




Children's and adolescents' rising animal-source food intakes in 1990–2018 were impacted by age, region, parental education and urbanicity

Received: 8 August 2022

Accepted: 9 March 2023

Published online: 20 April 2023

 Check for updates

Victoria Miller ^{1,2,3} ✉, Patrick Webb ¹, Frederick Cudhea¹, Jianyi Zhang^{1,4}, Julia Reedy¹, Peilin Shi¹, Josh Erndt-Marino¹, Jennifer Coates¹, Renata Micha^{1,5}, Dariush Mozaffarian ¹ & Global Dietary Database*

Animal-source foods (ASF) provide nutrition for children and adolescents' physical and cognitive development. Here, we use data from the Global Dietary Database and Bayesian hierarchical models to quantify global, regional and national ASF intakes between 1990 and 2018 by age group across 185 countries, representing 93% of the world's child population. Mean ASF intake was 1.9 servings per day, representing 16% of children consuming at least three daily servings. Intake was similar between boys and girls, but higher among urban children with educated parents. Consumption varied by age from 0.6 at <1 year to 2.5 servings per day at 15–19 years. Between 1990 and 2018, mean ASF intake increased by 0.5 servings per week, with increases in all regions except sub-Saharan Africa. In 2018, total ASF consumption was highest in Russia, Brazil, Mexico and Turkey, and lowest in Uganda, India, Kenya and Bangladesh. These findings can inform policy to address malnutrition through targeted ASF consumption programmes.

Child malnutrition is devastating globally, including micronutrient deficiencies, stunting, underweight and wasting, as well as growing diet-related syndromes, including overweight, obesity and poor metabolic health¹. While undernutrition decreased over recent decades, an estimated 149 million children under 5 years were stunted in 2020, and 45 million children were wasted². These conditions remain most prevalent in Asia and Africa². In addition, more than 372 million infants and young children have micronutrient deficiencies³, which can inhibit healthy growth and development, and increase child mortality⁴; and 38 million children are overweight, with prevalence rates rising steadily in most geographic regions^{1,2,5}. The 2021 *Lancet* series on adolescent nutrition emphasized the scarcity of nationally representative data

to characterize adolescent diets during this important developmental period^{6–8}. Nutrition during childhood and adolescence affects linear growth, body composition, brain growth and development, and immune function^{9–11}. The consequences of poor diet during adolescence are exemplified by the doubling of obesity rates, as well as increased anaemia between 1990 and 2016¹².

Animal-source foods (ASF) have an important dietary influence on the health of children and adolescents. ASF are rich in amino acids, fatty acids and several micronutrients of concern, including iron, zinc, iodine and vitamin A, intake of which is widely deficient in lower-income countries¹³. Specific ASF have other health benefits, such as omega-3 fatty acids in fish, calcium and vitamin D in dairy, probiotics in yogurt and

¹Friedman School of Nutrition Science and Policy, Tufts University, Boston, MA, USA. ²Department of Medicine, McMaster University, Hamilton, Ontario, Canada. ³Population Health Research Institute, Hamilton, Ontario, Canada. ⁴Division of General Internal Medicine and Primary Care, Brigham and Women's Hospital, Boston, MA, USA. ⁵Department of Food Science and Nutrition, University of Thessaly, Thessaly, Greece. *A list of authors and their affiliations appears at the end of the paper. ✉e-mail: Victoria.Miller@Tufts.edu

menaquinones in cheese. In a meta-analysis of randomized controlled trials, food-based animal protein supplementation during infancy and early childhood increased child weight, increased height-for-age z-score and reduced the risk of stunting, but had no effect on height alone or wasting¹⁴.

At the same time, different ASF have implications for planetary health—particularly livestock production for red meat, which increases greenhouse gas emissions and has other negative environmental effects^{3,15}—as well as negative implications for health later in adulthood, particularly related to processed meat¹⁶. Thus, beyond direct impacts during childhood and adolescence, food habits and preferences developed at younger ages translate to adulthood¹⁷, with long-term implications for human and planetary health. Understanding the distribution and heterogeneity in intakes of ASF among children and adolescents around the world is critical for establishing priorities to promote healthy growth and development during childhood, developing dietary preferences to promote health in adulthood and reducing the environmental impacts of food production and consumption.

Some limited nutritional data on ASF consumption are systematically collected, standardized and reported for <5 and ≥15 years of age in low-income countries^{18,19}. Prior global or regional reports did not assess ASF intakes among children 5–14 years old^{20–22}. In a recent report, we provided global estimates of ASF consumption among children (<19 years)²³. However, detailed information by age was not reported. Importantly, ASF consumption and malnutrition may also both vary in children and adolescents according to sociodemographic characteristics, such as parental education and urban or rural residence. Furthermore, such variation may not be uniform by world region, country, age group or time. However, distributions of global ASF intake by children and adolescents according to age, parental education and urbanicity have not previously been reported.

To address these major gaps in knowledge, we investigated and report on intakes of major categories of ASF among children and adolescents by age (from birth to age 19 years), sex, parental education level, urbanicity, country and world region between 1990 and 2018, using systematically collected and standardized individual-level national dietary surveys and Bayesian modelling from the Global Dietary Database (GDD).

Results

Global, regional and national total ASF consumption

Worldwide, total ASF consumption by children and adolescents (from birth to age 19 years) in 2018 was 1.9 servings per day (95% uncertainty interval: 1.9, 2.1), ranging from 0.8 in South Asia to 4.2 in Central/Eastern Europe and Central Asia (Fig. 1). Globally, ASF consumption varied 4.5-fold by age group, from 0.6 in age <1 year to 2.5 in 15–19 years. Among the world's 20 most populous countries, mean ASF intake was highest in Russia, Brazil, Mexico and Turkey (range: 3.0–5.0 servings per day), and lowest in Uganda, India, Kenya and Bangladesh (range: 0.7–0.8; Fig. 2).

Global, regional and national consumption of dairy

Mean milk intake globally was 103 g d⁻¹ (98, 109; equivalent to 0.4 servings per day); cheese intake, 6 g d⁻¹ (6, 7; equivalent to 0.1 servings per day); and yogurt intake, 18 g d⁻¹ (15, 21; equivalent to 0.5 servings per week; Fig. 1). Globally, mean milk intake was highest among ages 10–14 years (115 g d⁻¹; 108, 122), followed by 5–9 years (112 g d⁻¹; 105, 118), 15–19 years (105 g d⁻¹; 100, 111), 3–4 years (92 g d⁻¹; 87, 98), 1–2 years (77 g d⁻¹; 73, 82) and <1 year (63 g d⁻¹; 58, 67).

A 5.5-fold difference in milk intake was found across regions, from 46 g d⁻¹ in sub-Saharan Africa to 252 in high-income countries (Fig. 1). Among populous countries, mean intakes were highest in Mexico, the United States, Brazil and Turkey (222–257 g d⁻¹), and lowest in Nigeria, the Democratic Republic of the Congo, Bangladesh and Tanzania (32–43 g d⁻¹).

Mean regional cheese intake ranged from 1 g d⁻¹ in South Asia and sub-Saharan Africa to 29 in Central/Eastern Europe and Central Asia (Fig. 1). Among populous countries, highest intakes were in the United States, Turkey, Russia and Mexico (15–26 g d⁻¹), and lowest in Uganda, the Democratic Republic of the Congo, Bangladesh, India, Tanzania, Pakistan, the Philippines, Nigeria and Kenya (≤1 g d⁻¹).

Mean regional consumption of yogurt ranged from 6 to 73 g d⁻¹ (Fig. 1). Among populous countries, national intakes were lowest in Uganda, Indonesia, Bangladesh, Tanzania and Kenya (≤5 g d⁻¹), and highest in Turkey, Russia, Iran and Mexico (23–105 g d⁻¹).

Global, regional and national consumption of eggs

Mean global intake of eggs was 17 g d⁻¹ (15, 20; equivalent to 0.3 servings per day) in 2018, with regional consumption 5- to 7-fold higher in Southeast and East Asia (5–34 g d⁻¹), Central/Eastern Europe and Central Asia, the Middle East and Northern Africa, and Latin America and the Caribbean compared with sub-Saharan Africa and South Asia (Fig. 1). Among populous countries, national intakes were lowest in the Democratic Republic of the Congo, Kenya, Tanzania, Uganda and Nigeria (≤4 g d⁻¹), and highest in Vietnam, China, Mexico and Russia (33 to 44 g d⁻¹). National egg intake was moderately correlated with intake of unprocessed red meat ($r = 0.6$) and processed meat ($r = 0.5$), but not seafood ($r = -0.03$).

Global, regional and national consumption of seafood

Worldwide, mean seafood consumption was 21 g d⁻¹ (20, 23; equivalent to 0.2 servings per day), ranging from 2 g d⁻¹ (2, 2) in age <1 year to 31 g d⁻¹ (29, 33) in 15–19 years (Fig. 1). Regionally, seafood intake was highest in Southeast and East Asia (32 g d⁻¹; 30, 35), followed by sub-Saharan Africa, Central/Eastern Europe and Central Asia, the Middle East and Northern Africa, and Latin America and the Caribbean. Intake was lowest in high-income countries and South Asia (-10 g d⁻¹). Among populous countries, mean intakes were highest in Vietnam, Indonesia, the Democratic Republic of the Congo and Bangladesh (37–43 g d⁻¹), and lowest in Pakistan, Ethiopia, Turkey, and the United States (≤6 g d⁻¹). National seafood intake was negatively correlated with unprocessed red meat intake ($r = -0.2$) and not correlated with processed meat intake ($r = 0.008$).

Global, regional and national consumption of meats

The mean global consumption of unprocessed red meat in 2018 was 40 g d⁻¹ (38, 42; equivalent to 0.4 servings per day), varying with age at 3 g d⁻¹ (3, 4) in children age <1 year, 9 g d⁻¹ (8, 9) in 1–2 years, 19 g d⁻¹ (17, 20) in 3–4 years, 38 g d⁻¹ (36, 41) in 5–9 years, 54 g d⁻¹ (51, 57) in 10–14 years and 59 g d⁻¹ (56, 63) in 15–19 years (Fig. 1). By region, unprocessed red meat consumption was highest across all ages in Central/Eastern Europe and Central Asia, and Southeast and East Asia, and lowest in South Asia and sub-Saharan Africa. Among the 20 most populous countries, intakes ranged widely from 3 to 152 g d⁻¹: highest in Russia, China, Brazil and Vietnam, and lowest in India, Bangladesh, Ethiopia and Uganda.

Globally, mean consumption of processed meat was 18 g d⁻¹ (15, 23; equivalent to 0.4 servings per day), with a 15-fold difference across regions (from 3 g d⁻¹ in South Asia to 44 g d⁻¹ in Central/Eastern Europe and Central Asia; Fig. 1). Among populous countries, national intakes were highest in the Philippines, Indonesia, Brazil and Russia (40–71 g d⁻¹), and lowest in Bangladesh, Kenya, India and Tanzania (≤4 g d⁻¹).

