studies examined trends in body composition beyond BMI and WC. While women had higher obesity prevalence than men in earlier decades, particularly between 1970–1980 and 1990–2000, recent data from multiple Western populations indicate that men have experienced greater relative BMI increases over the past 10–15 years, with NHANES data showing a +1.4 kg/m² increase in men compared with +0.7 kg/m² in women between 1999 and 2018 (51). BMI-defined obesity rose markedly over this period, but BF%-defined obesity did not change, suggesting that BMI may overestimate actual adiposity increases at the population level (51).

Individuals may have a “normal” BMI yet carry substantial fat mass, a phenomenon described as “normal weight obesity” (54).

In the Tromsø Study population in Norway, longitudinal changes in body composition were reported between 2001 and 2016, including increases in total fat mass and VAT (44). Younger adults (40–49 years) showed the most pronounced fat gain, particularly women, while lean mass remained stable despite rising fat mass (44).

Population-level changes in body composition extend beyond what is captured by BMI alone, supporting the importance of more comprehensive anthropometric assessment in epidemiological surveillance. However, body composition data remain limited compared with BMI and WC data, and long-term trend analyses using direct composition measures are largely absent. No studies identified in this review reported secular trends in skinfold thickness or body fat topography over recent decades, representing an important gap in the current evidence base.

4.2.4 Body Height and Body Proportions

Secular trends in adult height are well documented globally, though not all were captured by the primary studies meeting the formal inclusion criteria of this review. Cole (2003) synthesised over 150 years of secular height data and concluded that adult height has increased continuously since the mid-nineteenth century, though the rate varies markedly by region (17). A more recent pooled analysis covering 200 countries confirmed that the largest gains were observed in South Korean women (+20.2 cm) and Iranian men (+16.5 cm), whereas minimal change was documented in many sub-Saharan African and South Asian countries (22). In Northern Europe and parts of Western Europe, adult height has plateaued in recent decades, while secular gains continue in Central and Eastern European populations (17–19,23). One historical analysis of skeletal remains in Milan over 2,000 years found no significant changes in mean adult stature across historical periods, suggesting that urban welfare infrastructure and stable living conditions can buffer populations against the negative secular trends documented elsewhere (24).

In rural west-central Poland, heights of adults surveyed across four ten-year interval surveys between 1986 and 2016 increased significantly: males gained 5.41 cm and females 2.95 cm overall, with annual increases of 0.15 cm/year and 0.09 cm/year respectively. These changes appeared mainly in birth cohorts after 1950, mirroring improved post-war socioeconomic and nutritional conditions (18). Comparable trends have been documented in Slovakia, with annual height increases of 0.14 cm in men and 0.10 cm in women between 1965 and 2022 (19).

The observed increases in adult height are consistently smaller than the parallel increases in BMI and particularly in waist circumference. This suggests that the global anthropometric shift over recent decades is predominantly a shift in body mass and shape rather than in body size in the traditional sense.

The secular increase in adult height occurs predominantly through an increase in leg length rather than trunk length. In Japan, the Cormic index (sitting height divided by standing height) showed a distinct pattern over the twentieth century: rising until the early 1940s, falling to a minimum in the 1970s, and rising again after 1980, with median height increasing by 12.8 cm in men and 15.4 cm in women between birth cohorts from 1920 to 1970 (20). These shifts in body proportions influence thoracic dimensions and lung function and may modify health risk by altering trunk-to-leg length ratios independently of overall stature (20).

Within the 32 studies meeting the formal inclusion criteria of this review, only cross-sectional evidence on body proportions was available: Pomeroy et al. (2021) demonstrated that adult stature, sitting height, and lower limb length vary systematically across populations in relation to population history and ecological conditions (26), and Sawada et al. (2017) examined associations between height, sitting height, and cause-specific mortality in a European cohort (30).

4.2.5 Regional Patterns

Substantial regional variation in the pace and magnitude of anthropometric changes was observed across the included studies. The global distribution of obesity prevalence between 1990 and 2022 is illustrated in Figure 4, which provides a regional overview before the country-specific findings are discussed below. The most pronounced increases occurred in North America, parts of Western Asia and North Africa, Southern Europe, and Oceania, while sub-Saharan Africa and parts of South Asia showed comparatively lower obesity prevalence in 2022.

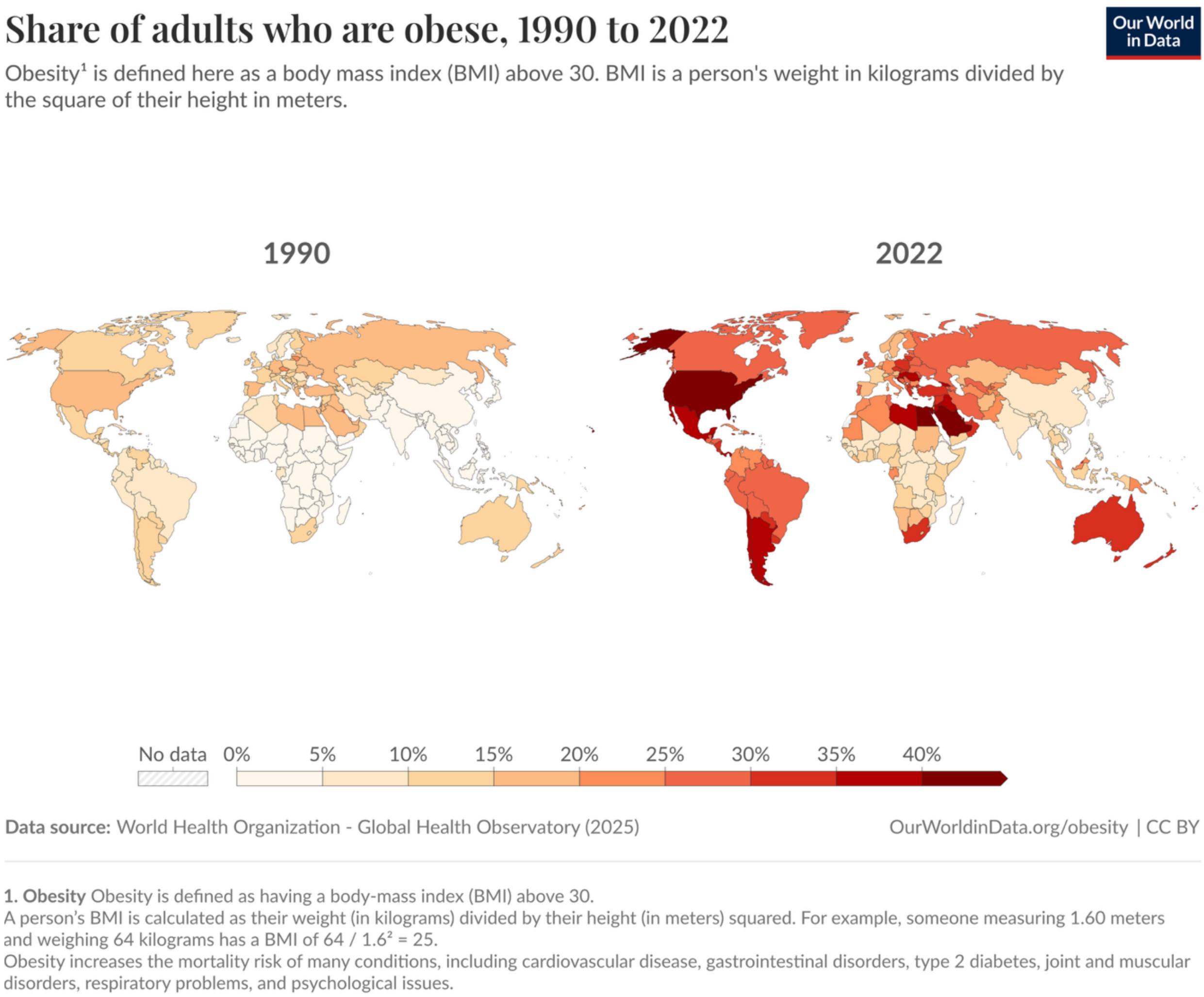


Figure 4 Share of adults with obesity (BMI≥30kg/m²) in 1990 and 2022. Data source: WHO - Global Health Observatory (2025). Reproduced from Our World in Data (53) under Creative Commons Attribution License CC BY 4.0.

Asia.

The Asian region showed particularly rapid increases in both BMI and central adiposity. Between 1993 and 2009, Chinese adults showed rising WC relative to BMI, especially at the 95th percentile (50). Men gained +2.8 kg/m² in BMI but +9.0 cm in WC, and women +1.5 kg/m² in BMI but +5.0 cm in WC (50). This illustrates that the BMI increase was markedly more pronounced in men than in women in this cohort, consistent with the broader shift towards male-driven BMI trends observed in recent decades. Holding BMI and age constant, mean WC values in 2009 were higher compared with 1993 by 3.2 cm in men and 2.1 cm in women (50). In Taiwan, the prevalence of general obesity increased modestly from 16% to 20% between 1993 and 2016, whereas abdominal obesity nearly doubled from 27% to 47% (47). Simultaneous changes in body weight and cardiovascular risk profiles were documented in Japan (40,45). In the Hisayama Study in Japan, predicted 10-year cardiovascular disease risk increased in all groups over five years, rising from 5.7% to 8.2% in those who became obese, compared with 5.9% to 6.9% in those who transitioned from obese to non-obese (45). The disease burden attributable to high BMI in Asia increased by 265% between 1990 and 2019, reaching 2.33 million deaths and 80.36 million Disability-Adjusted Life Years (DALYs), with the most pronounced increases in South and Southeast Asian countries (7). This is particularly concerning given that Asian populations experience metabolic complications at lower BMI thresholds compared with populations of European descent, with the WHO recommending lower BMI cut-off points for public health action in Asian populations (12,16).

