Rocz Panstw Zakl Hig 2026;77(1):75-82
https://roczniki.pzh.gov.pl/
https://doi.org/10.32394/rpzh/225361

ORIGINAL ARTICLE

OBESITY, INSUFFICIENT PHYSICAL ACTIVITY AND LIFE EXPECTANCY ACROSS 172 COUNTRIES: A LONGITUDINAL ECOLOGICAL PANEL STUDY

Ekaterina Lyulina[1], *Gulsara Asatova*[2], *Lesya Korobeynikova*[3], *Georgiy Korobeynikov*[3]

[1]Department of Marital Arts, Uzbek State University of Physical Education and Sport, Chirchik, Uzbekistan
[2]Graduate Studies Office, Uzbek State University of Physical Education and Sport, Chirchik, Uzbekistan
[3]Department of Combat Sports, National University of Ukraine on Physical Education and Sport, Kyiv, Ukraine

ABSTRACT

Background. Obesity and insufficient physical activity are major global health risks, but their population-level associations with life expectancy may overlap because both evolve with economic and epidemiological transition.
Objective. To compare the strength and robustness of the associations of adult obesity prevalence and insufficient physical activity with life expectancy at birth in a longitudinal ecological panel of countries.
Material and Methods. Annual country-level data for 2000-2020 were analysed. The full source panel contained 4,095 country-year observations from 195 countries, and the primary complete-case sample included 3,365 observations from 172 countries. Life expectancy at birth was the outcome. Adult obesity prevalence and insufficient physical activity were the main exposures. Models included two-way fixed-effects specifications with country-clustered standard errors, one-year lagged exposures, a joint lagged specification, country-specific time trends, a non-linear obesity model, a smoking sensitivity analysis, and three-year and five-year lag sensitivity models.
Results. In standalone lagged models, obesity ($\beta = -0.3017$, $p < 0.001$) and insufficient physical activity ($\beta = -0.0716$, $p = 0.020$) were inversely associated with life expectancy. In the joint lagged model, obesity remained significant ($\beta = -0.2873$, $p < 0.001$), whereas insufficient physical activity attenuated to non-significance ($\beta = -0.0153$, $p = 0.643$). In the country-specific time-trends model, obesity remained significant ($\beta = -0.2496$, $p = 0.040$), but insufficient physical activity did not ($\beta = 0.1325$, $p = 0.457$). Three-year and five-year lag models supported this pattern.
Conclusions. In this country-level panel, adult obesity prevalence showed a more robust inverse association with life expectancy than insufficient physical activity. The findings should not be interpreted as evidence that obesity alone causes lower life expectancy. Rather, obesity may represent a cumulative marker of overlapping metabolic, social, environmental, and policy-related processes that shape population longevity.

Supplementary information: The online version contains supplementary material available at 10.32394/rpzh/225361

Keywords: *obesity, motor activity, life expectancy, epidemiology, longitudinal studies, public health, risk factors*

INTRODUCTION

Obesity and insufficient physical activity are among the most important modifiable contributors to the global burden of non-communicable disease. The World Health Organization (WHO) defines obesity in adults as a body mass index of 30 kg/m² or higher [1]. Insufficient physical activity is also a major population health risk and contributes to the burden of non-communicable diseases (NCDs) [2].

Recent surveillance makes the public health relevance of both exposures clear. Global pooled estimates suggest that adult insufficient physical activity increased from 23.4% in 2000 to 31.3% in 2022, equivalent to approximately 1.8 billion adults not meeting recommended activity levels [3]. In parallel, evidence from NCD Risk Factor Collaboration (NCD-RisC) and the Global Burden of Disease (GBD) indicates that adult obesity has increased substantially and is projected to remain a major chronic-disease driver in the coming decades [4, 5]. Obesity is associated with multiple cardiometabolic complications and heterogeneous metabolic phenotypes [6, 7]. WHO guidance also emphasizes that regular physical activity supports cardiovascular, metabolic, musculoskeletal and mental health [8].