Across nations in 2018, unprocessed red meat and processed meat were moderately correlated ($r = 0.5$). In most countries, unprocessed red meat consumption exceeded processed meat consumption; for example, Papua New Guinea (231 versus 10 g d⁻¹), Latvia (178 versus 47 g d⁻¹), Montenegro (179 versus 52 g d⁻¹), Croatia (219 versus 94 g d⁻¹) and South Africa (135 versus 19 g d⁻¹). Notable exceptions included Sierra Leone (9 versus 67 g d⁻¹), Mongolia (58 versus 114 g d⁻¹),

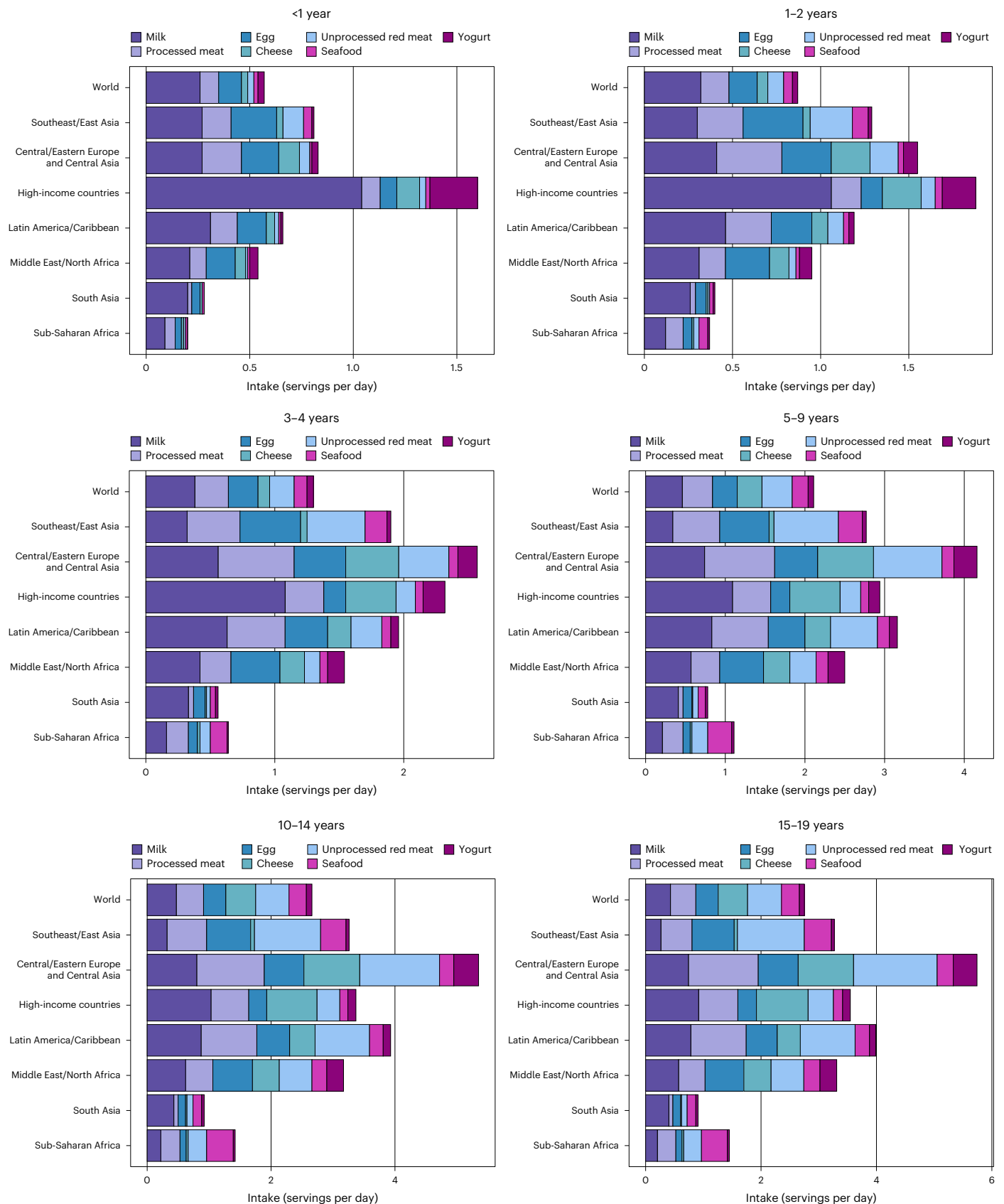


Fig. 1 | Mean global and regional consumption of ASF in 2018 (servings per day) by age. One serving of unprocessed red meat = 100 g; total processed meat = 50 g; seafood = 100 g; egg = 55 g; cheese = 42 g; yogurt = 245 g; and milk = 245 g.

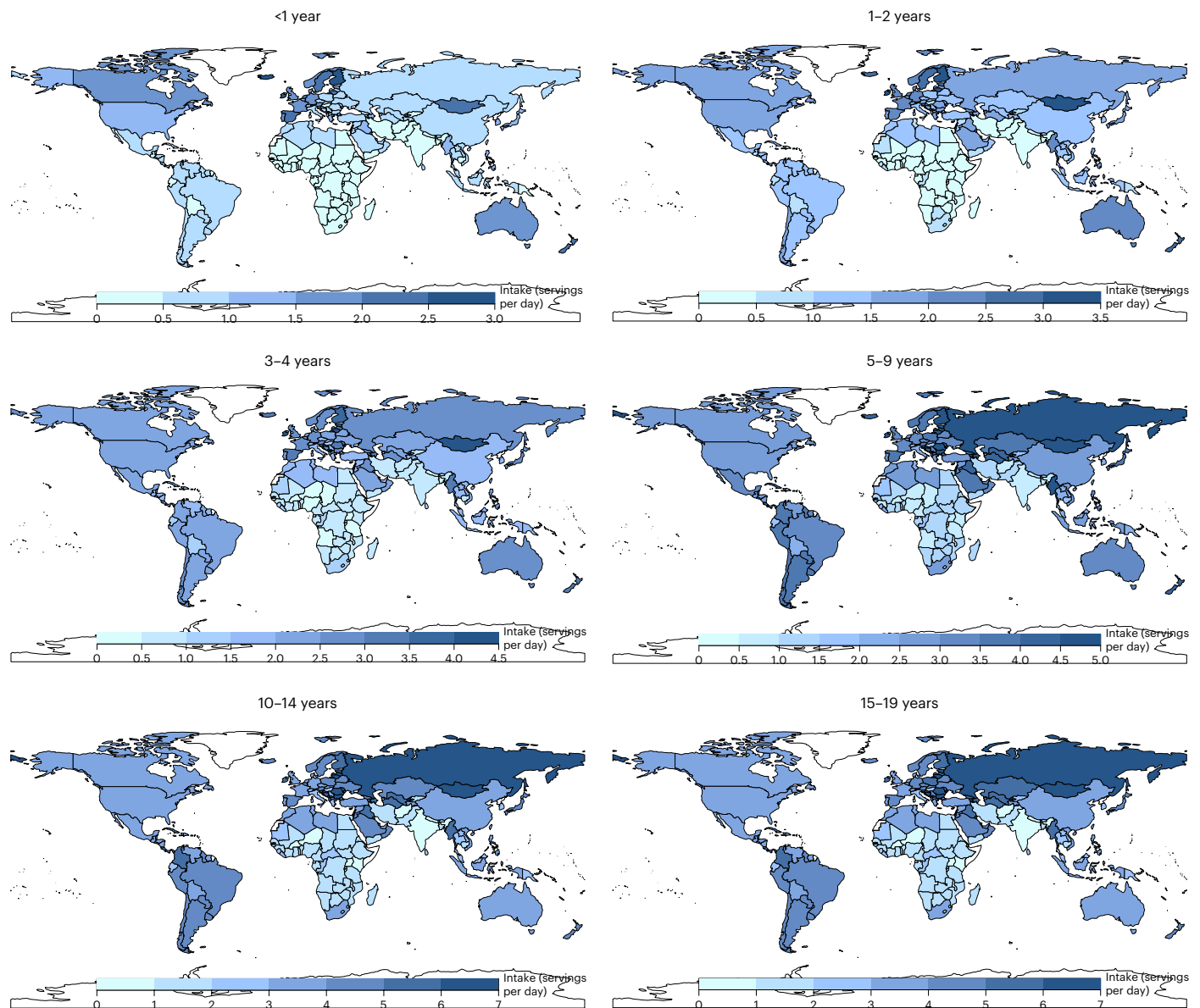


Fig. 2 | Mean national consumption of total ASF (milk, cheese, yogurt, eggs, seafood, unprocessed red meat and processed meat) in 2018 (servings per day), by age. Of 185 countries, 68, representing 16.3% of the global child population, had mean ASF consumption of ≥ 3 servings per day.

the Philippines (24 versus 71 g d⁻¹), Armenia (52 versus 95 g d⁻¹) and Georgia (13 versus 56 g d⁻¹).

Extended Data Figs. 1–7 show the consumption of each ASF by age group.

Differences by sex, education and urbanicity

Globally, mean consumption of most ASF was similar among girls compared with boys, except girls had slightly higher intakes of seafood (+0.04 servings per week; 0.01, 0.07) and milk (+0.03 servings per week; 0.01, 0.06). These differences were generally consistent by age.

Mean intakes of all ASF globally were higher among children and adolescents with more educated parents. In absolute servings, global differences by parental education were largest for milk (+1.7 servings per week; 1.6, 1.9), followed by eggs (+0.7 servings per week; 0.6, 0.9), seafood (+0.5 servings per week; 0.4, 0.6), processed meat (+0.4 servings per week; 0.08, 0.8), yogurt (+0.3 servings per week; 0.3, 0.4), cheese (+0.3 servings per week; 0.2, 0.3) and unprocessed red meat (+0.2 servings per week; 0.2, 0.3; Fig. 3). Among different

world regions, the largest differences in absolute intakes by parental education were seen for unprocessed red meat, seafood, eggs and yogurt in sub-Saharan Africa; for milk and cheese in Latin America and the Caribbean; and for processed meat in Southeast and East Asia.

Globally, children and adolescents residing in urban areas consumed more ASF than those in rural areas. Largest global differences (absolute intakes) in urban versus rural consumption were for processed meat (+0.6 servings per week; 0.06, 1.3) followed by milk (+0.5 servings per week; 0.4, 0.7), eggs (+0.4 servings per week; 0.3, 0.6), yogurt (+0.3 servings per week; 0.2, 0.6), seafood (+0.2 servings per week; 0.09, 0.3), cheese (+0.2 servings per week; 0.02, 0.3) and unprocessed red meat (+0.2 servings per week; 0.1, 0.2; Fig. 4). The corresponding largest regional differences in urban versus rural consumption were for unprocessed red meat, egg, cheese and yogurt in Latin America and the Caribbean; processed meat in Southeast and East Asia; seafood in Central/Eastern Europe and Central Asia, and Latin America and the Caribbean; and milk in high-income countries.