Americas.

In the United States, multiple studies documented continued increases in both general and abdominal obesity. Between 1988 and 2006, BMI rose by 1.8 kg/m² and WC by 4.7 cm (49). After adjusting for BMI, an independent WC increase of 0.9 cm remained, consistent across BMI categories, sexes, and racial-ethnicity groups (49). Between 2001 and 2018, general obesity prevalence rose from approximately 30% to 42%, and abdominal obesity from approximately 48% to 58% (52). Additional evidence confirmed that secular changes in body composition extended beyond BMI, including changes in BF% (51). This disproportionate central adiposity trend was also confirmed in Mexican adults, where the largest WC increases at constant BMI were found in young women (20–29 years), with +6.6 cm in Mexico at a constant BMI of 25 kg/m² between 1999 and 2012, providing additional evidence from a Latin American context (8). In Chile, the future NCD burden attributable to overweight was projected to increase significantly, with BMI continuing to rise at 0.4% per year. Approximately 669,000 NCD cases and 117,000 deaths attributable to overweight were projected for 2020 to 2030, with CVDs accounting for 58.5% of attributable deaths, reflecting the ongoing rise in obesity prevalence in the region (6).

Europe.

European-specific trend data were more limited in the included studies. Increases in body fat mass and VAT were reported in a Norwegian population cohort between 2001 and 2016 (44). In the Tromsø Study, total fat mass increased by approximately 1.5 to 2.0 kg across all age groups, with the most pronounced increases among women aged 40 to 49 years. Visceral adipose tissue increased in both sexes, while lean mass remained largely stable (44). Analysis of data from the Health Survey for England (1992–2008) showed that WC increased disproportionately relative to BMI among English adults (8), consistent with the pattern observed in other countries. A study using data from the EPIC cohort across 10 European countries examined associations between body proportions and mortality but did not report trend data (30). Although these studies provide some evidence of increasing adiposity in European populations, large-scale trend analyses covering Europe remain underrepresented in the current literature.

Africa.

Sub-Saharan Africa-specific evidence was limited in this review. One systematic review and meta-analysis documented increasing rates of both general and central obesity in Nigeria, with a pooled overweight prevalence of 25.0%, obesity prevalence of 14.3%, mean BMI of 25.6 kg/m², and mean WC of 86.5 cm, with higher rates among women and urban populations (41). An estimated 21 million overweight and 12 million obese adults were projected for Nigeria in 2020 (41). Although the global pooled analyses included in this review (2,37,38) incorporated data from sub-Saharan African countries, no additional region-specific trend study from sub-Saharan Africa met the inclusion criteria. Given the rapid urbanisation and nutrition transition occurring across the continent (3), this represents a gap in the evidence base.

Multi-regional comparison.

A cross-regional comparison following cohorts in both Brazil and Thailand over eight years documented that overweight and obesity prevalence increased two- to three-fold in both cohorts, with higher socioeconomic status associated with greater weight gain in males, while an inverse socioeconomic status-obesity pattern was observed in females in both countries (43). This inverse pattern among women provides additional evidence for the recent stabilisation, and in some contexts decline, of female obesity prevalence in several countries. Global analyses show that while BMI has increased almost universally, the most rapid recent increases have shifted from high-income countries to low- and middle-income countries, reflecting the globalisation of the obesity epidemic (2,3).

4.3 Health Associations

How do BMI, WC, WHR, WHtR, body proportions, and body composition relate to health risks?

4.3.1 BMI and Non-Communicable Disease Burden

Obesity, and central obesity in particular, is a leading modifiable risk factor for CVD, T2DM, and several cancers (5,27). The non-communicable disease (NCD) burden attributable to high BMI has grown markedly, with particularly rapid increases in Asia (7) and projected further growth in countries undergoing nutrition transition (6).

An individual-participant meta-analysis of 239 prospective studies covering 10.6 million adults across four continents demonstrated that all-cause mortality increased progressively above a BMI of

25 kg/m², with the highest risk increases at BMI levels exceeding 30 kg/m² (5). Obesity was also associated with a shorter overall life expectancy and a higher lifetime risk of CVD, including heart failure, coronary heart disease, and stroke (34).

The global burden of atrial fibrillation attributable to high BMI has increased substantially since 1990, reflecting the growing impact of the obesity epidemic on cardiac arrhythmias worldwide (35). The disease burden attributable to high BMI in Asia increased markedly between 1990 and 2019, with the largest relative increases in South and Southeast Asian countries (7). The future burden of NCDs attributable to overweight in Chile was projected to continue increasing, reflecting ongoing trends in the region (6). The global burden of mortality attributable to obesity has risen substantially since 1990, with particularly pronounced increases in Western Asia and North Africa, and North America, as shown in Figure 5.

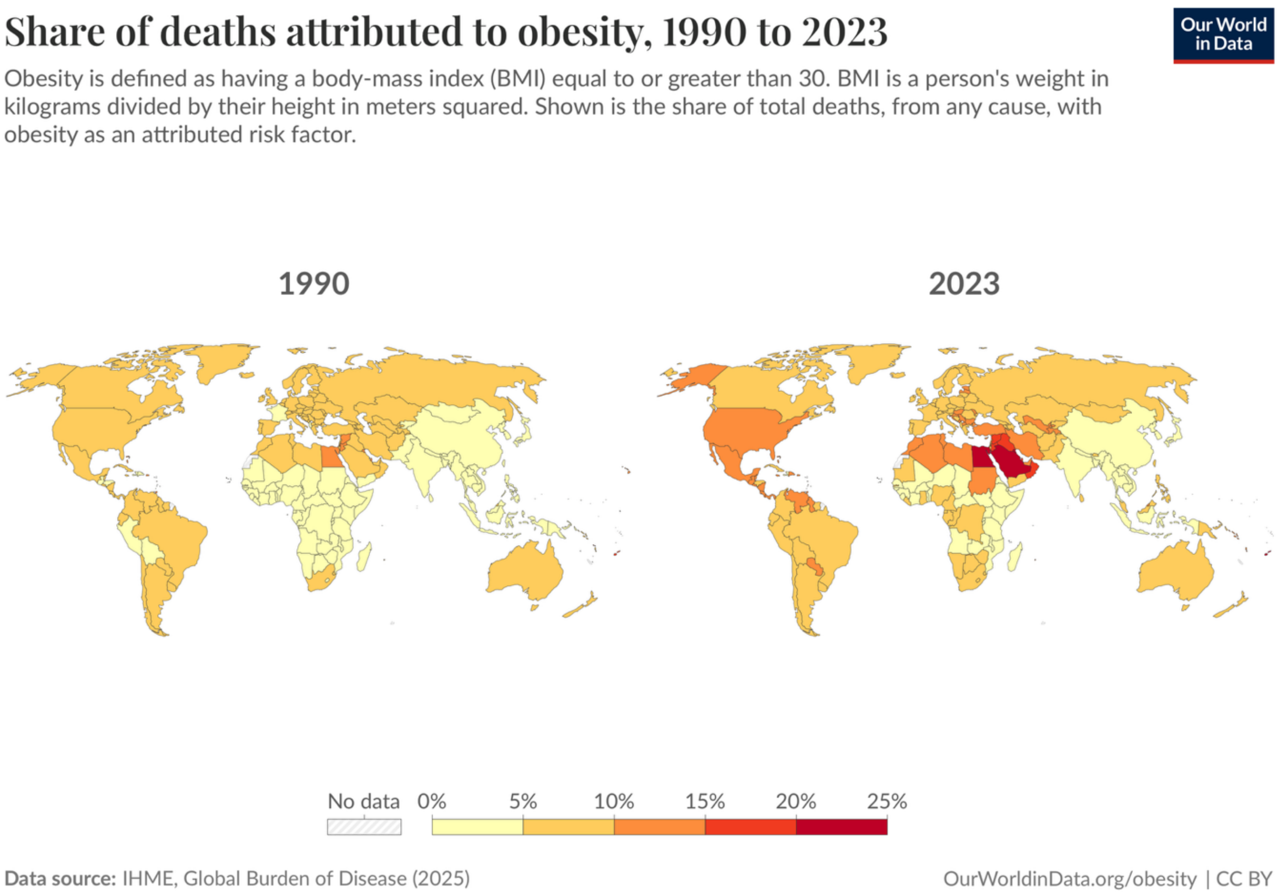


Figure 5 Share of deaths attributed to obesity as a risk factor, 1990 to 2023. Data source: Institute for Health Metrics and Evaluation (IHME), Global Burden of Disease (2025). Reproduced from Our World in Data (53) under Creative Commons Attribution License CC BY 4.0.

One systematic review reported that overweight (BMI 25–<30 kg/m²) was associated with lower all-cause mortality (hazard ratio (HR) 0.94, 95% confidence interval (CI) 0.91–0.96), grade 1 (corresponding to WHO Class I) obesity showed no notable excess mortality (HR 0.95, 95% CI 0.88–1.01), and only grade 2 to 3 obesity (BMI ≥35 kg/m²) (corresponding to WHO Class II–III) was associated with significantly elevated mortality (HR 1.29, 95% CI 1.18–1.41) (36). This shows the complexity of the BMI-mortality relationship and the limitations of BMI as a sole indicator of health risk.

4.3.2 Central Adiposity and Metabolic Risk

Several studies demonstrated that central adiposity measures provide independent and additive risk information beyond BMI. In a consensus statement from the International Atherosclerosis Society and the International Chair on Cardiometabolic Risk Working Group on Visceral Obesity, Ross et al. (2020) concluded that WC should be routinely measured in clinical practice as it provides cardiometabolic risk information beyond what BMI captures. The statement noted that commonly used WC thresholds (≥102 cm for men, ≥88 cm for women in populations of European descent) identify individuals at elevated cardiometabolic risk, and that the full strength of the WC-health risk association is realised only after adjustment for BMI (10). A systematic review and meta-analysis covering 305,851 adults across 18 countries demonstrated that WHtR had 4–5% higher AUC values than BMI for predicting cardiometabolic risk factors, with the ranking WHtR > WC > BMI consistent across all outcomes, both sexes, and diverse ethnic groups (13).