Corresponding author: Ekaterina Lyulina, Department of Marital Arts, Uzbek State University of Physical Education and Sport, Chirchik, Uzbekistan; email: sportuz8@gmail.com

Publisher: National Institute of Public Health NIH - National Research Institute

Individual-level evidence indicates that physical activity, cardiorespiratory fitness and adiposity are interrelated but not interchangeable predictors of mortality and life expectancy [9-13]. At the population level, however, disentangling the independent epidemiological roles of obesity and insufficient physical activity remains methodologically challenging. Both indicators co-vary with economic development, urbanization, demographic ageing, shifts in occupational and transport systems, food environments, health-care access and broader epidemiological transition. As a result, cross-national associations may reflect shared macro-structural drivers rather than entirely separate population-level processes [14-16].

A key gap in the literature is that, although obesity and insufficient physical activity are both well-established population health risks, fewer longitudinal cross-national studies directly compare their relative associations with life expectancy within the same analytical framework. At the ecological level, it remains uncertain whether insufficient physical activity retains an independent association with life expectancy after obesity and structural time trends are included, or whether its statistical signal largely overlaps with obesity and shared macro-social change.

Therefore, the aim of this study was to compare the relative strength and robustness of the associations of adult obesity prevalence and insufficient physical activity with life expectancy at birth in a longitudinal ecological panel. The study addressed two questions: (1) Are adult obesity prevalence and insufficient physical activity each independently associated with life expectancy at birth in cross-national longitudinal models? (2) Do any of these exposures retain an independent association with life expectancy after adjustment for structural covariates, country and year fixed effects, and stricter temporal specifications?

MATERIAL AND METHODS

Study design

A longitudinal ecological panel design was used based on harmonized annual country-level data from 2000 to 2020.

Data sources and variables

Data were derived from official international repositories, primarily the World Health Organization Global Health Observatory and the World Bank World Development Indicators [17-20]. The dependent variable was life expectancy at birth, measured in years. The two main explanatory variables were adult obesity prevalence, defined as the age-standardized percentage of adults with BMI $\geq$ 30 kg/m², and the age-standardized prevalence of insufficient physical activity among adults aged 18 years and older.

Time-varying country-level covariates were included to reduce omitted-variable bias. These covariates were log GDP per capita, urban population as a percentage of total population, current health expenditure as a percentage of GDP, alcohol consumption per capita in litres of pure alcohol, and the proportion of the population aged 65 years and older. Smoking prevalence was available only for a substantially smaller subset of country-year observations and was therefore used in a separate sensitivity analysis rather than in the main models.

Reporting guideline

This study was reported in accordance with the STROBE recommendations, applied where relevant to an ecological design, including reporting of data sources, eligibility criteria, missing data, statistical methods and limitations [21, 22].

Country and observation eligibility, missing data, and analytical sample

No eligibility restrictions were applied at the country level. All countries available in the source repositories were retained, and the analytical sample was determined solely by data availability under complete-case estimation. Countries were included when they had at least one available country-year record for the study period in the harmonized source panel. The full 2000-2020 source panel contained 4,095 country-year records from 195 countries with at least one available indicator. Because variables differed in temporal coverage, observation counts varied across indicators and model specifications. The main inferential sample was defined by complete-case availability for the joint lagged two-way fixed-effects model and included 3,365 country-year observations from 172 countries. Accordingly, the 172 countries reported in the title and main text refer to the restricted complete-case analytical sample used for the primary regression models. Because inclusion was based on data availability rather than probability sampling, the analytical sample should be interpreted as a broad data-available country panel rather than as a statistically representative sample of all countries. Nevertheless, the panel retained countries across diverse socioeconomic, demographic and epidemiological contexts.

Missing data were handled using listwise deletion within each model specification; no multiple imputation was applied. This approach was chosen because the study relied on secondary international indicators which are frequently modelled or smoothed by the original data providers and because the aim was to preserve transparent comparability across fixed-effects specifications. The smaller smoking-observed sample comprised 744 country-year observations from 150 countries after applying the same lagged complete-case criterion.

Life expectancy audit and data cleaning

The life-expectancy variable was audited for implausible values before the final analyses. Six country-year records with life expectancy below 40 years were identified in the 2000-2020 panel. Because these values were inconsistent with plausible country-level life expectancy during the study period, they were treated as missing. No replacement values were imputed. Following this audit, the minimum observed life expectancy in the cleaned analytical panel was 40.27 years.