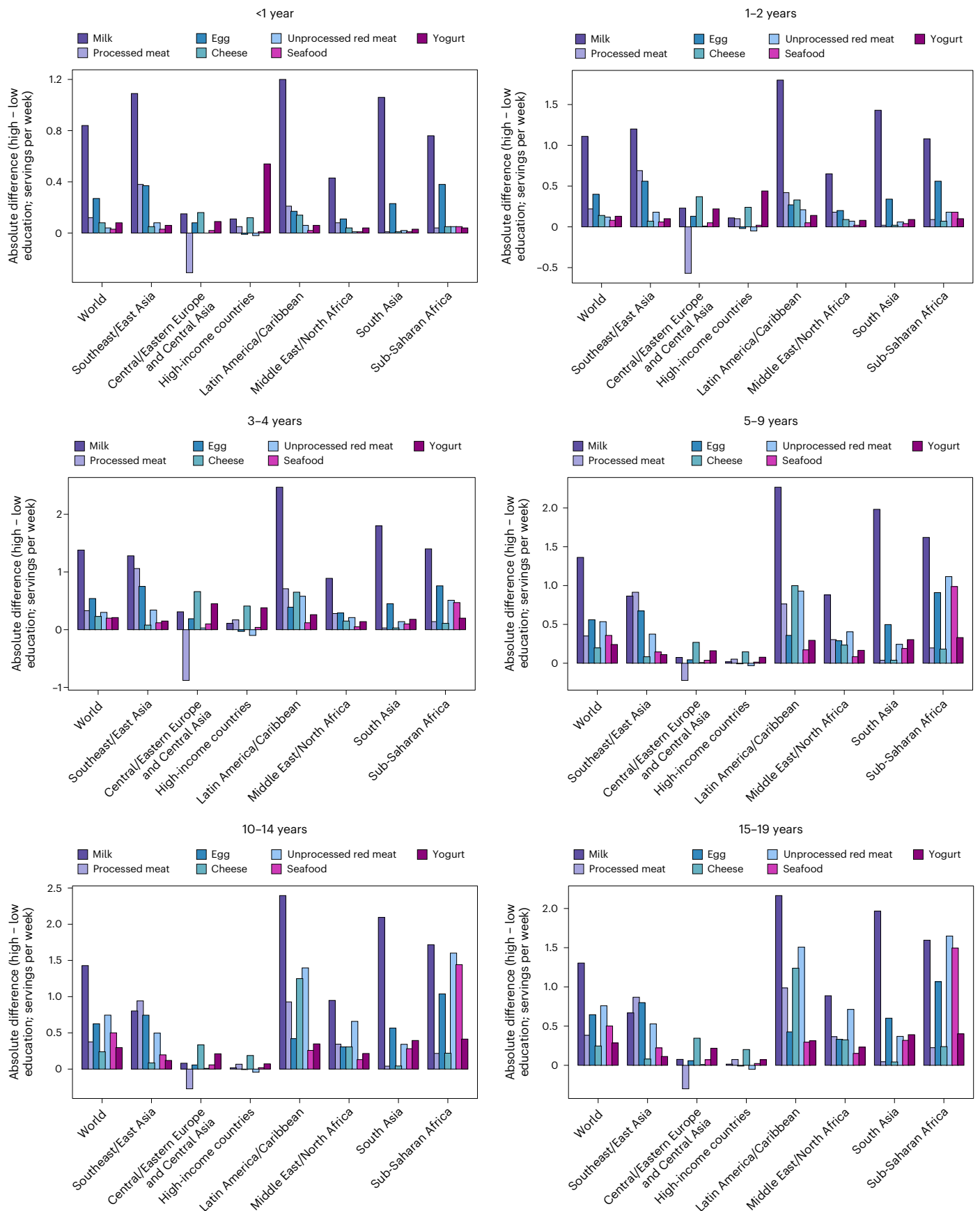


Fig. 3 | Mean global and regional difference in consumption of ASF according to parental education in 2018, by age. One serving of unprocessed red meat = 100 g; total processed meat = 50 g; seafood = 100 g; egg = 55 g; cheese = 42 g; yogurt = 245 g; and milk = 245 g. The absolute differences by parental education

were computed at the stratum level and aggregated to the global and regional mean differences, comparing high education (≥ 12 years) to low education (< 6 years).

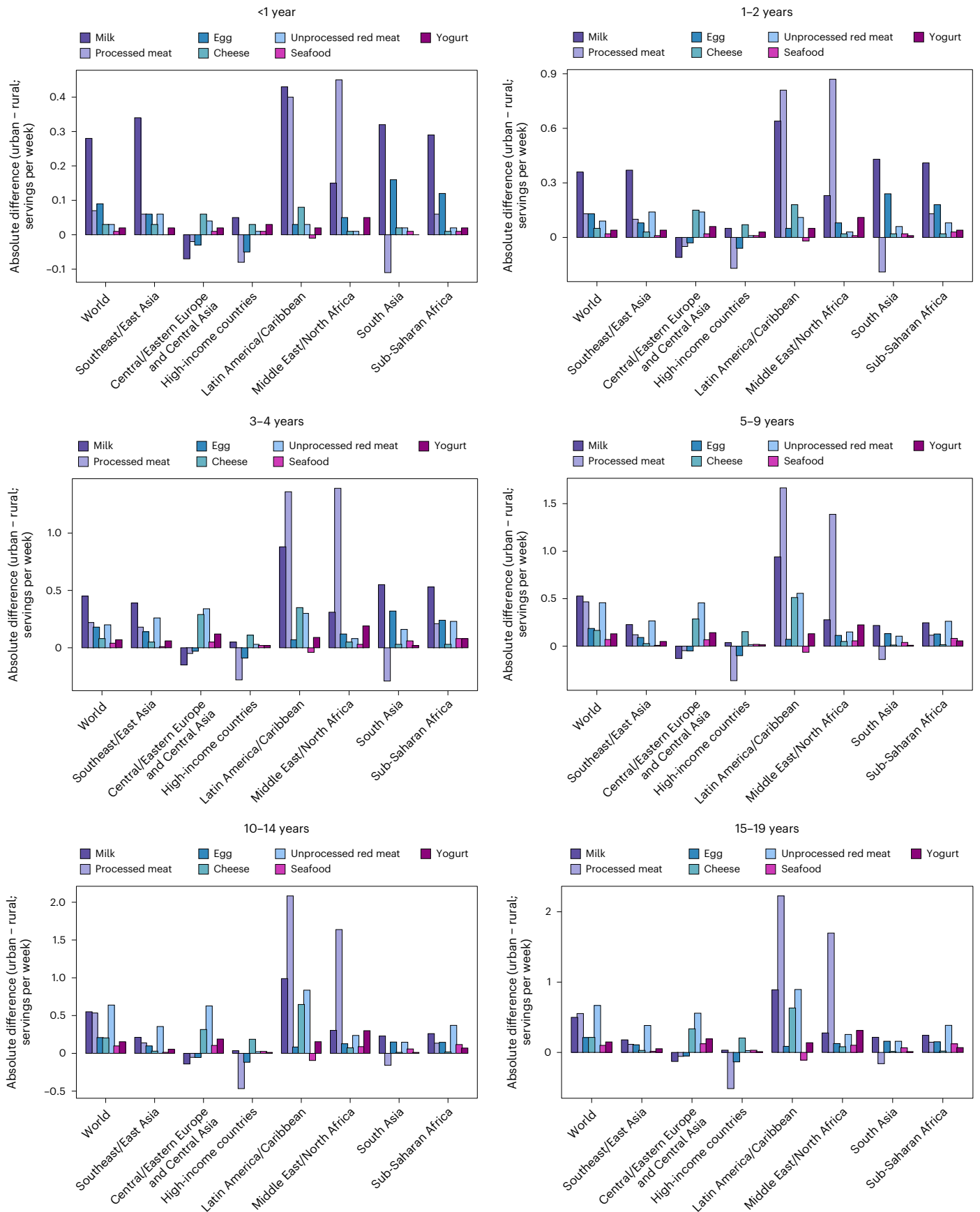


Fig. 4 | Mean global and regional difference in consumption of ASF between urban residence versus rural residence in 2018 by age. One serving of unprocessed red meat = 100 g; total processed meat = 50 g; seafood = 100 g;

egg = 55 g; cheese = 42 g; yogurt = 245 g; and milk = 245 g. The absolute difference by urbanicity was computed as the difference at the stratum level and aggregated to the global and regional mean differences using weighted population proportions.

Differences between 1990 and 2018

Between 1990 and 2018, mean total ASF consumption increased globally by +0.5 servings per week (0.4, 0.6; Fig. 5). Intake increased in all regions except sub-Saharan Africa, with the largest increase in Southeast and East Asia. Among populous countries, absolute increases were largest in Brazil (+1.8 servings per week; 1.6, 2.0), China (+1.8 servings per week; 1.6, 2.1), Vietnam (+1.6 servings per week; 1.2, 2.1) and Mexico (+1.1 servings per week; 1.0, 1.2). Decreases larger than 0.2 servings were seen in 32 of 185 countries, largest in Tanzania (−1.1 servings per week; −1.3, −0.9), Iran (−0.3 servings per week; −0.4, −0.2) and Kenya (−0.2 servings per week; −0.3, −0.2; Fig. 6). Global increases in total ASF consumption were higher at older ages, with increases of +0.3 servings per week (0.2, 0.3) in children <1 year and +0.7 servings per week (0.6, 0.8) in age 15–19 years.

Regional variation in trends for milk was substantial, from increases of +2.4 servings per week in Latin America and the Caribbean (2.2, 2.6) and +0.3 servings per week in high-income countries (0.3, 0.4), to no change in the Middle East and Northern Africa, and decreases in sub-Saharan Africa (−0.03 servings per week; −0.06, −0.01; Fig. 5). Among populous countries, Brazil experienced the largest increase (+4.5 servings per week; 4.0, 5.2), followed by Mexico (+4.1 servings per week; 3.7, 4.5), Turkey (+2.3 servings per week; 1.5, 3.6) and Russia (+2.3 servings per week; 1.7, 3.0), while the largest decreases were in the Philippines (−2.7 servings per week; −3.0, −2.4), Iran (−1.7 servings per week; −1.9, −1.5) and Kenya (−0.9 servings per week; −1.0, −0.8).

Cheese intake increased globally by +0.1 servings per week (0.05, 0.2), with increased consumption in the high-income countries (+0.4 servings per week; 0.2, 0.7), and Latin America and the Caribbean (+0.4 servings per week; 0.2, 0.5; Fig. 5). Among populous nations, largest national increases were in Mexico (+0.6 servings per week; 0.5, 0.7), the United States (+0.4 servings per week; 0.3, 0.5), Iran (+0.3 servings per week; 0.2, 0.4) and Brazil (+0.2 servings per week; 0.1, 0.3); only Turkey experienced a decrease (−0.4 servings per week; −0.5, −0.3; Fig. 6).

Global yogurt consumption was stable between 1990 and 2018 (+0.02 servings per week; −0.01, 0.04; Fig. 5). Intakes did not substantially increase or decrease in any region. Among populous nations, intakes increased in Mexico (+0.04 servings per week; 0.02, 0.07), the United States (+0.01 servings per week; 0.01, 0.02) and Egypt (+0.01 servings per week; 0.01, 0.03). A decrease in intake occurred in Iran (−0.2 servings per week; −0.3, −0.07), Turkey (−0.04 servings per week; −0.08, −0.01) and Brazil (−0.03 servings per week; −0.06, −0.01).

Egg consumption doubled globally, increasing by +1.0 servings per week (0.8, 1.2), with increases in all regions (range +0.3 to +2.8) except high-income countries and sub-Saharan Africa, largest in Southeast and East Asia (Fig. 5). Across populous countries, greatest increases were in Vietnam (+4.8 servings per week; 3.4, 6.6), China (+3.7 servings per week; 2.5, 5.2) and Mexico (+2.5 servings per week; 2.3, 2.8). Greatest decreases were in Ethiopia (−0.5 servings per week; −0.6, −0.4), Tanzania (−0.4 servings per week; −0.5, −0.3), Kenya (−0.4 servings per week; −0.4, −0.3) and the Democratic Republic of the Congo (−0.1 servings per week; −0.1, −0.09).

Globally, seafood intake increased by +0.2 servings per week (0.1, 0.2), a small change but still representing a near doubling between 1990 and 2018 (Fig. 5). The largest regional increase was +0.9 servings per week (0.8, 1.1) in Southeast and East Asia, and the largest decrease was −0.5 servings per week (−0.6, −0.4) in sub-Saharan Africa. Across populous countries, greatest increases were in Vietnam (+2.3 servings per week; 1.6, 3.3), China (+1.2 servings per week; 1.0, 1.3), Bangladesh (+0.9 servings per week; 0.7, 1.1) and Indonesia (+0.8 servings per week; 0.7, 1.0). Largest decreases were in Tanzania (−7.6 servings per week; −9.1, −6.3), the Philippines (−2.4 servings per week; −2.7, −2.2), Uganda (−0.9 servings per week; −1.0, −0.8) and the Democratic Republic of the Congo (−0.5 servings per week; −0.6, −0.4).

Notably, unprocessed red meat intake only meaningfully increased in Southeast and East Asia (+3.9 servings per week; 3.5, 4.4) and

Latin America and the Caribbean (+1.2 servings per week; 1.1, 1.3), while it declined in Central/Eastern Europe and Central Asia (−0.7 servings per week; −1.0, −0.5; Fig. 5). Among populous countries, largest increases were in China (+6.1 servings per week; 5.3, 6.9), Brazil (+2.4 servings per week; 2.2, 2.7), Mexico (+1.1 servings per week; 1.0, 1.3) and Egypt (+1.0 servings per week; 0.9, 1.1), and largest decreases were in Russia (−1.5 servings per week; −1.8, −1.0), Iran (−1.0 servings per week; −1.2, −0.9) and the United States (−0.4 servings per week; −0.4, −0.3).