The relationship between adiposity and T2DM is well established and appears to be dose dependent. A systematic review and dose-response meta-analysis of 216 cohort studies comprising 26 million adults and 2.3 million T2DM cases reported a relative risk of 1.72 per 5-unit BMI increase and 1.61 per 10 cm WC increase, with the WC association persisting after BMI adjustment (27). Among all conventional measures, WHtR showed the strongest per-standard-deviation association with T2DM risk (27). These findings confirm that both general and central adiposity contribute to diabetes risk, though central adiposity measures may capture additional risk not reflected by BMI alone (10,16,27).

Combined changes in body weight and WC were more predictive of all-cause mortality than either measure alone among Chinese adults. Participants who lost weight but gained WC had the highest mortality risk (HR 1.69, 95% CI 1.46–1.96), whereas stable weight with WC loss was the only joint-change category not associated with elevated mortality (42). In a Japanese cohort, predicted 10-year CVD risk rose least in those who transitioned from obese to non-obese (5.9–6.9%) and most steeply in those who became obese (5.7–8.2%) (45).

Among Brazilian adults, WHtR proved more sensitive than the BMI-WC combination for detecting early health risk: 26% of adult men and 10.4% of adult women classified as "no risk" by BMI-WC showed increased risk when assessed by WHtR (14). In Indonesian adults, WHtR showed the strongest association with both diabetes (adjusted odds ratio (AOR) 3.17, 95% CI 2.42–4.15) and hypertension (AOR 2.13, 95% CI 1.93–2.36), and it yielded the highest area under the curve (AUC) values, for detecting diabetes in men (0.731) and hypertension in both sexes (48).

Beyond cardiometabolic outcomes, central adiposity was independently associated with pancreatic cancer mortality after adjusting for BMI, with hazard ratios of 1.09 per 0.1 WHR increase and 1.07 per 10 cm WC increase (39). Being overweight or obese during early adulthood (ages 18–21) was associated with approximately 40% higher pancreatic cancer mortality (HR 1.43 for BMI ≥30), suggesting that the duration and timing of excess adiposity may matter for cancer development (39).

4.3.3 Body Proportions and Health

A smaller subset of studies examined the relationship between body proportions and health outcomes. Using data from the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort involving over 400,000 European adults, one study found that greater height was positively associated with cancer mortality in women (HR Quintile 5 (Q5) vs. Quintile 1 (Q1) = 1.17) but inversely associated with circulatory disease mortality in men (HR Q5 vs. Q1 = 0.63) (30). Sitting height was unrelated to cancer mortality but was inversely linked with circulatory and respiratory disease mortality (men HR Q5 vs Q1 = 0.45 for respiratory mortality; women HR = 0.60) (30). These conflicting associations suggest that different body segments may relate to distinct biological pathways.

Shorter stature was associated with increased T2DM risk in a Korean cohort of over 21 million adults (46). The lowest height quintile had a 23% higher diabetes risk than the tallest quintile after multivariable adjustment, though this inverse association was observed only in lean individuals (BMI <23 kg/m²) (46), consistent with the life-course associations discussed in Section 3.2.4. Body proportions vary systematically across populations due to population history and ecological factors, indicating that anthropometric risk assessment must account for population-specific variation (26).

Leg length, measured directly or estimated as standing height minus sitting height, has attracted growing interest as a marker of early developmental conditions and as an independent correlate of later-life health outcomes. Because limb growth during infancy and childhood is particularly responsive to nutrition and environmental exposures, leg length is considered a more sensitive indicator of early developmental conditions than trunk length (17,21,26). In a comprehensive review, Bogin and Varela-Silva (2010) reported that relatively short legs are associated with increased risks for overweight, coronary heart disease, type 2 diabetes, impaired glucose and insulin regulation, and liver dysfunction, while relatively longer legs are associated with better early-life nutrition, but also with moderately increased risk for certain cancers such as colorectal, prostate, and postmenopausal breast cancer, possibly mediated through insulin-like growth factor 1 (IGF-1) pathways (21). Secular analyses in Japan and in European populations indicate that most of the observed increase in adult stature over the past century has resulted from gains in leg length rather than trunk length (17,20). Resulting shifts in relative leg length have been shown to influence lung function, with up to 50% of the age-adjusted variation in spirometry volumes in Japanese cohorts attributable to cohort differences in the sitting height-to-standing height ratio (20). These findings support that body proportions, and leg length in particular, should be considered alongside conventional adiposity indicators when assessing population-level health risk.

4.3.4 BMI Limitations as a Health Indicator

A recurring theme across the included studies was the limitation of BMI as a sole indicator of adiposity and health risk. In a critical review, Nuttall (2015) argued that BMI poorly reflects individual-level adiposity and fat distribution and that reliance on BMI alone may lead to misleading health risk assessments (12). A review of multiple anthropometric parameters concluded that no single measure adequately captures all dimensions of body size and composition relevant to health (12,25).

Direct body composition measures such as BF%, DXA, and VAT were reported in only four of the included studies (16,27,44,51), and none examined the independent association between directly measured body composition and health outcomes at the population level. The WHO Expert Consultation (16) noted that Asian populations have a higher body fat percentage than European populations at the same BMI, contributing to elevated cardiometabolic risk below standard BMI thresholds. This limited evidence base for direct body composition measures further underscores the reliance on proxy indicators such as BMI and WC in the current literature.

The empirical evidence reviewed in Sections 4.2.2 and 4.3.2 reinforces these concerns: WC has increased disproportionately relative to BMI in multiple populations (8,49,50), and central adiposity measures consistently outperform BMI in predicting metabolic risk (10,27,48). Standard BMI thresholds were primarily derived from populations of European origin and may not adequately capture metabolic risk in all ethnic groups (12,16). In response, the WHO recommended lower public health action points of 23 kg/m² for overweight and 27.5 kg/m² for obesity in Asian populations (16), further challenging the universal applicability of standard BMI thresholds.

4.4 Contributing Factors

What are the major contributing factors driving changes in adult body size and body composition? The included studies provide limited but consistent evidence on factors contributing to the observed trends, although a comprehensive analysis of determinants was beyond the scope of this review.

4.4.1 Environmental and Socioeconomic Factors

The nutrition transition in low- and middle-income countries is characterised by shifts towards energy-dense diets, increased consumption of processed foods, and declining physical activity associated with urbanisation and economic development (3). These changes have been considered primary drivers of the rapid increases in obesity prevalence observed in countries previously characterised by undernutrition (3). In high-income countries, obesity tends to be more prevalent among lower socioeconomic groups, whereas in many low- and middle-income countries, higher socioeconomic status is associated with greater obesity burden, particularly among men (3). Urban populations generally have a higher obesity prevalence, but this gap is narrowing in some regions as rural areas increasingly adopt urban dietary and lifestyle patterns (3). These same dietary and activity shifts also explain the disproportionate increase in waist circumference relative to BMI documented in Section 4.2.2 (8).

Trends in body size and central adiposity reflect broader socioeconomic and lifestyle transitions. Global life expectancy at birth has risen from approximately 66.8 years in 2000 to over 71 years in 2021 (55), but these gains have been unevenly distributed within populations. Income inequality, reflected in national Gini indices, has widened in many countries despite overall economic growth (56). The resulting health burden has shifted accordingly, with the share of deaths and disability attributable to high BMI rising across most regions, and the most pronounced relative increases observed in South and Southeast Asia (7). Future prognoses for low- and middle-income countries indicate continued growth in non-communicable disease burden attributable to overweight and obesity (6). The global trends illustrated in Figures 2–5 reflect the geographic alignment between economic development, dietary change, and rising adiposity, consistent with the nutrition transition framework (3). Figures 2 and 3 show that the largest mean BMI increases between 1975 and 2016 in both sexes occurred in the United States, parts of Western Asia and North Africa, and parts of Latin America, regions undergoing rapid economic development and urbanisation. Figure 4 confirms that this BMI shift is accompanied by a substantial rise in obesity prevalence, particularly in North America, Western Asia and North Africa, Southern Europe, and Oceania. Figure 5 demonstrates that the resulting health burden, measured as share of deaths attributed to obesity, has risen disproportionately in the same regions, reaching over 15% of total deaths in parts of Western Asia and North Africa by 2023.

Nutrition acts as a biological factor affecting body composition. Endocrine-disrupting chemicals present in foods, water, soil, and air have been hypothesised to contribute to the disproportionate increase in waist circumference relative to BMI, by altering hormonal regulation of fat distribution (57). Chronic psychosocial stress, which activates the hypothalamic-pituitary-adrenal axis and promotes central fat deposition, may represent an additional contributor (58). The implications of these mechanisms for the observed shift towards central adiposity are discussed further in Section 5.2.

4.4.2 Biological and Developmental Factors

Several biological and developmental factors contribute to population-level variation in body size and body composition. Genetic and epigenetic factors reflect long-term human evolution and adaptation to local environmental conditions. Populations have developed body proportions best suited to their native ecological region, influenced by climate, altitude, food availability, and disease exposure. Population history explains a substantial portion of the observed variation in adult body proportions (17,26). Adult body size and composition are also shaped by conditions during foetal development, infancy and childhood growth. Adequate nutrition during critical developmental stages is essential for optimal growth, while undernutrition during these periods may produce underdeveloped stature while paradoxically increasing susceptibility to central adiposity in later life (17). Current circumstances, including present-day nutrition, physical activity, stress, sleep patterns, and overall lifestyle, interact with inherited predispositions to shape adult body size and composition.