Statistical analysis

The analytical strategy was designed to reduce the risk of misleading inference arising from shared temporal trends and co-evolving macro-structural change. One-year lagged exposures were used in the primary models to establish temporal ordering between country-level risk indicators and life expectancy while preserving the largest possible complete-case analytical sample. First, separate one-year-lagged two-way fixed-effects (TWFE) models were estimated for obesity and for insufficient physical activity. These models included country fixed effects, year fixed effects and robust standard errors clustered by country. Second, a joint lagged model included both exposures simultaneously in order to assess whether each retained an independent association with life expectancy after adjustment for the other exposure.

Third, a country-specific time-trends (CSTT) specification added a separate linear time trend for each country as a stricter test against spurious associations driven by country-specific modernization trajectories. Fourth, a non-linear obesity model added current obesity prevalence and a quadratic obesity term to evaluate whether the association with life expectancy became stronger at higher obesity prevalence. Fifth, a smoking-based sensitivity analysis was estimated on the smaller smoking-observed subsample. Because the effects of obesity-related metabolic risk on mortality and population longevity may develop over longer periods, additional three-year and five-year lag sensitivity models were estimated.

All regression models adjusted for log GDP per capita, urbanization, health expenditure, alcohol consumption per capita and the share of the population aged 65 years and older. Statistical significance was assessed at $p < 0.05$. Analyses were conducted in Stata 14.2. For descriptive panel diagnostics, between-country and within-country standard deviations were calculated for the main indicators, where the between-country standard deviation captures cross-national heterogeneity and the within-country standard deviation captures temporal variation within countries over 2000-2020.

Ethical considerations

The study was ecological and used publicly accessible, aggregated country-level data. No individual patient data were analysed and ethics committee approval was not required. Because the study relied on secondary international data repositories, no informed consent procedures were applicable.

RESULTS

Descriptive statistics

Table 1 summarizes the descriptive statistics for the 2000-2020 panel. Mean life expectancy across country-year observations was 69.63 years (SD = 8.87). Regarding the main exposures, the prevalence of insufficient physical activity averaged 26.46% (SD = 10.88), whereas the average prevalence of adult obesity was 18.51% (SD = 12.45). The mean urbanization level was 56.62%, mean current health expenditure was 6.17% of GDP, and mean alcohol consumption was 5.46 litres per capita. Observation counts differed across variables because of indicator-specific missingness. Table S1 (supplementary material) documents variable-specific country coverage and average years of observation, and Table S2 (supplementary material) reports between-country and within-country variation in the main indicators. The within-country standard deviations for life expectancy (2.33 years), insufficient physical activity (3.04 percentage points) and adult obesity prevalence (2.79 percentage points) indicate that the panel contained temporal variation relevant for fixed-effects estimation, although between-country heterogeneity was larger for most indicators.

In the 2000-2020 analytical panel, life expectancy ranged from 40.27 years in the Central African Republic in 2014 to 84.67 years in Japan in 2020.

Main regression models

In the lagged standalone models, both exposures were inversely associated with life expectancy (Table 2). The obesity-only coefficient was larger in magnitude ($\beta = -0.3017$, $p < 0.001$) than the coefficient for insufficient physical activity ($\beta = -0.0716$, $p = 0.020$). Once both exposures were introduced simultaneously, obesity remained negatively and statistically significantly associated with life expectancy ($\beta = -0.2873$, $p < 0.001$), whereas insufficient physical

Table 1. Descriptive statistics for the 2000–2020 analytical panel

Variable	Obs.	Mean	SD	Min-Max
Life expectancy (years)	3,732	69.63	8.87	40.27-84.67
Insufficient physical activity (%)	4,095	26.46	10.88	3.17-64.65
Obesity prevalence (%)	4,074	18.51	12.45	0.31-69.94
GDP per capita	3,914	21,274.47	23,126.92	702.60-145,591.02
Log GDP per capita	3,914	9.36	1.17	6.55-11.89
Urbanization (%)	4,053	56.62	22.94	8.04-100.00
Health expenditure (% of GDP)	3,934	6.17	2.83	1.11-24.23
Alcohol consumption (litres per capita)	3,891	5.46	4.18	0.00-19.40
Smoking prevalence (%)	984	25.14	11.45	3.60-68.00
Population aged 65+ (%)	4,053	7.68	5.55	0.86-28.92

Note. Life-expectancy values below 40 years (n = 6) were audited, considered implausible, and treated as missing. Observation counts are variable-specific because missingness differed across indicators. The primary complete-case joint TWFE model included 3,365 country-year observations from 172 countries.