Increases in processed meat consumption occurred in 4 regions (range +0.5 to +1.5 servings per week), with no change in the Middle East and Northern Africa, South Asia or sub-Saharan Africa (Fig. 5). Among populous countries, increases were seen in 11 of 25 nations, largest in the Philippines (+6.2 servings per week; 4.9, 7.7), Brazil (+3.9 servings per week; 2.9, 5.1) and Indonesia (+3.7 servings per week; 1.4, 6.3); and a decrease only in Mexico (−0.7 servings per week; −1.0, −0.4).

Discussion

We systematically quantified ASF consumption among children and adolescents in 185 countries in 1990 and in 2018. Our results show that global mean intake of total ASF was almost 2 servings per day in 2018 but varied from <1 serving per day in South Asia to >4 servings per day in Central/Eastern Europe and Central Asia. Our findings also identified substantial heterogeneity by type of ASF, age, parental education and urban versus rural residence. As ASF intake is important for both human and planetary health, with differing impacts by life stage and type of ASF, these findings are highly relevant to health and nutrition professionals, scientists, policymakers, the private sector and the public, and can be used to inform policies and programmes to improve ASF consumption among specific population groups.

At global and regional levels, mean total ASF intake was lower at younger ages. Generally, milk intake contributed around half of total ASF servings in the youngest age groups, while intakes of ASF were more varied in older age groups. Consumption of cheese, seafood and especially yogurt generally contributed the fewest daily servings across all ages and regions. These findings demonstrate consistent shifts in the types and quantities of ASF consumed as children and adolescents age across the globe. These results also support the importance of early life interventions to improve types of ASF consumption for optimal childhood health, dietary preferences for disease prevention in adulthood and planetary health targets.

Infants and young children are particularly vulnerable to various forms of undernutrition due to their high energy and nutrient needs, small stomachs and increased sensitivity to anti-nutrients^{24,25}. In addition to obvious manifestations such as stunting, poor diet during early life may adversely affect metabolic health, cognitive performance, physical activity and immune function, creating negative health and economic consequences in adulthood¹³. The prevalence of micronutrient deficiencies including for iron, zinc, iodine, folate, vitamin A, vitamin B12 and vitamin D are high globally, but disproportionately impact children in South Asia and sub-Saharan Africa^{26–28}, where intakes of ASF were lowest. Organ meats, fish, eggs and ruminant meat are micronutrient dense and can help address nutritional gaps among children in low-income countries^{29–31}. Yet, we found that intakes of seafood, eggs and unprocessed red meat were very low among children in South Asia and sub-Saharan Africa, and increased only slightly over time, highlighting the urgency of new dietary policies to address childhood and adolescent malnutrition in these regions.

Children and adolescents' intakes of ASF were highest in Central/Eastern Europe and Central Asia, Latin America and the Caribbean, and high-income countries. In adulthood, different ASF subtypes have varying associations with diet-related chronic diseases, with beneficial associations observed for fish, milk, cheese and yogurt, generally neutral associations for eggs, and harmful associations for red meat and especially processed meat¹⁶. Additionally, compared with ruminant meats (goat, lamb/mutton and especially beef), eggs,

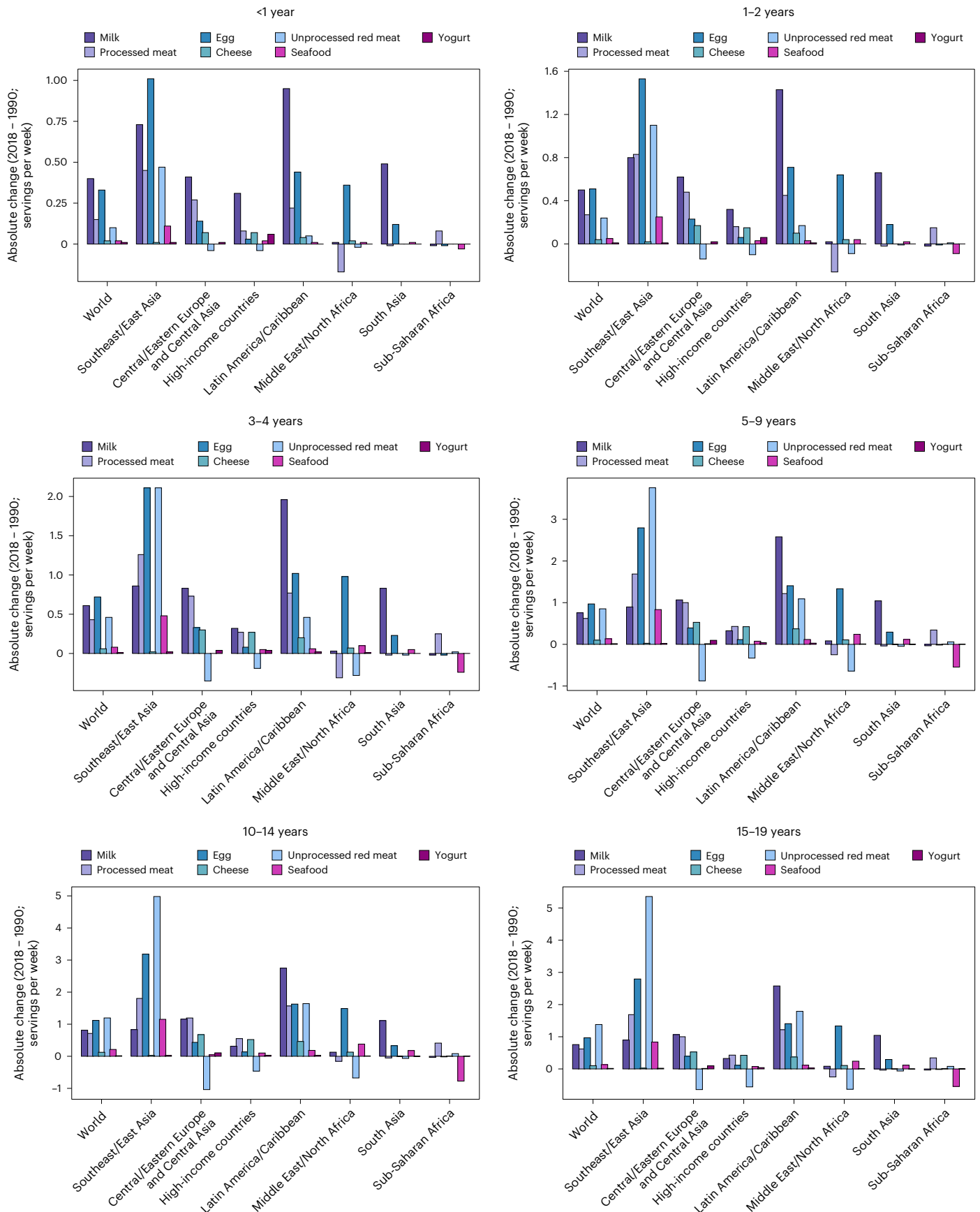


Fig. 5 | Mean global and regional absolute change in consumption of ASF between 1990 and 2018 (servings per week) by age. 1 serving of unprocessed red meat = 100 g; total processed meat = 50 g; seafood = 100 g; egg = 55 g; cheese

= 42 g; yogurt = 245 g; milk = 245 g. The absolute difference between 2018 and 1990 was computed as the difference at the stratum level and aggregated to the global and regional mean differences using weighted population proportions.

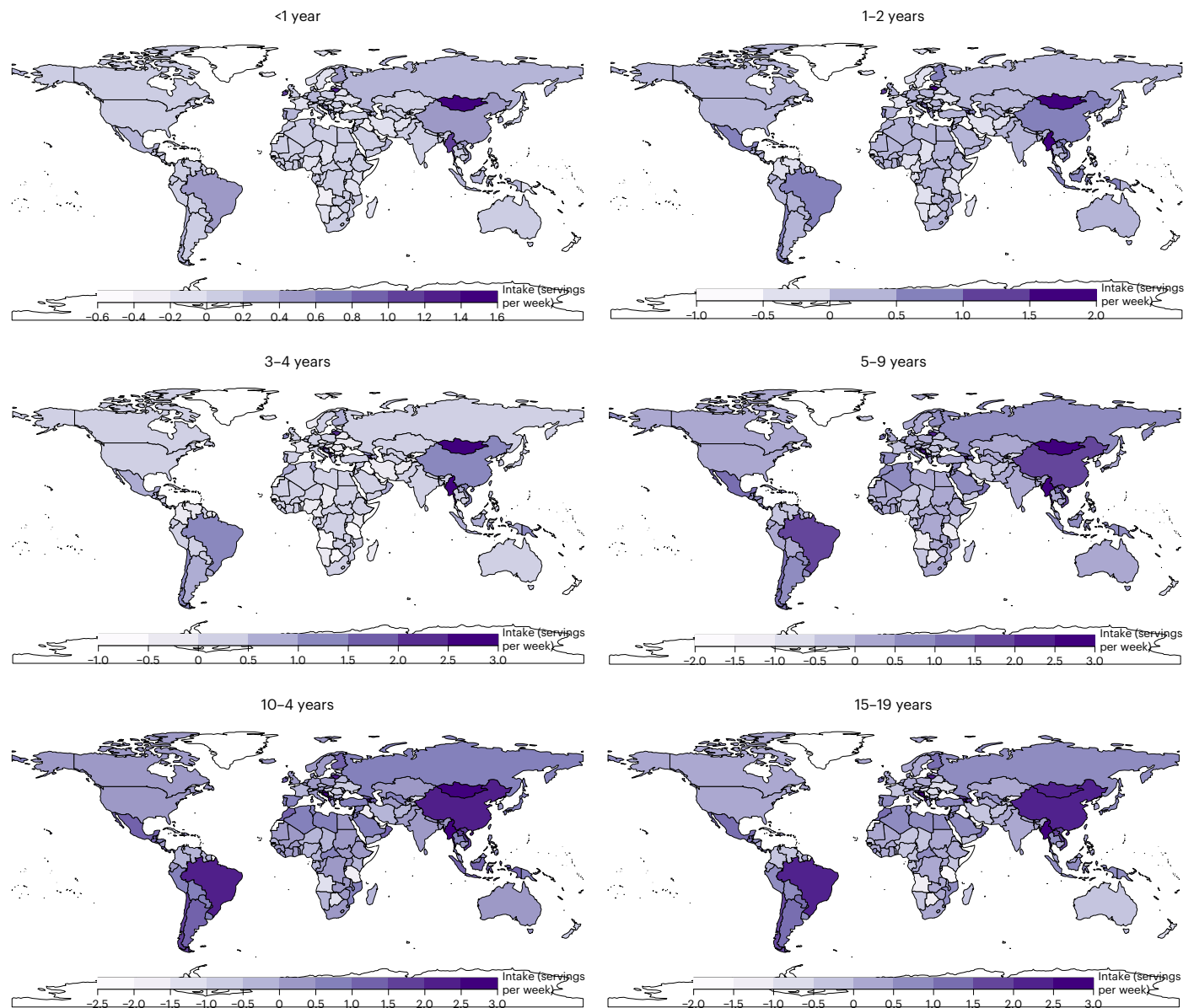


Fig. 6 | Mean national absolute change in consumption of ASF between 1990 and 2018 (servings per week) by age. The absolute difference between 2018 and 1990 was computed as the difference at the stratum level and aggregated to the global and regional mean differences using weighted population proportions for 2018.

dairy and seafood have lower environmental impacts, including for greenhouse gas emissions, land use, energy use, acidification potential and eutrophication potential^{32–34}. Yet, our results show that consumption of red and processed meat was generally higher than other ASF in these regions, especially among adolescents. Among populations with adequate ASF consumption, substituting seafood and dairy in place of meats would engender both human and planetary health benefits³⁵.