A longitudinal study following cohorts in Brazil and Thailand over eight years documented significant increases in BMI in both populations, reflecting the influence of changing lifestyle patterns in rapidly developing economies (43). The findings showed that body size dynamics in young adults are particularly influenced by the transition from traditional to urbanised lifestyles, illustrating how biological predispositions interact with environmental change (43).

4.5 Methodological Quality and Literature Gaps

What methodological issues affect the interpretation of trends and associations, and what gaps remain in the literature?

4.5.1 Data and Measurement Limitations

A fundamental limitation identified across the literature is the predominant reliance on BMI as the sole anthropometric indicator in large-scale surveillance. Of the 32 included studies, 28 assessed BMI, but only 18 reported WC data, 5 included WHtR, 4 included WHR, and 4 studies reported direct body composition measures. This overreliance on BMI limits the ability to detect trends in central adiposity and body composition that may be critical for understanding health risks (10,12). Measurement protocols for WC varied across studies, with different anatomical landmarks used for measurement (e.g., midpoint between iliac crest and lowest rib, umbilical level, or narrowest waist), limiting comparability (10). Self-reported versus directly measured anthropometric data further complicated cross-study comparisons, since self-reporting typically yields underestimated weight values and overestimated height values, leading to systematic underestimation of BMI (12,25).

4.5.2 Study Design Considerations

The included studies varied considerably in design, ranging from large-scale pooled analyses of population-based surveys to single-centre cross-sectional studies. Cross-sectional studies, which constituted a large proportion of the included evidence, cannot establish temporal sequences between anthropometric changes and health outcomes. The meta-analyses and pooled analyses provided strong evidence for global trends but were dependent on the quality and comparability of the underlying primary data.

Few studies provided longitudinal data on body composition changes within the same individuals over time. Lundblad et al. (2021) was one of the few to report longitudinal body composition data (44), and Yiengprugsawan et al. (2016) followed cohorts over eight years (43). Most trend analyses relied on repeated cross-sectional surveys, which capture population-level changes but may be affected by changes in survey methodology, response rates, or population composition over time.

4.5.3 Geographic and Temporal Gaps

While global analyses (2,37,38) provided broad coverage, regional studies were concentrated in East Asia and North America. Europe was represented primarily by one Norwegian cohort study and one multi-country analysis of body proportions and mortality. Africa was represented by only one country-specific systematic review (41), although global pooled analyses (2,37,38) included African data within their broader coverage. Latin American evidence was limited to Chile, Brazil, and one multi-country analysis including Mexico (8). Sub-Saharan Africa, Western Asia and North Africa, Central Asia, and the Pacific Islands were not represented by any region-specific studies in this review, although global analyses identified these regions as having particularly high obesity prevalence.

Most trend analyses covered periods ending between 2014 and 2019, with limited data on the most recent trends post-2020. Given the potential impact of the coronavirus disease 2019 (COVID-19) pandemic on physical activity, dietary patterns, and body weight, this represents an important gap in the current evidence base.

4.6 Publication Bias

Several sources of potential publication bias should be considered when interpreting the findings of this review. The search was limited to two databases (PubMed and Google Scholar), which may have resulted in incomplete coverage of the available literature. The restriction to English-language publications may have excluded relevant research from non-English-speaking regions, particularly in sub-Saharan Africa, Western Asia and North Africa, Central Asia, Latin America, and the Pacific Islands, where a substantial body of literature is published in local languages.

Of the studies identified as potentially relevant, 28 could not be included because full texts were not accessible through available institutional VPN or open-access channels. This may have introduced a bias towards studies published in open-access journals or by well-funded research groups.

The geographic distribution of the included studies also reflected potential bias. Regional studies were concentrated in East Asia and North America, with limited representation from sub-Saharan Africa, Western Asia and North Africa, Central Asia, Latin America, and the Pacific Islands. This imbalance means that the findings of this review are disproportionately informed by data from high-income countries and selected middle-income countries.

Due to the qualitative nature of the synthesis, formal statistical assessments of publication bias, such as funnel plots or Egger's test, were not applicable.

5. DISCUSSION

5.1 Summary

This literature review synthesised evidence from 32 studies to examine global trends in adult body size, body proportions, and body composition, their associations with health risk, contributing factors, and methodological gaps in the existing literature.

Adult BMI and obesity prevalence have increased consistently across almost all countries and regions over the past four decades, with no population achieving a sustained reversal (2,37,38). At the same time, WC has increased disproportionately relative to BMI in multiple populations, indicating a shift in body fat distribution towards greater central adiposity that carries significant metabolic risks (8,9,49,50). Finally, BMI alone is insufficient to characterise adiposity-related health risk, and complementary indicators such as WC, WHR, WHtR, and direct body composition measures provide important additional information (10,27,48).

The observed trends are driven primarily by the global nutrition transition, urbanisation, and declining physical activity, moderated by population-specific biological variation (3,26,43). Significant geographic and methodological gaps were identified, including underrepresentation of sub-Saharan Africa, Western Asia and North Africa, Central Asia, and the Pacific Islands, and a predominant reliance on BMI with limited reporting of other anthropometric measures (9,12). Complementing these primary findings, narrative integration of additional literature (17–24) documented that adult height has increased globally, though less rapidly than BMI or waist circumference, and predominantly through gains in leg length rather than trunk length. Cross-sectional evidence within the included studies further showed that body proportions vary systematically across populations and show differential associations with cause-specific mortality (26,30). These findings indicate that the anthropometric transformation of recent decades is dominated by shifts in body mass and shape, rather than body size, with important consequences for surveillance and clinical practice.

5.2 Central Adiposity as a Critical Finding

The most important finding of this review is the consistent evidence that central adiposity is increasing faster than BMI trends alone. This disproportionate increase was observed across high-income countries such as the United States (49) and England (8), rapidly developing economies including China (50) and Mexico (8), and in global analyses encompassing 13.2 million adults (9). That pooled central obesity prevalence rose from 31.3% (1985–1999) to 48.3% (2010–2014) within three decades underlines the scale and consistency of this shift and raises the question of whether current surveillance frameworks are adequate to capture it (9). In Taiwan, abdominal obesity prevalence nearly doubled over two decades, while general obesity, as measured by BMI, increased only modestly (47).

VAT is the primary driver of the metabolic complications associated with obesity, including insulin resistance, dyslipidaemia, chronic low-grade inflammation, and elevated cardiovascular risk (28,29). If WC is rising faster than BMI, surveillance systems based on BMI alone are likely to underestimate the true development of metabolic risk. This concern was raised by Ross et al. (2020), who called for routine measurement of WC in clinical practice alongside BMI (10).

The reasons why central adiposity is increasing faster than BMI are not yet fully understood. Shifts towards energy-dense diets and reductions in physical activity may preferentially promote visceral fat accumulation (3,28,29). Other potential contributors include chronic psychosocial stress, which has been shown to activate the hypothalamic-pituitary-adrenal axis and promote central fat deposition (58), and environmental endocrine disruptors that may alter fat distribution patterns (57). More research is needed to clarify the relative contribution of these factors.

5.3 BMI Limitations and Alternative Indicators

A second major theme emerging from this review is the growing recognition that BMI, despite its prevalent use, has major limitations as an indicator of adiposity and health risk. Nuttall (2015) documented the historical development of BMI and argued that it was never intended to serve as a measure of individual adiposity (12). As discussed in Section 4.3.4, no single anthropometric measure captures all dimensions of adiposity relevant to health, which highlights the value of multi-indicator assessment (12,25).

Overweight, as classified by BMI, was associated with lower, not higher, all-cause mortality (36), a finding that has generated major debate in the literature. This so-called “obesity paradox” may partly reflect the inability of BMI to distinguish between fat mass and lean mass, or to capture the distribution of body fat. Adipose tissue is now recognised as an active endocrine organ that produces hormones and inflammatory mediators (28,29). Its metabolic activity appears to intensify during certain disease processes. Extreme excess of adipose tissue, particularly visceral fat, is clearly associated with metabolic dysfunction. This evolving understanding further complicates the interpretation of the “obesity paradox” based on BMI alone. Individuals classified as normal weight by BMI may carry excess visceral fat, while those classified as overweight may have favourable body composition with greater lean mass, a phenomenon described as “normal weight obesity” (54).

Several alternative indicators demonstrated superior performance in the reviewed studies. WHtR emerged as a particularly promising measure, outperforming BMI, WC, and WHR for detecting diabetes and hypertension in both Brazilian (14) and Indonesian (48) populations. This is consistent with a larger body of evidence suggesting that WHtR consistently ranked above both WC and BMI for predicting cardiometabolic risk across outcomes, sexes, and ethnic groups, with 4% to 5% higher AUC values than BMI (13). WHtR reclassified 26% of men and 10.4% of women as at risk who were missed by the BMI-WC combination (14), and showed stronger associations with diabetes (AOR 3.17) and hypertension (AOR 2.13) than BMI alone in Indonesian adults (48). The practical advantage of a universal boundary value (WHtR ≥0.5) applicable across sex and ethnic groups further supports its use as a screening tool (13).

The combination of BMI with WC, as recommended by Ross et al. (2020), represents a practical first step, while the inclusion of WHtR and, where feasible, direct body composition measures would further enhance risk stratification (10).

5.4 Regional Patterns

The WHO reports that the worldwide prevalence of adult obesity more than doubled between 1990 and 2022, with 43% of adults now classified as overweight and 16% as obese (1), confirming the trends documented by the studies included in this review. The NCD Risk Factor Collaboration, which produced several of the pooled analyses included here (2), remains the most comprehensive source of global anthropometric trend data.