Table 2. Main lagged regression models

Variable	(1) Lagged obesity only	(2) Lagged inactivity only	(3) Joint lagged TWFE	(4) Joint lagged CSTT
Lagged obesity	-0.3017 (0.0591)**		-0.2873 (0.0685)	-0.2496 (0.1207)*
Lagged inactivity		-0.0716 (0.0306)*	-0.0153 (0.0329)**	0.1325 (0.1779)
Log GDP per capita	2.6720 (0.6814)**	3.0200 (0.7445)**	2.7163 (0.6948)**	0.6082 (0.4518)
Urbanization	0.0226 (0.0448)	0.0497 (0.0458)	0.0236 (0.0441)	-0.0989 (0.0835)
Health expenditure	0.0968 (0.0663)	0.1026 (0.0677)	0.0977 (0.0660)	0.0275 (0.0468)
Alcohol	-0.1906 (0.0833)*	-0.1792 (0.0839)*	-0.1862 (0.0822)*	-0.0280 (0.0592)
Population aged 65+	-0.6674 (0.0926)**	-0.5720 (0.0926)**	-0.6561 (0.0873)**	-0.1572 (0.1002)
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Country-specific linear trends	No	No	No	Yes
Observations	3,365	3,365	3,365	3,365
Countries (clusters)	172	172	172	172
R^2/within R^2	0.7135	0.6922	0.7137	0.9946

Note. Unstandardized coefficients with country-clustered robust standard errors in parentheses. TWFE – two-way fixed effects; CSTT – country-specific time trends. * $p < 0.05$, ** $p < 0.001$.

activity attenuated markedly and was no longer statistically significant (β = -0.0153, p = 0.643).

The country-specific time-trends model provided a stricter temporal test because it included country fixed effects, year effects and each country's own linear trajectory. In this specification, lagged obesity remained statistically significant (β = -0.2496, p = 0.040), whereas lagged insufficient physical activity did not (β = 0.1325, p = 0.457).

Additional analyses

Table 3 presents the non-linear obesity model and smoking sensitivity models. In the non-linear model, the quadratic obesity term was negative and statistically significant (β = -0.0044, p = 0.010), suggesting that the association between obesity prevalence and life expectancy became more adverse at higher levels of obesity prevalence. The linear obesity coefficients were not individually significant, which is common when a variable enters the model in both linear and squared form.

Of the 984 country-year records with available smoking data, 744 remained after applying the one-year lag and complete-case criterion used in the regression model. In the smoking-observed subsample, obesity remained statistically significant before and after smoking adjustment, whereas insufficient physical activity remained non-significant. Lagged smoking itself was not statistically significant in the adjusted sensitivity model (β = -0.0278, p = 0.355).

Table 3. Additional analyses: non-linear obesity model and smoking robustness

Variable	(1) Non-linear obesity model	(2) Smoking subsample, no smoking	(3) Smoking subsample + smoking
Lagged obesity	-1.2046 (0.8733)	-0.3106 (0.0720)***	-0.3013 (0.0749)***
Lagged inactivity	-0.0355 (0.0305)	-0.0047 (0.0332)	-0.0039 (0.0335)
Lagged smoking			-0.0278 (0.0299)
Obesity	1.1851 (0.7968)		
Obesity squared	-0.0044 (0.0017)*		
Log GDP per capita	2.0865 (0.6863)**	1.8420 (0.5919)**	1.8149 (0.5975)**
Urbanization	-0.0077 (0.0442)	0.0483 (0.0290)†	0.0444 (0.0290)
Health expenditure	0.0876 (0.0638)	0.1553 (0.0905)†	0.1536 (0.0900)†
Alcohol	-0.1754 (0.0795)*	-0.1841 (0.0856)*	-0.1879 (0.0850)*
Population aged 65+	-0.6118 (0.0852)***	-0.6365 (0.0942)***	-0.6413 (0.0937)***
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	3,365	744	744
Countries (clusters)	172	150	150
Within R^2	0.7259	0.7556	0.7564