Several studies have demonstrated nutritional benefits from regularly consuming ASF during childhood^{25,36,37}, but mean ASF consumption remains less than 2 servings per day, particularly in low-income countries. Several factors may be a barrier to ASF intake, including affordability, nutritional knowledge, parental education, household income, household ownership of livestock and social norms and beliefs^{25,38,39}. Our findings show higher ASF consumption among children and adolescents with more educated parents, and children and adolescents residing in urban areas. Similarly, the International Study of Childhood Obesity, Lifestyle and the Environment study reported that household socioeconomic status was related to children's

dietary intakes across countries⁴⁰. Interestingly, we found that differences in ASF intake by both parental education and urbanicity tended to be larger at older ages for all ASF subtypes. Considering our findings, additional research examining the influence of parental education and urbanicity on diet across childhood and adolescence is needed within and across countries.

Previously, a study of 130,432 children aged 6–23 months enrolled in the Demographic Health Survey found that 50.7% of children 6–11 months, 66.4% 12–17 months and 69.8% 18–23 months consumed at least 1 ASF per day²⁵. Among this population, milk and red/white meat were more commonly consumed than eggs or fish²⁵, which generally agrees with our results. Data from 41 countries collected by the Gallup World Poll reported that most adolescents (≥ 15 years of age) consumed at least 1 ASF per day, but with less than 70% of adolescents from Mozambique, Burkina Faso and Tanzania consuming 1 ASF per day⁴¹. Consistent with our findings, the percentage of adolescents consuming at least 1 daily serving of unprocessed red meat was highest in Vietnam and China⁴¹.

Strengths of our study should be highlighted. Bayesian hierarchical modelling was used to incorporate data on >400 individual-level surveys and address heterogeneity, and sampling and modelling uncertainty²³. We estimated intakes of several ASF subtypes, many of which have not previously been systematically reported for children >5 years of age. We investigated global, regional and national differences by important demographic characteristics, and over time.

Potential limitations should also be considered. Despite extensive efforts to identify data on ASF intakes, survey availability was limited for some ASF subtypes (for example, cheese and yogurt), age groups, countries and years^{23,42}. Differences in individual survey design and dietary assessment required certain decisions about serving sizes, food group definitions, energy adjustment and the disaggregation of household-level data when standardizing the dietary surveys²³. However, our detailed standardization methods have previously been reported to allow for transparency^{42–44}. The GDD was originally designed to estimate intakes of foods and nutrients with potential causal relationships with non-communicable diseases. As the data searches, extraction and harmonization did not include poultry, we are not able to estimate poultry intake, but we plan to do this in future iterations of the GDD²³. Consequently, the omission of poultry intake may underestimate total ASF consumption, particularly among children and adolescents in high-income countries, Latin America and the Caribbean, and China, where the per capita availability of poultry is highest⁴⁵. Although absolute intake of poultry is likely to be lowest among children and adolescents in South Asia and sub-Saharan Africa⁴⁵, poultry consumption may contribute a substantial proportion of total ASF among these populations. Additionally, we did not collect data on breastfeeding or formula use, and we were unable to account for energy intake from breastfeeding or formula among infants. Lastly, individual-level dietary surveys are subject to sampling and measurement bias, and despite incorporating additional uncertainty in the Bayesian hierarchical models, these types of bias cannot be ruled out⁴⁶.

In conclusion, we found that global ASF consumption among children and adolescents was approximately 2 servings per day, but with substantial variation across regions, countries, age groups, parental education level, urbanicity and the types of ASF consumed.

Methods

Data sources and retrieval

We produced comprehensive, comparable estimates of dietary intakes of 53 major foods and nutrients in 185 countries as a part of the GDD. Detailed methods and standardized data collection have been reported^{23,42–44,47}. In brief, we systematically searched for individual-level national surveys for dietary intakes worldwide, with additional data obtained through communication with researchers and government authorities⁴². We prioritized nationally and sub-nationally representative surveys, and surveys collected at the individual level using standardized 24-hour recalls, food frequency questionnaires or short standardized questionnaires (for example, Demographic Health Survey questionnaire)⁴². Surveys from large cohort studies or household budget surveys in populous countries were selected when nationally or sub-nationally representative individual-level surveys were not identified⁴². Surveys focused on special populations (for example, pregnant women, lactating women, individuals with a specific disease) were excluded⁴².

GDD 2018 incorporated 1,248 dietary surveys from 188 countries, comprising 99% of the world's population²³. Data on ASF consumption (milk, cheese, yogurt, eggs, seafood, unprocessed red meat, processed red meat) were reported in 498 surveys²³, including 429 with data on children and adolescents, defined as between age 0 to 19 years (Supplementary Table 3). These 429 surveys included 3.3 million children from 125 countries, representing 93.1% of the global child population (Supplementary Table 4). Most surveys were nationally representative

(88.1%), collected at the individual level (78.1%), and included data by rural and/or urban residence (71.1%) and by parental education (53.4%).

Data extraction and harmonization

Data were extracted for each survey using standardized methods on survey characteristics and diet metrics, units, means and standard deviations of intake, in subgroups jointly stratified by age group, sex, parental education and urban/rural residence^{23,42}. Standardized protocols assessed data for extraction errors and survey quality including selection bias, sample representativeness, response rate and validity of diet assessment method^{23,42}. Data were standardized to mean individual intakes using the average of all days of dietary assessment; harmonized dietary definitions and units of measures across surveys; and adjusting for total energy based on age-specific energy intakes^{23,42}. For children <1 year of age, intakes were energy adjusted to 700 kcal d⁻¹; for 1–<2 years, 1,000 kcal d⁻¹; for 2–5 years, 1,300 kcal d⁻¹; for 6–10 years, 1,700 kcal d⁻¹; and for 11–19 years, 2,000 kcal d⁻¹ (refs. 23,42). Data harmonization and energy adjustment analyses were performed using SAS v9.4 (SAS Institute), Stata v14.0 (StataCorp LLC) and RStudio v1.1.453 (RStudio).

Modelling and uncertainty

A Bayesian model was used to account for missingness, differences in survey methods, representativeness, time and uncertainty²³. The model incorporated a nested hierarchical structure, with random effects by country and region, globally, and jointly stratified for age (<1, 1–2, 3–4, 5–9, 10–14, 15–19 years), sex (boys, girls), parental education (<6 years of education, ≥6 to <12 years, ≥12 years) and urbanicity (urban, rural residence)²³. For each ASF, primary model inputs were stratified survey data on quantitative intakes, survey characteristics (dietary assessment method, diet metric) and country-year-specific covariates²³. The model included overdispersion of survey-level variance for surveys that were not nationally representative or not stratified by smaller age groups (≤10 years), sex, education or urbanicity. Uncertainty of each stratum-specific estimate was quantified using 4,000 runs to determine posterior distributions of consumption jointly by country, year and demographic subgroup²³. The median intake and 95% uncertainty interval for each stratum were calculated from the 50th, 2.5th and 97.5th percentiles of the 4,000 draws, respectively²³. Validity was assessed by fivefold cross-validation (randomly omitting 20% of the raw survey data, run 5 times), comparing predicted versus observed intakes; and by assessment of implausible estimates and visual assessment of global heat maps²³. A second time component Bayesian model was used to strengthen differences in estimates over time for diet factors with food or nutrient availability data (United Nations Food and Agriculture Organization Food Balance Sheets⁴⁵ and the Global Expanded Nutrient Supply project^{48,23}). The results were based on these two Bayesian models, as described in detail in the Supplementary Information. Analyses were completed using RStudio v3.3 and Stan v2.29.

Statistical analysis

The model estimated mean intake of each ASF and its statistical uncertainty for each of the 72 population strata (jointly by age group, sex, education and urbanicity) from 185 countries, for 1990 and 2018. Using data on population weights, we estimated global, regional, national and within-country population subgroup intakes of ASF by calculating population-weighted averages of the stratum-specific estimates for each of the 72 demographic strata in each country-year²³. Population weights for each stratum in 1990 and 2018 were derived from the United Nations Population Division⁴⁹, with supplemental data on education and urbanicity from Barro–Lee⁵⁰ and the United Nations^{23,51}. Intakes were calculated as grams per day and servings per day or week using standardized portion sizes²³. A serving size of milk was defined as 245 g; 42 g for cheese; 245 g for yogurt; 55 g

for eggs; 100 g for seafood; 100 g for unprocessed red meat; and 50 g for total processed meat. Spearman correlations evaluated relationships between mean intakes of different ASF. When comparing subgroups and trends over time, absolute differences in consumption were calculated using all 4,000 posterior predictions at each stratum level to incorporate the full spectrum of uncertainty²³. Differences in intakes between 1990 and 2018 were standardized to the 2018 population weights to account for changes in demographics over time²³.

Ethics statement

This modelling study was exempt from ethical review board approval because it was based on published data and nationally representative, de-identified data sets without personally identifiable information. Individual surveys underwent ethical review board approval required for the applicable local context.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

The modelled estimates are available for download from the Global Dietary Database (<https://www.globaldietarydatabase.org/>). Survey-level information and original data download weblinks are also provided for all public surveys; and survey-level microdata or stratum-level aggregate data are provided for direct download for all non-public surveys granted consent for public sharing by the data owner. Data on national food and nutrient supplies are available for download from the United Nations Food and Agriculture Organization (<https://www.fao.org/faostat/en/#data>) and the Global Expanded Nutrient Supply (GENUS) model dataset (<https://dataverse.harvard.edu/dataverse/GENUS>). Data on population demographics are available for download from the United Nations Population Division (<https://population.un.org/wpp/DataQuery/>).

Code availability

The statistical coding is available from the corresponding author on reasonable request.