The disproportionate increase in WC relative to BMI identified in this review has now been documented across at least six countries on three continents (8,9,44,47,49,50), suggesting that it represents a genuine global phenomenon rather than an artefact of measurement differences. Compared with the extensive literature on BMI trends, relatively few studies have examined trends in body composition or body proportions at the population level. The Tromsø Study (44) and NHANES analyses (51) represent important contributions, but long-term, multi-country trend data on fat mass, lean mass, and VAT remain limited. This gap is significant because changes in body composition may have health risks that are not captured by either BMI or WC (10,12).

5.5 Secular Trends in Adult Height

The evidence on secular trends in adult height provides an important complementary perspective to the trends in BMI and waist circumference documented in the formally included studies. Global analyses show that adult height has increased substantially since the mid-nineteenth century, with particularly pronounced gains in the twentieth century (17). However, the rate of increase has slowed in Northern Europe, where adult height has approached a plateau, while populations in Central and Eastern Europe continue to show significant secular gains (17–19,22). Not all populations follow this pattern: a recent analysis of 549 skeletal remains spanning 2,000 years in Milan (Italy) found no statistically significant changes in mean stature across historical periods, attributed to the relatively stable living conditions and historical welfare infrastructure of the city, which may have buffered the lower social classes against the negative secular trends documented elsewhere in Europe (24). This illustrates that secular trends in height are context-dependent and cannot be assumed uniform even within the same continent.

The secular increase in adult height is much less pronounced than the parallel increases in BMI and waist circumference documented throughout this review. For example, rural adults in Poland between 1986 and 2016 gained approximately 5.4 cm in men over three decades (0.15 cm/year), whereas mean BMI rose more steeply and waist circumference disproportionately (18). This disparity supports the interpretation that the global anthropometric transformation over recent decades is dominated by shifts in body composition and body shape, rather than by proportional increases in overall body size.

The secular increase in height has occurred predominantly through gains in leg length (17,20), with implications for both body proportions and health-risk assessment. The combined shift towards longer legs and disproportionately increasing waist circumference means that contemporary adult populations differ from historical cohorts not only in body mass but also in body shape and proportion in ways that BMI alone cannot capture.

5.6 Regional Gaps and Risks

The included studies revealed substantial regional gaps in both the magnitude and the pace of anthropometric changes. While high-income countries continue to experience gradual increases in obesity prevalence, the most rapid recent increases have occurred in low- and middle-income countries undergoing nutritional and economic transitions (16). In Asia, the combination of rapidly increasing BMI and the heightened metabolic susceptibility of Asian populations at lower BMI thresholds, for which the WHO has recommended reduced cut-off points of 23 kg/m² for overweight and 27.5 kg/m² for obesity (16), creates a particularly concerning public health scenario.

The geographic imbalances in the available evidence are equally concerning. Sub-Saharan Africa, despite undergoing rapid urbanisation and nutrition transition, was represented by only one country-specific study (41), with additional African data available only through the global pooled analyses (2,37,38). Latin America was represented primarily through Chile (6), Brazil (14), and one multi-country analysis including Mexico (8). Sub-Saharan Africa, Western Asia and North Africa, Central Asia, and the Pacific Islands were not represented by any region-specific studies, despite being identified by global analyses as having among the highest obesity prevalence worldwide (2,37,38). These gaps show that more investment in anthropometric surveillance is needed in underrepresented regions.

5.7 Impact on Public Health and Clinical Practice

At the surveillance level, the evidence strongly supports incorporating WC into routine population monitoring alongside BMI. National health surveys that currently report only BMI-based obesity prevalence are likely to underestimate the true burden of metabolically relevant adiposity, particularly in populations where central fat accumulation is increasing disproportionately. In some populations, BMI-based surveillance may also overestimate true adiposity, for example in populations with relatively high lean mass, a reservation relevant to European, especially Northern European, populations.

Characterisation of abdominal adiposity requires assessment of both subcutaneous and visceral adipose tissue in the trunk region, and their specific associations with health outcomes. Imaging methods (DXA, MRI) and standardised skinfold measurements should complement WC measurement to more fully capture body fat topography. BMI can underestimate adiposity in populations with relatively high body fat at equivalent BMI values, as documented in Asian and African populations (12,16), further reinforcing the need for multi-indicator anthropometric assessment.

At the clinical level, the findings support the recommendation by Ross et al. (2020) that WC should be measured routinely in clinical encounters as a vital sign (10). The evidence reviewed here shows that WHtR deserves further evaluation as a potential addition to clinical screening guidelines, given its consistent performance among diverse populations and its practical simplicity (13).

From a public health perspective, the identification of nutrition transition and declining physical activity as key contributing factors (3,8) suggests that public policy interventions targeting the food environment, as well as promoting active transport and occupational activity, may be particularly important in countries undergoing rapid economic development. The fact that the most rapid increases in obesity are now occurring in low- and middle-income countries highlights the need for context-specific interventions which account for the unique socioeconomic and cultural factors driving the epidemic in these settings (2,3).

5.8 Strengths and Limitations

This literature review was conducted according to PRISMA 2020 guidelines (15), employed a comprehensive search strategy across two databases supplemented by backward citation tracking, and addressed a broad set of research questions spanning trends, health associations, contributing factors, and methodological quality. The inclusion of 32 studies covering diverse geographic regions, study designs, and anthropometric indicators provides a comprehensive overview of the current evidence base.

As discussed in Section 4.6, several sources of potential publication bias were identified, including the limitation to two databases and English-language publications. Studies from other research databases, as well as non-English publications from underrepresented regions, may have been missed. Additional limitations include the heterogeneity of study designs, populations, and outcome measures. A quantitative meta-analysis was not feasible, and the synthesis remained qualitative. The search and screening were performed by a single reviewer, which increases the risk of selection bias compared with the dual-reviewer approach recommended by PRISMA guidelines (15).

As noted in Section 4.5, the evidence base itself contains significant geographic and methodological imbalances that limit the generalisability of the findings. No included study reported secular trends in subcutaneous adipose tissue (skinfold thickness) or body fat topography, which represents an important gap in the current literature and a promising direction for future research. Sub-Saharan Africa, Western Asia and North Africa, Central Asia, and the Pacific Islands were not represented by region-specific studies, meaning that the global patterns described in this review are disproportionately informed by data from high-income countries and East Asia.

6. CONCLUSION

This literature review demonstrates that adult body mass index and waist circumference have increased consistently across almost all populations over recent decades, with central adiposity rising disproportionately relative to overall body mass. This indicates a population-level shift in body fat distribution that carries significant metabolic risk and is not adequately captured by body mass index alone. Simultaneous secular gains in adult height have been considerably smaller and have occurred predominantly through increases in leg length, indicating that the anthropometric transformation of recent decades is dominated by changes in body mass and shape rather than body size in the traditional sense. Body mass index alone is insufficient as an indicator of adiposity-related health risk. Complementary indicators, particularly waist circumference and waist-to-height ratio, capture metabolic risk that body mass index misses. The evidence base is constrained by an over-reliance on body mass index, non-standardised waist circumference measurement protocols, and substantial geographical underrepresentation of sub-Saharan Africa, Western Asia and North Africa, Central Asia, and the Pacific Islands.

7. RECOMMENDATIONS

The conclusive findings of this review highlight different indicators for future surveillance, research, and clinical practice, which the following five recommendations address.

First, national health surveys and surveillance systems should incorporate waist circumference alongside body mass index as a routine measure to better capture trends in central adiposity.
Second, large-scale longitudinal studies are needed to assess multiple anthropometric indicators simultaneously, including waist-to-height ratio, body proportions, and, where feasible, direct body composition measures.
Third, investment in population-level anthropometric surveillance in underrepresented regions, particularly sub-Saharan Africa, Western Asia and North Africa, Central Asia, as well as the Pacific Islands, is essential.
Fourth, standardised measurement protocols for waist circumference should be adopted across studies and surveillance systems to improve cross-study comparability.
Fifth, future research should investigate post-2020 anthropometric trends to assess the potential impact of the coronavirus disease 2019 pandemic on body size and composition at the population level.
These measures would incorporate a more accurate characterisation of population-level metabolic risk than is possible with body mass index alone and provide the evidence base required to address the rising burden of obesity-related disease worldwide.