Note. The smoking analysis compares models on the same smoking-observed lagged subsample. Unstandardized coefficients with country-clustered robust standard errors in parentheses. † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4. Sensitivity analysis: 3-year and 5-year lag models

Variable	(1) 3-year lag	(2) 5-year lag
Lagged obesity	-0.3046 (0.0730)***	-0.3185 (0.0785)***
Lagged inactivity	-0.0130 (0.0343)	-0.0104 (0.0351)
Log GDP per capita	2.5535 (0.7048)***	2.2967 (0.7081)**
Urbanization	0.0060 (0.0520)	-0.0147 (0.0614)
Health expenditure	0.0547 (0.0686)	0.0127 (0.0762)
Alcohol	-0.1880 (0.0758)*	-0.1960 (0.0720)**
Population aged 65+	-0.6486 (0.0858)***	-0.6447 (0.0853)***
Country FE	Yes	Yes
Year FE	Yes	Yes
Observations	3,036	2,702
Countries (clusters)	172	172
Within R^2	0.6893	0.6504

Note. Models include country fixed effects, year fixed effects and the same covariates as the main joint TWFE model. Unstandardized coefficients with country-clustered robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Lag sensitivity analysis

Because the biological and epidemiological effects of obesity-related metabolic risk may develop over longer periods than one year, 3-year and 5-year lag sensitivity models were estimated (Table 4). The pattern was consistent with the primary joint model. Lagged obesity remained inversely and significantly associated with life expectancy in both the 3-year lag model ($\beta = -0.3046$, $p < 0.001$) and the 5-year lag model ($\beta = -0.3185$, $p < 0.001$). By contrast, lagged insufficient physical activity remained non-significant in both sensitivity specifications.

DISCUSSION

Principal findings

The main finding was that adult obesity prevalence showed a more stable inverse association with life expectancy than insufficient physical activity once both exposures were modelled jointly. Insufficient physical activity was inversely associated with life expectancy in the standalone model, which is consistent with evidence linking physical activity and fitness to better health and longevity [2, 8-11]. However, this association attenuated after obesity was included, suggesting that at the country level a substantial part of the statistical signal for insufficient physical activity overlaps with obesity and with broader structural processes that shape both behavioral and metabolic risk.

These ecological findings can be read alongside individual-level evidence that reaches a different emphasis. Using the UK Biobank cohort, Zaccardi and colleagues reported that participants with a brisk walking pace had longer life expectancy across the spectrum of body-mass index and other adiposity indices [10], and the accompanying commentary interpreted fitness as predicting longevity largely regardless of adiposity [11]. The present country-level results do not contradict this evidence; rather, they operate at a different level of analysis. At the individual level, fitness captures a proximal physiological capacity. At the population level, obesity prevalence and insufficient physical activity reflect more distal behavioral and structural exposures whose signals are partly shared with obesity and broader development trends. The attenuation of insufficient physical activity in the joint models is therefore consistent with either partial mediation through adiposity or common structural confounding, a distinction the present ecological design cannot resolve. The significant quadratic obesity term is also consistent with individual-level evidence that the BMI–mortality association is graded and non-linear [13].

The persistence of the obesity coefficient is consistent with recent global evidence showing the continuing growth of adult obesity and its substantial cardiometabolic burden [4-7, 13]. Importantly, the present findings should not be read as evidence that obesity is an isolated causal determinant of life expectancy. At the ecological level, obesity prevalence may operate as a cumulative marker of multiple overlapping processes, including food environments, socioeconomic conditions, chronic disease burden, health-care access and treatment quality, physical activity environments, transport systems, and national policy responses.

Interpretation of lag sensitivity findings

The three-year and five-year lag sensitivity models strengthened the robustness of the core result. Obesity remained significantly associated with life expectancy under both longer lag structures, while insufficient physical activity remained non-significant. This pattern is relevant because one-year lags may be too short to capture the full biological footprint of metabolic risk. Nevertheless, even the longer lags used here cannot fully represent lifetime exposure histories or cumulative disease pathways, and therefore the results should remain interpreted as longitudinal ecological associations rather than individual-level causal effects.