References

1. *The State of the World's Children 2019: Children, Food and Nutrition: Growing Well in a Changing World* (UNICEF, 2019); <https://www.unicef.org/reports/state-of-worlds-children-2019>
2. *Malnutrition Data* (UNICEF, WHO & World Bank, 2021); <https://data.unicef.org/resources/dataset/malnutrition-data/>
3. Swinburn, B. A. et al. The global syndrome of obesity, under-nutrition, and climate change: *The Lancet Commission report*. *Lancet* **393**, 791–846 (2019).
4. Caulfield, L. E. et al. in *Disease Control Priorities in Developing Countries* (eds Jamison, D. T. et al.) Ch. 28 (The International Bank for Reconstruction and Development/The World Bank & Oxford Univ. Press, 2006).
5. *Global Obesity Observatory* (World Obesity, 2022); <https://data.worldobesity.org/tables/prevalence-of-child-overweight-including-obesity-3/>
6. Norris, S. A. et al. Nutrition in adolescent growth and development. *Lancet* **399**, 172–184 (2022).
7. Neufeld, L. M. et al. Food choice in transition: adolescent autonomy, agency, and the food environment. *Lancet* **399**, 185–197 (2022).
8. Hargreaves, D. et al. Strategies and interventions for healthy adolescent growth, nutrition, and development. *Lancet* **399**, 198–210 (2022).
9. Siervogel, R. M. et al. Puberty and body composition. *Horm. Res.* **60**, 36–45 (2003).
10. Lassi, Z. S. et al. Review of nutrition guidelines relevant for adolescents in low- and middle-income countries. *Ann. N. Y. Acad. Sci.* **1393**, 51–60 (2017).
11. Lowe, C. J., Morton, J. B. & Reichelt, A. C. Adolescent obesity and dietary decision making—a brain-health perspective. *Lancet Child Adolesc. Health* **4**, 388–396 (2020).
12. Azzopardi, P. S. et al. Progress in adolescent health and wellbeing: tracking 12 headline indicators for 195 countries and territories, 1990–2016. *Lancet* **393**, 1101–1118 (2019).
13. Dror, D. K. & Lindsay, A. The importance of milk and other animal-source foods for children in low-income countries. *Food Nutr. Bull.* **32**, 227–243 (2011).
14. Pimpin, L. et al. Effects of animal protein supplementation of mothers, preterm infants, and term infants on growth outcomes in childhood: a systematic review and meta-analysis of randomized trials. *Am. J. Clin. Nutr.* **110**, 410–429 (2019).
15. Hilborn, R., Banobi, J., Hall, S. J., Pucylowski, T. & Walsworth, T. E. The environmental cost of animal source foods. *Front. Ecol. Environ.* **16**, 329–335 (2018).
16. Miller, V. et al. Evaluation of the quality of evidence of the association of foods and nutrients with cardiovascular disease and diabetes: a systematic review. *JAMA Netw. Open* **5**, e2146705 (2022).
17. Mikkilä, V., Räsänen, L., Raitakari, O. T., Pietinen, P. & Viikari, J. Longitudinal changes in diet from childhood into adulthood with respect to risk of cardiovascular diseases: The Cardiovascular Risk in Young Finns Study. *Eur. J. Clin. Nutr.* **58**, 1038–1045 (2004).
18. *The Demographic and Health Surveys Program* (The DHS Program, 2019); <http://www.dhsprogram.com>
19. Global Diet Quality Project. *Measuring What the World Eats: Insights from a New Approach* (Global Alliance for Improved Nutrition & Harvard T.H. Chan School of Public Health, 2022); <https://doi.org/10.36072/dqq2022>
20. Micha, R. et al. Global, regional and national consumption of major food groups in 1990 and 2010: a systematic analysis including 266 country-specific nutrition surveys worldwide. *Brit. Med. J. Open* **5**, e008705 (2015).
21. Singh, G. M. et al. Global, regional, and national consumption of sugar-sweetened beverages, fruit juices, and milk: a systematic assessment of beverage intake in 187 countries. *PLoS ONE* **10**, e0124845 (2015).
22. Afshin, A. et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **393**, 1958–1972 (2019).
23. Miller, V. et al. Global, regional, and national consumption of animal-source foods between 1990 and 2018: findings from the Global Dietary Database. *Lancet Planet. Health* **6**, e243–e256 (2022).
24. Michaelsen, K. F. et al. Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age. *Food Nutr. Bull.* **30**, S343–S404 (2009).
25. Headey, D., Hirvonen, K. & Hoddinott, J. Animal sourced foods and child stunting. *Am. J. Agric. Econ.* **100**, 1302–1319 (2018).
26. Beal, T., Massiot, E., Arsenaault, J. E., Smith, M. R. & Hijmans, R. J. Global trends in dietary micronutrient supplies and estimated prevalence of inadequate intakes. *PLoS ONE* **12**, e0175554 (2017).
27. *World Development Indicators* (World Bank, 2019); <http://data.worldbank.org/data-catalog/world-development-indicators>
28. Stevens, G. A. et al. Micronutrient deficiencies among preschool-aged children and women of reproductive age worldwide: a pooled analysis of individual-level data from population-representative surveys. *Lancet Glob. Health* **10**, e1590–e1599 (2022).

29. Beal, T. et al. Micronutrient gaps during the complementary feeding period in South Asia: A Comprehensive Nutrient Gap Assessment. *Nutr. Rev.* **79**, 26–34 (2021).
30. White, J. M. et al. Micronutrient gaps during the complementary feeding period in 6 countries in Eastern and Southern Africa: a Comprehensive Nutrient Gap Assessment. *Nutr. Rev.* **79**, 16–25 (2021).
31. Ortenzi, F. & Beal, T. Priority micronutrient density of foods for complementary feeding of young children (6–23 months) in South and Southeast Asia. *Front. Nutr.* <https://doi.org/10.3389/fnut.2021.785227> (2021).
32. Clark, M. T. D. Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. *Environ. Res. Lett.* **12**, 064016 (2017).
33. Clark, M. A., Springmann, M., Hill, J. & Tilman, D. Multiple health and environmental impacts of foods. *Proc. Natl Acad. Sci. USA* **116**, 23357–23362 (2019).
34. Clune, S., Crossin, E. & Verghese, K. Systematic review of greenhouse gas emissions for different fresh food categories. *J. Clean. Prod.* **140**, 766–783 (2017).
35. Springmann, M. et al. The healthiness and sustainability of national and global food based dietary guidelines: modelling study. *Brit. Med. J.* **370**, m2322 (2020).
36. Krasevec, J., An, X., Kumapley, R., Bégin, F. & Frongillo, E. A. Diet quality and risk of stunting among infants and young children in low- and middle-income countries. *Matern. Child Nutr.* **13**, e12430 (2017).
37. Zaharia, S. et al. Sustained intake of animal-sourced foods is associated with less stunting in young children. *Nat. Food* **2**, 246–254 (2021).
38. Haileselassie, M. et al. Why are animal source foods rarely consumed by 6–23 months old children in rural communities of northern Ethiopia? A qualitative study. *PLoS ONE* **15**, e0225707 (2020).
39. Wong, J. et al. Factors influencing animal-source food consumption in Timor-Leste. *Food Secur.* <https://doi.org/10.1007/s12571-018-0804-5> (2018).
40. Manyanga, T. et al. Socioeconomic status and dietary patterns in children from around the world: different associations by levels of country human development? *BMC Public Health* **17**, 457 (2017).
41. *Gallop World Poll* (The Food Systems Dashboard, 2022); <https://www.foodsystemsdashboard.org/indicators>
42. Miller, V. et al. Global Dietary Database 2017: data availability and gaps on 54 major foods, beverages and nutrients among 5.6 million children and adults from 1220 surveys worldwide. *Brit. Med. J. Glob. Health* **6**, e003585 (2021).
43. Khatibzadeh, S. et al. A global database of food and nutrient consumption. *Bull. World Health Organ.* **94**, 931–934 (2016).
44. Micha, R. et al. Estimating the global and regional burden of suboptimal nutrition on chronic disease: methods and inputs to the analysis. *Eur. J. Clin. Nutr.* **66**, 119–129 (2012).
45. FAOSTAT (FAO, 2021); <https://www.fao.org/faostat/en/#data>
46. Imamura, F. et al. Dietary quality among men and women in 187 countries in 1990 and 2010: a systematic assessment. *Lancet Glob. Health* **3**, e132–e142 (2015).
47. Miller, V. et al. Global dietary quality in 185 countries from 1990 to 2018 show wide differences by nation, age, education, and urbanicity. *Nat. Food* **3**, 694–702 (2022).
48. Smith, M. R., Micha, R., Golden, C. D., Mozaffarian, D. & Myers, S. S. Global Expanded Nutrient Supply (GENUS) model: a new method for estimating the global dietary supply of nutrients. *PLoS ONE* **11**, e0146976 (2016).
49. *Total population by sex (thousands)*. (United Nations Population Division, 2019); <https://population.un.org/wpp/DataQuery/2019>
50. Barro, R. & Lee, J. A new data set of educational attainment in the world, 1950–2010. *J. Dev. Econ.* **104**, 184–198 (2013).
51. *Urban Population (% of Total Population)*. (United Nations Population Division, 2018); <https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS>

Acknowledgements

We thank the Global Dietary Database Consortium for sharing and harmonizing their dietary surveys in accordance with the Global Dietary Database methods. This study was supported by grants from the Bill and Melinda Gates Foundation (OPP1176681; PI D.M.) and from the American Heart Association (20POST35200069; PI V.M.). The Bill and Melinda Gates Foundation contributed to study design during the grant application process; the funders otherwise had no role in data collection and analysis, decision to publish or preparation of the manuscript.

Author contributions

V.M., P.W. and D.M. conceptualized and designed the study. V.M., R.M., J.R. and J.C. were involved in the data collection. V.M., F.C., J.Z., P.S. and J.E.-M. conducted the analyses for the study. V.M., P.W. and D.M. drafted the manuscript. All the authors interpreted the data, read the final manuscript, reviewed it for important intellectual content and approved its submission. V.M. and D.M. are the guarantors of this work. The GDD Consortium members provided critical survey data to inform the Global Dietary Database dietary intake prediction models used in this analysis.

Competing interests

V.M. reports a research grant from the Canadian Institutes of Health Research, outside the submitted work. P.W. reports research grants and contracts from the United States Agency for International Development and personal fees from the Global Panel on Agriculture and Food Systems for Nutrition, outside the submitted work. J.Z., J.R. and P.S. report research funding from Nestle, outside the submitted work. J.C. reports research funding from the Bill and Melinda Gates Foundation and the United States Agency for International Development, outside the submitted work. R.M. reports grants from National Institute of Health, Nestle, and Danone, personal fees from Bunge, Development Initiatives, outside the submitted work. D.M. reports research funding from the National Institutes of Health and the Bill and Melinda Gates Foundation; personal fees from GOED, Bunge, Indigo Agriculture, Motif FoodWorks, Amarin, Acasti Pharma, Cleveland Clinic Foundation, America's Test Kitchen, and Danone; scientific advisory board member for Brightseed, DayTwo, Elysium Health, Filtricine, HumanCo, and Tiny Organics; and chapter royalties from UpToDate, all outside the submitted work. The other authors declare no competing interests.

Additional information

Extended data is available for this paper at <https://doi.org/10.1038/s43016-023-00731-y>.

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1038/s43016-023-00731-y>.

Correspondence and requests for materials should be addressed to Victoria Miller.

Peer review information *Nature Food* thanks Anne-Maria Pajari and the other, anonymous, reviewer(s) for their contribution to the peer review of this work.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this

article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.