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9. ANNEXES

9.1 Data Extraction and Synthesis Table

No	Author (Year)	Study Design	Population	Region	Period	AP	Outcomes	Key Findings	RQ
1	NCD Risk Factor Collaboration (2016)	Pooled analysis population-based measurement studies	Adults ≥18 yrs; both sexes; N = 19.2 million	Global (200 countries, 21 regions)	1975–2014	BMI	Mean BMI; prevalence of underweight, overweight, obesity (severe/morbid)	Global age-standardised mean BMI: increased ~21.7—~24.2 kg/ m² (men); ~22.1—~24.4 kg/ m² (women). Obesity prevalence: increased 3.2–10.8% (men); 6.4–14.9% (women). Meeting the 2025 global obesity target was deemed virtually impossible if post-2000 trends persisted.	A
2	Finucane et al. (2011)	Systematic analysis of health examination surveys; Bayesian hierarchical model	Adults ≥20 yrs; both sexes; 960 country-yrs; N = 9.1 million	Global (199 countries, 21 subregions)	1980–2008	BMI	Age-standardised mean BMI trends by country, region, and sex; overweight/obesity prevalence	Global mean BMI: increased by 0.4 kg/m²/decade (men); 0.5 kg/m²/decade (women). The largest rise: Oceania (GBD region, i.e. Pacific Island nations, excluding Australia and New Zealand). Central/Eastern Europe and Central Africa: flat or declining trends (women). In 2008, an estimated 1.47 billion adults had BMI ≥25.	A
3	Stevens et al. (2012)	Systematic analysis; Bayesian hierarchical model	Adults ≥20 yrs; both sexes; 960 country-yrs; N = 9.1 million; 243 health examination surveys	Global (199 countries, 21 subregions)	1980–2008	BMI	Age-standardised prevalence of overweight and obesity by country, year, and sex	Global age-standardised obesity prevalence: nearly doubled from 6.4–12.0% (1980–2008); half the rise occurring 2000–2008. Overweight prevalence: increased 24.6–34.4%. Highest prevalence: Oceania (GBD region, i.e. Pacific Island nations, excluding Australia and New Zealand). Lowest prevalence: South/Southeast Asia.	A
4	Wong et al. (2020)	Systematic review and meta-analysis	Adults ≥15 yrs; both sexes; N = 13.2 million	Global (Europe, Asia, Americas, Africa)	1985–2014	WC	Prevalence of central obesity by age, sex, race, region, income level, and time trend	Pooled central obesity prevalence: 41.5%, increasing 31.3 (1985–1999)–48.3% (2010–2014). Females (47.6%) > males (30.4%), in older adults, urban residents, and higher-income countries. Young adults (15–40 years) showed a drastic increase over time (16.3–33.9%).	A
5	Wong and Yu (2022)	Serial cross-sectional analysis of three waves of nationally	Taiwanese adults 20–79 yrs; both sexes; n = 2,989 / 2,495 / 2,880 in 3 waves	Taiwan (nationally representative, urban and rural)	1993–2016	BMI, WC	Age-specific trends in mean BMI, mean WC, and prevalence of underweight, overweight, general	General obesity prevalence: increased 16–20% (1993–2016). Abdominal obesity: nearly doubled 27–47%. WC: increased rapidly across nearly all subgroups. BMI trends: were more heterogeneous, increasing mainly in men and younger adults.	A, B

No	Author (Year)	Study Design	Population	Region	Period	AP	Outcomes	Key Findings	RQ
		representative surveys					obesity, and abdominal obesity	The plateau in female general obesity may reflect thin-ideal norms in East Asia.	
6	Adeloye et al. (2021)	Systematic review and meta-analysis	Adults ≥15 yrs; both sexes; N = 52,816; 35 studies	Nigeria (national and 6 geopolitical zones)	1990–2020	BMI, WC	Prevalence of overweight and obesity; pooled mean BMI and WC	Pooled prevalence of overweight: 25.0% Pooled prevalence of obesity: 14.3%, with higher rates among women and urban population. Mean BMI: 25.6 kg/m² Mean WC: 86.5 cm. Estimated 21 million overweight and 12 million obese adults were projected for Nigeria in 2020.	A, B
7	Albrecht et al. (2015)	Repeated cross-sectional analysis of population-based surveys	Adults 20–49 yrs; both sexes (Mexico: women only); NHANES, HSE, CHNS, Mexican nutrition surveys	USA, England, China, Mexico	1988–2012 (country specific)	BMI, WC	Change in WC relative to BMI over time	WC: increased disproportionately relative to BMI across all four countries, except Black men in the US. Young women (20–29 years): particularly in Mexico (+6.6 cm) and China (+4.6 cm) at constant BMI of 25 kg/m² showed the largest increases. Men: the trend increase was most prominent in China (+4.8 cm). This suggests a shift toward greater abdominal adiposity beyond what BMI alone captures.	A, B
8	Walls et al. (2011)	Repeated cross-sectional analysis	Adults ≥20 yrs; both sexes, N = 15,349 (1988-94) / 4,176 (2005-06)	USA (nationally representative)	1988–1994 vs. 2005–2006	BMI, WC	Independent change in WC beyond BMI-expected change; WC risk category shifts	BMI: increased by 1.8 kg/m² WC: increased by 4.7 cm. After adjusting for BMI, an independent WC increase of 0.9 cm remained, consistent across BMI categories, sexes, and race-ethnicity groups but restricted to adults <50. The proportion with high-risk WC increased within every BMI category.	A, B
9	Stern et al. (2014)	Pooled cross-sectional analysis	Adults 20–59 yrs; both sexes; N = 6,094 men and 6,709 women	China (9 provinces, urban/rural/suburban)	1993 vs. 2009	BMI, WC	Temporal trends in BMI and WC distributions; change in WC at equivalent BMI over time	BMI and WC increased significantly, with the largest gains at the upper end of the distribution (95th percentile: men +2.8 kg/m², +9.0 cm WC; women +1.5 kg/m², +5.0 cm WC). Holding BMI and age constant, men had 3.2 cm and women 2.1 cm higher WC in 2009 than in 1993. The BMI-independent WC increase was greater among obese vs. lean individuals and among younger vs. older women.	A, B,D
10	Townsend et al. (2024)	Cross-sectional analysis	Adults 20–59 yrs; both sexes; N = 2,100	USA	1999–2018 (NHANES)	BMI, BF %, BW	Secular trends in BMI-defined vs. BF%-defined obesity	BMI: increased in both men (+1.4 kg/m²) and women (+0.7 kg/m²) from 1999–2018. BF %: remained stable in men and slightly decreased in women. BMI-defined obesity increased while BF%-defined obesity did not change, suggesting BMI may overestimate actual adiposity increases at population level.	A, D

No	Author (Year)	Study Design	Population	Region	Period	AP	Outcomes	Key Findings	RQ
11	Lundblad et al. (2021)	Population-based cohort study	Adults 40–88 yrs; both sexes (58-63% women); n = 1,662 / 901 / 3,670 (three waves)	Norway (Tromsø municipality)	2001–2016 (three survey waves)	DXA, VAT, LM, BMI, WC	Secular and longitudinal trends in body composition	Total fat and VAT mass increased 2001–2016, with a larger increase during 2007–2016 than 2001–2007. Younger adults (40–49 years) showed the most pronounced fat gain, particularly women. Women had higher total fat mass; men had higher VAT. LM remained stable despite rising fat mass.	A, D
12	Sun et al. (2022)	Serial cross-sectional analysis	Adults 20–79 yrs; both sexes; n = 44,184; 9 survey cycles	USA	2001–2018 (9 biennial NHANES cycles)	BMI, WC	Prevalence trends of general obesity and abdominal obesity	General obesity prevalence: increased ~30–~42% and abdominal obesity ~48–~58% over 2001–2018. BMI and WC distributions shifted rightward. Males showed significant increases across all obesity classes. Females showed a possible plateau in BMI after 2015–2016. Abdominal obesity prevalence was consistently higher in females.	A
13	Yatsuya et al. (2014)	Global trend analysis and review of prospective cohort studies	Adults ≥20 yrs; both sexes; cohorts N = ~1,000–>1,000,000	Global (WHO 6 regions); cohort studies from USA, Europe, Japan, China, Korea	2000–2011	BMI	Overweight/obesity; incidence of CAD, ischemic stroke, haemorrhagic stroke	Overweight/obesity prevalence: highest in the Americas (61.1%) and Europe (54.8%), females disproportionately affected in most regions except Europe. Higher BMI was positively associated with CAD and ischemic stroke incidence largely independent of known mediators; the association with haemorrhagic stroke was less consistent.	A, B
14	Khan et al. (2018)	Population-based pooled analysis of prospective cohort studies	Adults 20–79 yrs; both sexes, free of clinical CVD; 190,672 person-examinations; 3.2 million person-years of FU	USA	1964–2015	BMI	Lifetime risk of incident total CVD and subtypes (MI, stroke, HF, CVD death); CVD-free life years	Compared with normal BMI, middle-aged overweight and obese adults had significantly higher lifetime CVD risk. Obesity was associated with shorter longevity and earlier CVD onset (by ~7 years for morbid obesity), with the strongest BMI-CVD association seen for HF (5-fold increase in morbidly obese men). Overweight individuals had similar total longevity as normal-weight adults but spent a greater proportion of life living with CVD.	B
15	Di Angelantonio et al. (2016)	Individual-participant-data meta-analysis	Adults 20–90 yrs; both sexes; N = 10.6 million (3.95 million in primary analysis); 385,879 deaths	Global (Europe, North America, East Asia, Australia/New Zealand, South Asia)	1970s–2015; median FU 13.7 yrs	BMI	All-cause and cause-specific mortality	All-cause mortality was lowest at BMI 20.0–25.0 and increased significantly in both overweight (HR 1.07–1.20) and all obesity grades (up to HR 2.76 for grade 3). Associations were broadly consistent across four continents, stronger in younger adults and men. Restricting to never-smokers without chronic disease eliminated the apparent protective effect of overweight.	B
16	Flegal et al. (2013)	Systematic review and meta-analysis of prospective observational studies	General adults; both sexes; N = >2.88 million; >270,000 deaths; 97 studies	North America and Europe, Australia, China, Japan, Brazil, Israel, India, Mexico	Search through September 2012	BMI	All-cause mortality	Overweight (BMI 25–<30): associated with significantly lower all-cause mortality (HR 0.94). Grade 1 obesity (BMI 30–<35): not associated with higher mortality (HR 0.95). Grades 2–3 obesity (BMI ≥35): significantly elevated mortality (HR 1.29). Findings persisted with measured weight/height and adequate adjustment.	B