Public health implications

The findings support integrated public health strategies rather than a narrow one-risk approach. Obesity prevention remains central because obesity may reflect cumulative metabolic and structural risk at the population level. However, physical activity promotion should not be downgraded; instead, it should be positioned as part of broader systems-oriented strategies that include healthier food environments, active transport, safe and walkable urban spaces, equitable access to prevention and treatment services, and policies targeting the social determinants of non-communicable disease. From this perspective, the attenuation of insufficient physical activity in joint models does not imply that activity is unimportant; it suggests that physical activity policies may be most effective when embedded within wider obesity and NCD prevention frameworks.

Strengths and limitations

This study has several strengths. It used a large longitudinal country-level panel, compared obesity and insufficient physical activity within the same analytical framework, applied a multi-model strategy, included country and year fixed effects, used country-clustered standard errors, incorporated a country-specific time-trends specification, audited implausible life-expectancy values, documented both between-country and within-country variation in the main indicators, and added three-year and five-year lag sensitivity models.

Several limitations should also be noted. First, ecological designs cannot identify individual-level causal pathways and are vulnerable to ecological fallacy. Second, complete-case estimation reduced the effective sample from 195 countries with at least one available indicator to 172 countries in the main models. Third, the study relied on international indicators that may be modelled, smoothed or estimated differently across countries. Fourth, residual confounding remains possible because the models did not directly include educational attainment, income inequality, quality and accessibility of healthcare, dietary patterns, prevalence of chronic diseases, food-system indicators, or detailed national health policies. These indicators were not included in the main regression models because harmonized annual country-level coverage was incomplete and would have substantially reduced the complete-case sample and cross-national comparability. Fifth, smoking data were sparse and available only for a smaller subset of countries and years. Sixth, lag models improve temporal ordering but cannot fully represent long-run cumulative exposure histories.

CONCLUSIONS

In this longitudinal country-level panel, adult obesity prevalence showed a more robust inverse association with life expectancy at birth than insufficient physical activity. Although insufficient physical activity was inversely associated with life expectancy in standalone models, this association attenuated after obesity and structural covariates were included. By contrast, the obesity association remained significant in the joint lagged model, in the country-specific time-trends specification and in three-year and five-year lag sensitivity models. These findings should be interpreted as ecological evidence and do not establish individual-level causality. Overall, the results support integrated public health strategies combining obesity prevention, physical activity promotion and broader non-communicable disease policy interventions.

Acknowledgements

The authors express sincere gratitude to Raufhon Salahodjaev for his dedication to science, his contribution to the dissemination of scientific knowledge, and his promotion of a culture of rigorous, independent, and evidence-based research.