© The Author(s) 2023

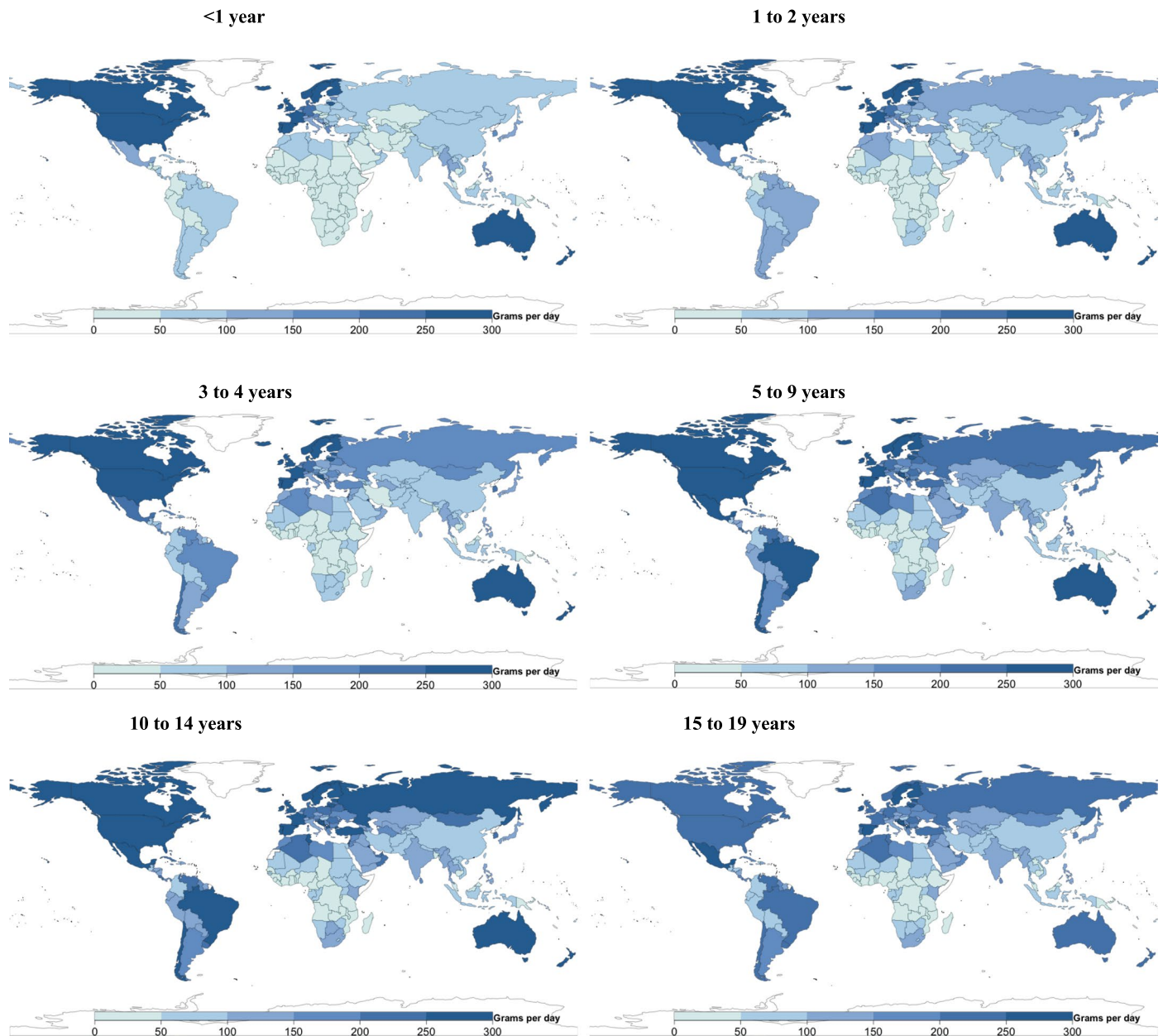
Global Dietary Database

Murat Bas⁶, Jemal Haidar Ali⁷, Suhad Abumweis⁸, Anand Krishnan⁹, Puneet Misra⁹, Nahla Chawkat Hwalla¹⁰, Chandrashekar Janakiram¹¹, Nur Indrawaty Liputo¹², Abdulrahman Musaiger¹³, Farhad Pourfarzi¹⁴, Iftikhar Alam¹⁵, Karin DeRidder¹⁶, Celine Termote¹⁷, Anjum Memon¹⁸, Aida Turrini¹⁹, Elisabetta Lupotto¹⁹, Raffaella Piccinelli¹⁹, Stefania Sette¹⁹, Karim Anzid²⁰, Marieke Vossenaar²¹, Paramita Mazumdar²², Ingrid Rached²³, Alicia Roviroso²⁴, María Elisa Zapata²⁴, Tamene Taye Asayehu²⁵, Francis Oduor²⁶, Julia Boedecker²⁶, Lilian Aluso²⁶, Johana Ortiz-Ulloa²⁷, J. V. Meenakshi²⁸, Michelle Castro²⁹, Giuseppe Grosso³⁰, Anna Waskiewicz³¹, Umber S. Khan³², Anastasia Thanopoulou³³, Reza Malekzadeh³⁴, Neville Calleja³⁵, Marga Ocke³⁶, Zohreh Etemad³⁶, Mohannad Al Nsour³⁷, Lydiah M. Waswa³⁸, Eha Nurk³⁹, Joanne Arsenaault⁴⁰, Patricio Lopez-Jaramillo⁴¹, Abla Mehio Sibai⁴², Albertino Damasceno⁴³, Carukshi Arambepola⁴⁴, Carla Lopes⁴⁵, Milton Severo⁴⁵, Nuno Lunet⁴⁵, Duarte Torres⁴⁶, Heli Tapanainen⁴⁷, Jaana Lindstrom⁴⁷, Suvi Virtanen⁴⁷, Cristina Palacios⁴⁸, Eva Roos⁴⁹, Imelda Angeles Agdeppa⁵⁰, Josie Desnaco⁵⁰, Mario Capanzana⁵¹, Anoop Misra⁵², Ilse Khouw⁵³, Swee Ai Ng⁵³, Edna Gamboa Delgado⁵⁴, Mauricio Caballero⁵⁵, Johanna Otero⁵⁶, Hae-Jeung Lee⁵⁷, Eda Koksai⁵⁸, Idris Guessous⁵⁹, Carl Lachat⁶⁰, Stefaan De Henauw⁶⁰, Ali Reza Rahbar⁶¹, Alison Tedstone⁶¹, Androniki Naska⁶¹, Angie Mathee⁶¹, Annie Ling⁶¹, Bemnet Tedla⁶¹, Beth Hopping⁶¹, Brahmam Ginnela⁶¹, Catherine Leclercq⁶¹, Charmaine Duante⁶¹, Christian Haerpfer⁶¹, Christine Hotz⁶¹, Christos Pitsavos⁶¹, Colin Rehm⁶¹, Coline van Oosterhout⁶¹, Corazon Cerdena⁶¹, Debbie Bradshaw⁶¹, Dimitrios Trichopoulos⁶¹, Dorothy Gauci⁶¹, Dulitha Fernando⁶¹, Elzbieta Sygnowska⁶¹, Erkki Vartiainen⁶¹, Farshad Farzadfar⁶¹, Gabor Zajkas⁶¹, Gillian Swan⁶¹, Guansheng Ma⁶¹, Gulden Pekcan⁶¹, Hajah Masni Ibrahim⁶¹, Harri Sinkko⁶¹, Helene Enghardt Barbieri⁶¹, Isabelle Sioen⁶¹, Jannicke Myhre⁶¹, Jean-Michel Gaspoz⁶¹, Jillian Odenkirk⁶¹, Kanitta Bundhamcharoen⁶¹, Keiu Nelis⁶¹, Khairul Zarina⁶¹, Lajos Biro⁶¹, Lars Johansson⁶¹, Laufey Steingrimsdottir⁶¹, Leanne Riley⁶¹, Mabel Yap⁶¹, Manami Inoue⁶¹, Maria Szabo⁶¹, Marja-Leena Ovaskainen⁶¹, Meei-Shyuan Lee⁶¹, Mei Fen Chan⁶¹, Melanie Cowan⁶¹, Mirnalini Kandiah⁶¹, Ola Kally⁶¹, Olof Jonsson⁶¹, Pam Palmer⁶¹, Peter Vollenweider⁶¹, Philippe Orfanos⁶¹, Renzo Asciak⁶¹, Robert Templeton⁶¹, Rokiah Don⁶¹, Roseyati Yaakub⁶¹, Rusidah Selamat⁶¹, Safiah Yusof⁶¹, Sameer Al-Zenki⁶¹, Shu-Yi Hung⁶¹, Sigrid Beer-Borst⁶¹, Suh Wu⁶¹, Widjaja Lukito⁶¹, Wilbur Hadden⁶¹, Wulf Becker⁶¹, Xia Cao⁶¹, Yi Ma⁶¹, Yuen Lai⁶¹, Zaiton Hjadaud⁶¹, Jennifer Ali⁶², Ron Gravel⁶², Tina Tao⁶², Jacob Lennert Veerman⁶³, Shashi Chiplonkar⁶⁴, Mustafa Arici⁶⁵, Le Tran Ngoan⁶⁶, Demosthenes Panagiotakos⁶⁷, Yanping Li⁶⁸, Antonia Trichopoulou⁶⁹, Noel Barengo⁷⁰, Anuradha Khadiolkar⁷¹, Veena Ekbote⁷¹, Noushin Mohammadifard⁷², Irina Kovalskys⁷³, Avula Laxmaiah⁷⁴, Harikumar Rachakulla⁷⁴, Hemalatha Rajkumar⁷⁴, Indrapal Meshram⁷⁴, Laxmaiah Avula⁷⁴, Nimmathota Arlappa⁷⁴, Rajkumar Hemalatha⁷⁴, Licia Iacoviello^{75,76}, Marialaura Bonaccio⁷⁵, Simona Costanzo⁷⁵, Yves Martin-Prevel⁷⁷, Katia Castetbon⁷⁸, Nattinee Jitnarin⁷⁹, Yao-Te Hsieh⁸⁰, Sonia Olivares⁸¹, Gabriela Tejeda⁸², Aida Hadziomeragic⁸³, Amanda de Moura Souza⁸⁴, Wen-Harn Pan⁸⁵, Inge Huybrechts⁸⁶, Alan de Brauw⁸⁷, Mourad Moursi⁸⁷, Maryam Maghroun⁸⁸, Augustin Nawidimbasa Zeba⁸⁹, Nizal Sarrafzadegan⁹⁰, Lital Keinan-Boker⁹¹, Rebecca Goldsmith⁹¹, Tal Shimony⁹¹, Irmgard Jordan⁹², Shivanand C. Mastiholi⁹³, Moses Mwangi⁹⁴, Yeri Kombe⁹⁴, Zipporah Bukania⁹⁴, Eman Alissa⁹⁵, Nasser Al-Daghri⁹⁶, Shaun Sabico⁹⁶, Martin Gulliford⁹⁷, Tshilenge S. Diba⁹⁸, Kyungwon Oh⁹⁹, Sanghui Kwon⁹⁹, Sihyun Park⁹⁹, Yoonsu Cho¹⁰⁰, Suad Al-Hooti¹⁰¹, Chanthaly Luangphaxay¹⁰², Daovieng Douangvichit¹⁰², Latsamy Siengsounthone¹⁰², Pedro Marques-Vidal¹⁰³, Constance Rybak¹⁰⁴, Amy Luke¹⁰⁵, Noppawan Piaseu¹⁰⁶, Nipa Rojroongwasinkul¹⁰⁷, Kalyana Sundram¹⁰⁸, Donka Baykova¹⁰⁹, Parvin Abedi¹¹⁰, Sandjaja Sandjaja¹¹¹, Fariza Fadzil¹¹², Noriklil Bukhary Ismail Bukhary¹¹³, Pascal Bovet^{114,115}, Yu Chen¹¹⁶, Norie Sawada¹¹⁷, Shoichiro Tsugane¹¹⁷, Lalka Rangelova¹¹⁸, Stefka Petrova¹¹⁸, Vesselka Duleva¹¹⁸, Anna Karin Lindroos¹¹⁹, Jessica Petrelius Sipinen¹¹⁹, Lotta Moraes¹¹⁹, Per Bergman¹¹⁹, Ward Siamusantu¹²⁰, Lucjan Szponar¹²¹, Hsing-Yi Chang¹²², Makiko Sekiyama¹²³, Khanh Le Nguyen Bao¹²⁴, Balakrishna Nagalla¹²⁵, Kalpagam Polasa¹²⁵, Sesikeran Boindala¹²⁵, Jalila El Atti¹²⁶, Ivonne Ramirez Silva¹²⁷, Juan Rivera Dommarco¹²⁷, Simon Barquera¹²⁷, Sonia Rodriguez Ramirez¹²⁷, Daniel Illescas-Zarate¹²⁸, Luz Maria Sanchez-Romero¹²⁸, Nayu Ikeda¹²⁹, Sahar Zaghoul¹³⁰, Anahita Houshiar-rad¹³¹, Fatemeh Mohammadi-Nasrabad¹³¹, Morteza Abdollahi¹³¹, Khun-Aik Chuah¹³², Zaleha Abdullah Mahdy¹³², Alison Eldridge¹³³, Eric L. Ding¹³⁴, Herculina Kruger¹³⁵, Sigrun Henjum¹³⁶, Anne Fernandez¹³⁷, Milton Fabian Suarez-Ortega¹³⁸, Nawal Al Hamad¹³⁹, Veronika Janska¹⁴⁰, Reema Tayyem¹⁴¹, Parvin Mirmiran¹⁴², Roya Kelishadi¹⁴³, Eva Warensjo Lemming¹⁴⁴, Almut Richter¹⁴⁵, Gert Mensink¹⁴⁵, Lothar Wieler¹⁴⁵, Daniel Hoffman¹⁴⁶, Benoit Salanave¹⁴⁷, Cho-il Kim¹⁴⁸, Rebecca Kuriyan-Raj¹⁴⁹, Sumathi Swaminathan¹⁴⁹, Didier Garriguet¹⁵⁰, Saeed Dastgiri¹⁵¹, Sirje Vaask¹⁵², Tilakavati Karupaiah¹⁵³, Fatemeh Vida Zohoori¹⁵⁴, Alireza Esteghamati¹⁵⁵, Maryam Hashemian^{156,157}, Sina Noshad¹⁵⁵, Elizabeth Mwaniki¹⁵⁶, Elizabeth Yakes-Jimenez¹⁵⁸, Justin Chileshe¹⁵⁹, Sydney Mwanza¹⁵⁹, Lydia Lera Marques¹⁶⁰, Alan Martin Preston¹⁶¹, Samuel Duran Aguero¹⁶², Mariana Oleas¹⁶³, Luz Posada¹⁶⁴, Angelica Ochoa¹⁶⁵, Khadijah Shamsuddin¹⁶⁶, Zalilah Mohd Shariff¹⁶⁷, Hamid Jan Bin Jan Mohamed¹⁶⁸, Wan Manan¹⁶⁸, Anca Nicolau¹⁶⁹, Cornelia Tudorie¹⁶⁹, Bee Koon Poh¹⁷⁰, Pamela Abbott¹⁷¹, Mohammadreza Pakseresht¹⁷², Sangita Sharma¹⁷², Tor Strand¹⁷³, Ute Alexy¹⁷⁴, Ute Nöthlings¹⁷⁴, Jan Carmikle¹⁷⁴, Ken Brown¹⁷⁵, Jeremy Koster¹⁷⁶, Indu Waidyatilaka¹⁷⁷, Pulani Lanerolle¹⁷⁷, Ranil Jayawardena¹⁷⁷, Julie M. Long¹⁷⁸, K. Michael Hambidge¹⁷⁸, Nancy F. Krebs¹⁷⁸, Aminul Haque¹⁷⁹, Gudrun B. Keding¹⁸⁰, Liisa Korkalo¹⁸¹, Majjaliisa Erkkola¹⁸¹, Riitta Freese¹⁸¹, Laila Eleraky¹⁸², Wolfgang Stuetz¹⁸², Inga Thorsdottir¹⁸³,