No	Author (Year)	Study Design	Population	Region	Period	AP	Outcomes	Key Findings	RQ
17	Jayedi et al. (2022)	Systematic review and dose-response meta-analysis	Adults ≥18 yrs, both sexes; N = 26 million; 2.3 million T2DM cases	Global (Europe, North America, Far East, Middle East, South Asia, Southeast Asia, Australia, South America, Africa)	1991–2021	BMI, WC, WHR, WHtR, BF %, VAI, ABSI, BAI, HC, TC.	T2DM incidence	BMI showed a strong positive linear association with T2DM risk (RR 1.72 per 5-unit increase), consistent across regions and ethnicities. WC had a similarly strong linear association (RR 1.61 per 10 cm), which persisted after adjustment for BMI. Among conventional measures, WHtR showed the strongest per-standard deviation association with T2DM risk.	B
18	Yuan et al. (2022)	Prospective cohort study	Adults ≥40 yrs; both sexes; N = 58,132 (DFTJ: 10,951; Kailuan: 47,181)	China (Shiyan City and Tangshan City)	2006–2010; 426,072 person-yrs	BW, WC	All-cause mortality	BW and WC changes showed U-shaped associations with mortality. Participants who lost weight but gained WC had the highest mortality risk (HR 1.69, 95% CI 1.46–1.96). Stable weight with WC loss was the only joint-change category not associated with elevated mortality.	B
19	Honda et al. (2022)	Longitudinal population-based cohort study	Adults 40–74 yrs; both sexes; N = 2,140	Japan (Hisayama, Fukuoka Prefecture)	2002–2007 (5-year FU)	BMI, WC, BW	Model-predicted 10-year CVD risk; individual CVD risk factors (BP, fasting glucose, HbA1c, HDL-C, LDL-C, triglycerides, liver enzymes, eGFR)	Predicted CVD risk increased over 5 years in all groups but increased least in those who transitioned from obese to non-obese (5.9–6.9%) and most steeply in those who became obese (5.7–8.2%). Weight loss in obese participants was associated with favourable changes in WC, BP, fasting glucose, HDL-C, triglycerides, and liver enzymes.	B
20	Corrêa et al. (2019)	Population-based cross-sectional study	Brazilian adults 20–65 yrs and older adults ≥60 yrs; both sexes; N = 8,235 and 5,494	Brazil (100 municipalities across 23 states, urban areas)	2008–2009	BMI, WC, WHtR	Health risk classification and association with systemic arterial HTN	WHtR identified more individuals at early health risk than the BMI-WC combination, 26% of adult men and 10.4% of adult women classified as “no risk” by BMI-WC showed increased risk by WHtR. WHtR demonstrated comparable ability to predict HTN prevalence ratios regardless of gender and age, suggesting it is a simpler and more sensitive screening tool.	B
21	Sartika et al. (2025)	Cross-sectional analysis of nationally representative survey data	Indonesian adults ≥18 yrs; both sexes; N = 7,699 (HTN), N = 2,203 (DM); 58.5% women	Indonesia (13 provinces, 312 enumeration areas)	2014	BMI, WC, WHR, WHtR	Prevalence and diagnostic performance (ROC/AUC) for DM and HTN; AOR	WHtR showed the strongest association with both DM (AOR 3.17, 95% CI 2.42–4.15) and HTN (AOR 2.13, 95% CI 1.93–2.36) and had the highest AUC for detecting DM in men (0.731) and HTN in both sexes. Lower population-specific cutoffs for BMI (22.72 kg/m²) and WC (83.35 cm) were proposed to improve sensitivity.	B
22	Kong et al. (2024)	Observational study based on	Adults aged 30–95 yrs; both sexes;	Global (21 GBD regions, 5 SDI quintiles)	1990–2021	BMI	Deaths and DALYs from AF attributable to high BMI	High BMI-related AF caused 27,000 deaths and 725,000 DALYs globally in 2021, a 376% increase since 1990. Females and adults ≥70: disproportionately higher burdem.	B

No	Author (Year)	Study Design	Population	Region	Period	AP	Outcomes	Key Findings	RQ
		global burden analysis	204 countries and territories					South Asia and Southeast Asia showed the fastest growth in age-standardized death rates, while Australasia had the highest absolute rates.	
23	Genkinger et al. (2015)	Pooled analysis of individual-level data of prospective cohort studies	Adults 18–85 yrs; both sexes; N = 647,478 (central adiposity analyses) / 1,096,492 (early adulthood BMI)	USA, Sweden, Australia	1980s–2010s; median FU 5–26 yrs	BMI, WC, WHR	Pancreatic cancer mortality; PAF	Central obesity: independently associated with pancreatic cancer mortality after adjusting for BMI (WHR: HR 1.09 per 0.1 increase; WC: HR 1.07 per 10 cm). Overweight/obese during early adulthood (ages 18–21): associated with ~40% higher pancreatic cancer mortality (HR 1.43 for BMI ≥30). The PAF was 13% for central adiposity and 6% for early adult BMI.	B
24	Sawada et al. (2017)	Prospective cohort study	Adults 20–70 yrs; both sexes; N = 409,748; 29,810 deaths during FU	Europe (10 countries: Denmark, France, Germany, Greece, Italy, Netherlands, Norway, Spain, Sweden, UK)	1992–2000, mean FU 12.5 yrs	Height, sitting height	All-cause and cause-specific mortality (cancer, circulatory disease, respiratory disease)	Greater Height: directly associated with cancer mortality (women HR Q5 vs Q1 = 1.17) but inversely associated with circulatory disease mortality (men HR Q5 vs Q1 = 0.63). Sitting height: not associated with cancer mortality but was inversely associated with circulatory disease mortality and respiratory disease mortality (men HR Q5 vs Q1 = 0.45; women 0.60).	B
25	Rhee et al. (2019)	Retrospective nationwide population-based cohort study	Korean adults; mean age ~47 yrs; both sexes; N = 21,122,422	South Korea	2009–2012; FU through 2015, median 5.6 yrs	Height, weight, BMI, WC	Incidence of new-onset DM	Shorter height: inversely associated with DM risk, the lowest height quintile had a 23% higher DM risk than the tallest quintile after multivariable adjustment. This inverse association was significant only in lean individuals (BMI <23 kg/m²) and those with normal fasting glucose (<100 mg/dL), suggesting obesity and hyperglycaemia overwhelm the height-DM relationship.	B
26	Ashwell et al. (2012)	Systematic review and meta-analysis	Adults 18–100 yrs; both sexes; N = 305,851; multiple ethnic groups (Caucasian, Asian, Afro-Caribbean, Indigenous Australian, Latin American, et al.)	Global (18 countries: Thailand, China, Hong Kong, Japan, Korea, Taiwan, Singapore, Iraq, Iran, Australia, New Zealand, Germany, Italy, Turkey, Canary Islands, Brazil, Chile, Jamaica, USA)	1985–2008	WHtR, WC, BMI	T2DM, HTN, dyslipidaemia, metabolic syndrome, CVD	WHtR: significantly better discriminatory power for cardiometabolic risk factors than BMI (4-5% higher AUC, $P < 0.01$) and was also statistically superior to WC ($P < 0.005$ for diabetes, hypertension, CVD, and all outcomes combined). The ranking WHtR > WC > BMI was consistent across all outcomes, both sexes, and diverse ethnic groups. A WHtR boundary value of 0.5 is recommended as a simple, universal screening threshold.	B
27	Ross et al. (2020)	Consensus Statement	Adults (review of multiple studies)	Global	Literature through June 2019	WC, BMI, WHR, WHtR	Clinical relevance of WC for cardiometabolic risk, morbidity, and mortality	WC: independent and additive risk information beyond BMI for predicting morbidity and mortality. The full strength of the WC-health risk association is realised only after adjustment for BMI.	B, D

No	Author (Year)	Study Design	Population	Region	Period	AP	Outcomes	Key Findings	RQ
								The authors recommend WC be adopted as a routine “vital sign” in clinical practice.	
28	WHO Expert Consultation (2004)	Expert consultation	Adults; Asian populations (China, Hong Kong, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand) and Pacific Islanders	Asia-Pacific	Literature reviewed up to 2002	BMI, BF %, WC	BMI-body fat relationship across ethnicities; BMI thresholds for T2DM and CVD risk in Asian populations	Asian populations: higher body fat percentage (than Europeans at the same BMI), and substantial cardiometabolic risk exists below the standard WHO overweight threshold of 25 kg/m². No universal BMI cut-off applicable to all Asian populations could be established (risk thresholds ranged 22–25 kg/m²). The consultation kept the existing WHO cut-offs but recommended additional public health action cut-off points 23–27.5 kg/m² for Asian populations.	B, D
29	Yiengprugsawan et al. (2016)	Comparative longitudinal cohort study	Adults 20–24 yrs; both sexes; Pelotas cohort (n = 5,914, 51% male) and Thai cohort (n = 9,893, 33% male)	Brazil (Pelotas) and Thailand (nationwide)	2004/2005 – 2012/2013 (8-year FU)	BMI (Western and Asian cut-offs)	Changes in BMI categories by socioeconomic status and sex	Overweight/obesity: prevalence increased 2-3-fold in both cohorts over 8 years. Higher SES: was associated with greater weight gain in males. Inverse SES-obesity pattern: was observed in females in both countries. Despite cultural differences, similar gender-specific SES gradients emerged.	C
30	Fuentes et al. (2023)	Multistate life table modelling study	Adults 20–80 yrs, both sexes; 3 Chilean National Health Surveys	Chile (nationally representative)	2003–2017 BMI trends; 2019–2030 simulation period	BMI	Projected NCD incidence and mortality (11 diseases) under 4 scenarios	BMI continuing to increase 0.4%/year, ~669,000 NCD cases and ~117,000 deaths attributable to overweight were projected for 2020–2030. Reducing overweight prevalence by 6.7% could prevent ~25,000 cases and ~5,000 deaths. Diabetes and CKD contributed most to attributable incidence, while CVDs accounted for 58.5% of attributable deaths.	B
31	Li et al. (2023)	Observational study	Adults and children (≥1 year); 45 Asian countries; high BMI defined as BMI >25 kg/m² for adults	Asia (45 countries across 6 subregions)	1990–2019	BMI	Numbers and age-standardised rates of deaths and DALYs attributable to high BMI; estimated annual percentage changes; population attributable fractions	Deaths attributable to high BMI in Asia increased 265% 1990–2019 (to 2.33 million), and DALYs increased by 268% (to 80.36 million). ASRs showed continuous upward trends, except in high-income Asia Pacific where rates declined. The burden shifted from women to men since 1995, and DM was the disease most affected by high BMI.	B, C
32	Pomeroy et al. (2021)	Cross-sectional comparative analysis of published	Adults; N = 571 male and n = 268 female population samples	Global	Historical and modern data (majority	Height, sitting height, LLL	Associations of stature and body proportions with temperature, humidity, net primary	Population history explained a large portion of variation in stature, sitting height, and LLL, often more than climatic/environmental variables. After adjusting for population history, temperature remained positively associated with LLL (consistent with Allen’s rule), while NPP was a consistent negative predictor of all anthropometric outcomes.	C

No	Author (Year)	Study Design	Population	Region	Period	AP	Outcomes	Key Findings	RQ
		anthropometric data	from indigenous groups worldwide		post-1870; sensitivity analysis for pre-1950)		productivity (NPP), and population history		

Annex 1 Data Extraction and Synthesis Table

9.2 Supplementary Table: Supervisor-Recommended References on Secular Trends in Adult Height and Body Proportions

The following references were integrated narratively to provide context on secular trends in adult height, relative leg length, and body proportions (see Section 2.1) and are not part of the formal 32-study synthesis or the PRISMA flow diagram. They are cited in Sections 3.1.1, 3.1.4, 4.2.4, 4.3.3, 4.4.2 and 5.5.