Funding

This work received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

1. World Health Organization. Obesity and overweight [Internet]. Geneva: World Health Organization; 2025. [cited 2026 Jun 9]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
2. World Health Organization. Physical activity [Internet]. Geneva: World Health Organization; 2024. [cited 2026 Jun 9]. Available from: https://www.who.int/news-room/fact-sheets/detail/physical-activity.
3. Strain T, Flaxman S, Guthold R, Semenova E, Cowan M, Riley LM, et al. National, regional, and global trends in insufficient physical activity among adults from 2000 to 2022: a pooled analysis of 507 population-based surveys with 5.7 million participants. Lancet Glob Health. 2024;12(8):e1232-e1243. doi: 10.1016/S2214-109X(24)00150-5.
4. Phelps NH, Singleton RK, Zhou B, Heap RA, Mishra A, Bennett JE, et al.; NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in underweight and obesity from 1990 to 2022: a pooled analysis of 3663 population-representative studies with 222 million children, adolescents, and adults. Lancet. 2024;403(10431):1027-1050. doi: 10.1016/S0140-6736(23)02750-2.
5. Ng M, Gakidou E, Lo J, Abate YH, Abbafati C, Abbas N, et al.; GBD 2021 Adult BMI Collaborators. Global, regional, and national prevalence of adult overweight and obesity, 1990-2021, with forecasts to 2050: a forecasting study for the Global Burden of Disease Study 2021. Lancet. 2025;405(10481):813-838. doi: 10.1016/S0140-6736(25)00355-1.
6. Blüher M. An overview of obesity-related complications: the epidemiological evidence linking body weight and other markers of obesity to adverse health outcomes. Diabetes Obes Metab. 2025;27(Suppl 2):3-19. doi: 10.1111/dom.16263.
7. Blüher M. Metabolically healthy obesity. Endocr Rev. 2020;41(3):bnaa004. doi: 10.1210/endrev/bnaa004.
8. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020;54(24):1451-1462. doi: 10.1136/bjsports-2020-102955.
9. Veerman L, Tarp J, Wijaya R, Wanjau MN, Möller H, Haigh F, et al. Physical activity and life expectancy: a life-table analysis. Br J Sports Med. 2025;59(5):333-338. doi: 10.1136/bjsports-2024-108125.
10. Zaccardi F, Davies MJ, Khunti K, Yates T. Comparative relevance of physical fitness and adiposity on life expectancy: a UK Biobank observational study. Mayo Clin Proc. 2019;94(6):985-994. doi: 10.1016/j.mayocp.2018.10.029.
11. Laukkanen JA, Kunutsor SK. Fitness equals longer life expectancy regardless of adiposity levels. Mayo Clin Proc. 2019;94(6):942-945. doi: 10.1016/j.mayocp.2019.04.016.
12. Hamilton MT, Hamilton DG, Zderic TW. Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. Diabetes. 2007;56(11):2655-2667. doi: 10.2337/db07-0882.
13. Aune D, Sen A, Prasad M, Norat T, Janszky I, Tonstad S, et al. BMI and all cause mortality: systematic review and non-linear dose-response meta-analysis of 230 cohort studies with 3.74 million deaths among 30.3 million participants. BMJ. 2016;353:i2156. doi: 10.1136/bmj.i2156.
14. Di Pietro G. Revisiting the impact of macroeconomic conditions on health behaviours. Econ Hum Biol. 2018;28:173-181. doi: 10.1016/j.ehb.2017.11.001.
15. Yang H, An R, Clarke CV, Shen J. Impact of economic growth on physical activity and sedentary behaviors: a systematic review. Public Health. 2023;215:17-26. doi: 10.1016/j.puhe.2022.11.020.
16. Araujo RHO, Duncombe SL, Werneck AO, Mielke GI, Silva DRP. Macroeconomic and social indicators are associated with prevalence and gender inequalities in physical activity among adolescents: a global perspective. J Phys Act Health. 2026:1-8. doi: 10.1123/jpah.2025-0491. Epub ahead of print.

17. World Health Organization. Obesity among adults, BMI >=30, prevalence (age-standardized estimate) (%) [Internet]. Geneva: World Health Organization. [cited 2026 Jun 9]. Available from: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/prevalence-of-obesity-among-adults-bmi-%3D-30-%28age-standardized-estimate%29-%28-%29.
18. World Health Organization. Physical activity, insufficient, among adults aged 18+ years, prevalence (age-standardized estimate) (%) [Internet]. Geneva: World Health Organization. [cited 2026 Jun 9]. Available from: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/prevalence-of-insufficient-physical-activity-among-adults-aged-18-years-%28age-standardized-estimate%29-%28-%29.
19. World Bank. World Development Indicators: life expectancy at birth, total (years), indicator SP.DYN.LE00.IN [Internet]. Washington (DC): World Bank. [cited 2026 Jun 9]. Available from: https://data.worldbank.org/indicator/SP.DYN.LE00.IN.
20. World Bank. World Development Indicators [Internet]. Washington (DC): World Bank. [cited 2026 Jun 9]. Available from: https://data.worldbank.org/.
21. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. PLoS Med. 2007;4(10):e296. doi: 10.1371/journal.pmed.0040296.
22. STROBE Initiative. STROBE checklists [Internet]. Bern: STROBE. [cited 2026 Jun 9]. Available from: https://www.strobe-statement.org/checklists/.

Received: 23.04.2026
Revised: 12.06.2026
Accepted: 02.07.2026