No	Author (Year)	Study Design	Population	Region	Period	AP	Outcomes	Key Findings	Used in Section
1	Cole (2003)	Narrative biological review	General populations; historical and contemporary data	Europe, USA, Japan (multi-country)	~1850–2000 (150 years)	Height, sitting height, leg length, BMI	Secular trends in human physical growth; underlying biology	Adult height has increased in most industrialised countries since the mid-19th century (e.g. Dutch men from 165 cm in 1860 to 181 cm in 1990). Height trend has plateaued in Northern Europe while continuing in Southern Europe. The secular increase in height occurs mainly in the first 2 years of life and is due almost entirely to an increase in leg length rather than trunk length.	3.1.1, 3.1.4, 4.2.4, 4.3.3, 4.4.2, 5.5
2	Bartowiak et al. (2024)	Serial cross-sectional survey (four decennial surveys)	Rural Polish adults 25–60 yrs; both sexes; parents of school children; N = 15,460	West-central Poland (Greater Poland region, 10 rural communities)	1986–2016	Height (self-reported, corrected for overestimation and age-related loss)	Secular changes in adult height	Males gained 5.41 cm, females 2.95 cm between 1986–2016. Annual gains of 0.15 cm (men) and 0.09 cm (women). Gains were significant only in cohorts born after 1950; cohorts born before 1950 (WWII era) showed minimal change. Male secular gains exceeded female gains.	4.2.4, 5.5
3	Hitka & Gejdoš (2023)	Observational longitudinal trend analysis	Adult Slovak population 18–25 yrs; both sexes; N = 11,052 (5,353 M, 5,699 F)	Slovakia (nationwide)	1965–2022	Height, body weight, BMI	Secular trends in stature, weight, and BMI	Annual height increase: 0.14 cm (men), 0.10 cm (women). Annual body weight increase: 0.19 kg (men), 0.08 kg (women). BMI showed continuous increase in both sexes. Slight decrease in BMI and body weight observed in last 3 years (2020–2022).	4.2.4, 5.5
4	Quanjer et al. (2015)	Observational cross-sectional, longitudinal cohort analysis	Healthy Japanese adults 17–95 yrs; both sexes; N = 20,336 (13,492 F); plus historical 17-yr-old cohorts	Japan	1932–2012 (Cormic index), 2007–2010 (spirometry)	Height, sitting height, leg length, Cormic index (sitting height/standing height ratio), FEV1, FVC	Secular changes in relative leg length; impact on spirometric reference values	Cormic index rose until 1942, fell to nadir in 1970s, rose again after 1980. Median height increased by 12.8 cm (men) and 15.4 cm (women) between 1920–1970 birth cohorts, then plateaued. Up to 50% of age-specific variation in FEV1 and FVC in Japanese cohorts attributable to cohort differences in Cormic index. Height increase occurred predominantly through gains in leg length, not trunk length.	3.1.4, 4.2.4, 4.3.3, 5.5

No	Author (Year)	Study Design	Population	Region	Period	AP	Outcomes	Key Findings	Used in Section
5	Bogin & Varela-Silva (2010)	Narrative review with meta-synthesis of empirical studies	General populations; children and adults; multiple ethnic groups	Global (multi-country)	Historical data	Leg length, sitting height ratio, Cormic index, relative leg length	Leg length as marker of early-life conditions; associations with health risks	Shorter legs relative to total stature are associated with greater risk of coronary heart disease, T2DM, impaired glucose/insulin regulation, hypertension, and liver dysfunction. Longer legs are associated with moderately increased risk of some cancers (colorectal, prostate, post-menopausal breast) possibly mediated via IGF-1. Leg length is a sensitive indicator of early developmental conditions. Populations with better living conditions show greater relative leg length.	3.1.4, 4.3.3
6	NCD Risk Factor Collaboratio n (2016)	Pooled analysis of population-based measurement studies (Bayesian hierarchical model)	Adults ≥18 yrs; both sexes; N = 18.6 million; 1,472 studies	Global (200 countries, 21 regions)	Birth cohorts 1896–1996	Height	Mean adult height trends by country, sex, and birth cohort	Largest gains: South Korean women (+20.2 cm) and Iranian men (+16.5 cm). Little change in many sub-Saharan African and South Asian countries. Tallest men born in the Netherlands (>182.5 cm). Shortest women in Guatemala (~149 cm). Height plateaued in Northern Europe and USA; continuing increase in parts of Southern/Eastern Europe and East Asia. Global height gap of ~20 cm between tallest and shortest populations persisted over the century.	4.2.4, 5.5
7	Podstawski & Żurek (2021)	Serial cross-sectional study (2-year intervals over 18 years)	Polish male university students aged 19–25 yrs; N = 2,691	Poland (University of Warmia and Mazury, Olsztyn)	2000–2018 (18-year interval)	Height, body weight, BMI, body composition, motor ability tests	Secular changes in anthropometric and motor characteristics	Students in 2018 were 1.7 cm taller than peers in 2000 (annual gain ~0.1 cm/year). Body mass and BMI decreased between 2000–2006, then steadily increased 2006–2018. Motor fitness scores improved until 2006, then declined. The secular trend of increasing height has continued but at a lower rate than in preceding decades.	4.2.4
8	Biehler-Gomez et al. (2023)	Diachronic skeletal anthropological analysis	Adult skeletal remains from necropolises of the urban poor; N = 549 (266 F, 283 M)	Milan, Italy (13 archaeological sites)	Roman era (1st–5th c. AD) to Contemporar y era (19th–21st c. AD) – ~2000 years	Stature (estimated from long bones via Trotter 1970 formulae)	Diachronic trend of adult stature	No statistically significant changes in adult stature across historical periods for either sex in Milan. Male stature ranged 167.6–169.8 cm; female stature 157.1–158.7 cm. Results attributed to stable urban living conditions, early welfare infrastructure, and socio-economic buffering against negative secular trends observed elsewhere in Europe.	4.2.4, 5.5

Annex 2 Supplementary Table: Supervisor-Recommended References on Secular Trends in Adult Height and Body Proportions

9.3 Abbreviations of Annexes

ABSI – A Body Shape Index

AF – Atrial Fibrillation

AOR – Adjusted Odds Ratio

AP – Anthropometric Parameters

ASR – Age-Standardised Rate

AUC – Area Under the Curve

BAI – Body Adiposity Index

BF% – Body Fat Percentage

BIA – Bioelectrical Impedance Analysis

BMI – Body Mass Index

BP – Blood Pressure

BW – Body weight

CAD – Coronary Artery Disease

CHNS – China Health and Nutrition Survey

CI – Confidence Interval

CKD – Chronic Kidney Disease

COVID-19 – Coronavirus Disease 2019

CVD – Cardiovascular Disease

DALYs – Disability-Adjusted Life Years

DFTJ – Dongfeng-Tongji (cohort)

DM – Diabetes Mellitus

DXA – Dual-Energy X-ray Absorptiometry

eGFR – Estimated Glomerular Filtration Rate

EPIC – European Prospective Investigation into Cancer and Nutrition

F – Female

FEV1 – Forced Expiratory Volume in 1 Second

FU – Follow Up

FVC – Forced Vital Capacity

GBD – Global Burden of Disease

HbA1c – Glycated Haemoglobin

HC – Hip Circumference

HDL-C – High- Density Lipoprotein C

HF – Heart Failure

HR – Hazard Ratio

HSE – Health Survey for England

HTN – Hypertension

IL-6 – Interleukin-6

LDL-C – Low-Density Lipoprotein Cholesterol

LLL – Lower Limb Length

LM – Lean Mass

M – Male

MI – Myocardial infarction

MRI – Magnetic Resonance Imaging

N – Total Number of participants

n – Number of participants in subgroups

NCD – Non-Communicable Disease

NHANES – National Health and Nutrition Examination Survey

NPP – Net Primary Productivity

PAF – Population Attributable fraction

Q1 – Quintile 1

Q5 – Quintile 5

ROC – Receiver Operating Characteristic

RQ – Research Question

RR – Relative Risk

SDI – Socio-Demographic Index

SES – Socioeconomic Status

T2DM – Type 2 Diabetes Mellitus

TC – Thigh Circumference

VAI – Visceral Adiposity Index

VAT – Visceral Adipose Tissue

WC – Waist Circumference

WHO – World Health Organization

WHR – Waist-to-Hip Ratio

WHtR – Waist-to-Height Ratio

WWII – World War II

Yrs – Years