Ingibjorg Gunnarsdottir¹⁸³, Lluís Serra-Majem¹⁸⁴, Foong Ming Moy¹⁸⁵, Simon Anderson¹⁸⁶, Rajesh Jeewon¹⁸⁷, Corina Aurelia Zugravu¹⁸⁸, Linda Adair¹⁸⁹, Shu Wen Ng¹⁸⁹, Sheila Skeaff¹⁹⁰, Dirce Marchionni¹⁹¹, Regina Fisberg¹⁹¹, Carol Henry¹⁹², Getahun Ersino¹⁹², Gordon Zello¹⁹², Alexa Meyer¹⁹³, Ibrahim Elmadafa¹⁹³, Claudette Mitchell¹⁹⁴, David Balfour¹⁹⁴, Johanna M. Geleijnse¹⁹⁵, Mark Manary¹⁹⁶, Tatyana El-kour¹⁹⁷, Laetitia Nikiema¹⁹⁸, Masoud Mirzaei¹⁹⁹ & Rubina Hakeem²⁰⁰

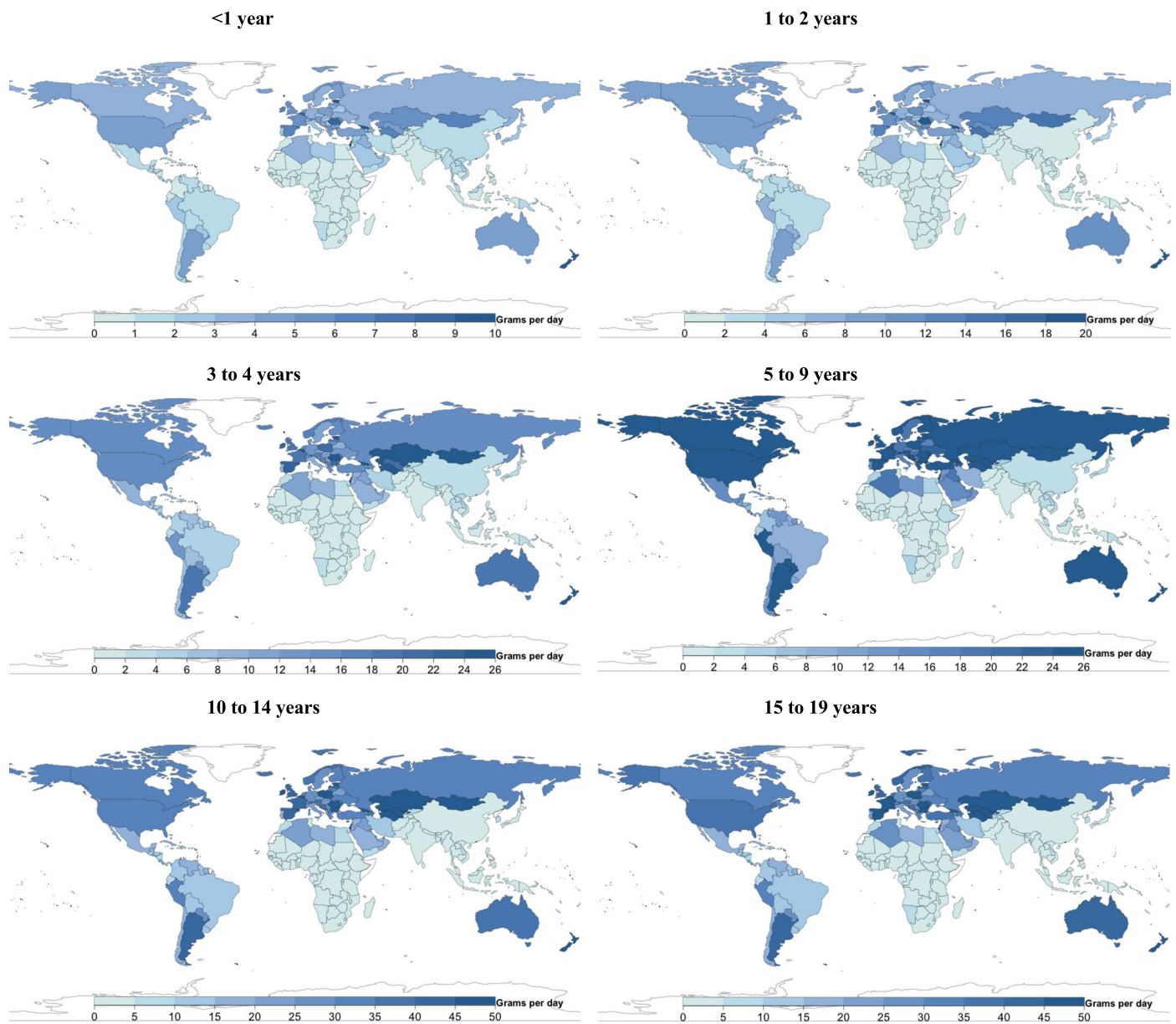
⁶Acibadem University, Istanbul, Turkey. ⁷Addis Ababa University, Addis Ababa, Ethiopia. ⁸Al Ain University, Abu Dhabi, UAE. ⁹All India Institute of Medical Sciences, New Delhi, India. ¹⁰American University of Beirut, Beirut, Lebanon. ¹¹Amrita School of Dentistry, Ernakulum, India. ¹²Andalas University, Padang, Indonesia. ¹³Arab Center for Nutrition, Manama, Bahrain. ¹⁴Ardabil University of Medical Sciences, Ardabil, Iran. ¹⁵Bacha Khan University, Charsadda, Pakistan. ¹⁶Belgian Public Health Institute, Brussels, Belgium. ¹⁷Biodiversity International, Maccaresse, Italy. ¹⁸Brighton and Sussex Medical School, Brighton, UK. ¹⁹CREA-Alimenti e Nutrizione, Rome, Italy. ²⁰Cadi Ayyad University, Benguerir, Morocco. ²¹Center for Studies of Sensory Impairment, Aging and Metabolism (CeSSIAM), Guatemala City, Guatemala. ²²Centre For Media Studies, New Delhi, India. ²³Centro de Atencion Nutricional Antimano (CANIA), Miami, FL, USA. ²⁴Centro de Estudios sobre Nutrición Infantil (CESNI), Buenos Aires, Argentina. ²⁵College of Applied Sciences, Department of Food Science and Applied Nutrition, Addis Ababa Science and Technology University, Addis Ababa, Ethiopia. ²⁶Consultative Group on International Agricultural Research (CGIAR), Montpellier, France. ²⁷Cuenca University, Cuenca, Ecuador. ²⁸Delhi School of Economics, University of Delhi, Delhi, India. ²⁹Departamento de Alimentacao Escolar, Sao Paulo, Brazil. ³⁰Department of Biomedical and Biotechnological Sciences, University of Catania, Catania, Italy. ³¹Department of CVD Epidemiology, Prevention and Health Promotion, Institute of Cardiology, Warsaw, Poland. ³²Department of Community Health Sciences, Aga Khan University, Karachi, Pakistan. ³³Diabetes Center, Second Department of Internal Medicine, Athens University, Athens, Greece. ³⁴Digestive Disease Research Institute, Tehran University of Medical Sciences, Tehran, Iran. ³⁵Directorate for Health Information & Research, Tarxien, Malta. ³⁶Dutch National Institute for Public Health and the Environment (RIVM), Bilthoven, Netherlands. ³⁷Eastern Mediterranean Public Health Network (EMPHNET), Amman, Jordan. ³⁸Egerton University, Njoro, Kenya. ³⁹Estonian National Institute for Health Development, Tallinn, Estonia. ⁴⁰FHI Solutions, Washington, DC, USA. ⁴¹FOSCAL and UDES, Bucaramanga, Colombia. ⁴²Faculty of Health Sciences, American University of Beirut, Beirut, Lebanon. ⁴³Faculty of Medicine, Eduardo Mondlane University, Maputo, Mozambique. ⁴⁴Faculty of Medicine, University of Colombo, Colombo, Sri Lanka. ⁴⁵Faculty of Medicine/Institute of Public Health, University of Porto, Porto, Portugal. ⁴⁶Faculty of Nutrition and Food Sciences, University of Porto, Porto, Portugal. ⁴⁷Finnish Institute for Health and Welfare, Helsinki, Finland. ⁴⁸Florida International University, Miami, FL, USA. ⁴⁹Folkhälsan Research Center, Helsinki, Finland. ⁵⁰Food and Nutrition Research Institute (DOST-FNRI), Manila, Philippines. ⁵¹Food and Nutrition Research Institute, Department of Science and Technology, Taguig City, Philippines. ⁵²Fortis CDOC Center for Excellence for Diabetes, New Delhi, India. ⁵³FrieslandCampina, Amersfoort, The Netherlands. ⁵⁴Fundacion Cardiovascular de Colombia, Bucaramanga, Colombia. ⁵⁵Fundacion INFANT and Consejo Nacional De Investigaciones Cientificas y Tecnicas (CONICET), Buenos Aires, Argentina. ⁵⁶Fundacion Oftalmologica de Santander (FOSCAL), Floridablanca, Colombia. ⁵⁷Gachon University, Seongnam-si, South Korea. ⁵⁸Gazi University, Yenimahalle/Ankara, Turkey. ⁵⁹Geneva University Hospitals, Geneva, Switzerland. ⁶⁰Ghent University, Ghent, Belgium. ⁶¹Global Dietary Database Consortium, Boston, MA, USA. ⁶²Government of Canada, Statistics Canada, Ottawa, Canada. ⁶³Griffith University, Gold Coast, Queensland, Australia. ⁶⁴HC Jehangir Medical Research Institute, Pune, India. ⁶⁵Hacettepe University Faculty of Medicine, Ankara, Turkey. ⁶⁶Hanoi Medical University, Hanoi, Vietnam. ⁶⁷Harokopio University, Athens (Kallithea), Greece. ⁶⁸Harvard School of Public Health, Cambridge, MA, USA. ⁶⁹Hellenic Health Foundation and University of Athens, Athens, Greece. ⁷⁰Herbert Wertheim College of Medicine, Miami, FL, USA. ⁷¹Hirabai Cowasji Jehangir Medical Research Institute, Pune, India. ⁷²Hypertension Research Center, Cardiovascular Research Center, Isfahan University of Medical Sciences, Isfahan, Iran. ⁷³ICCAS (Instituto para la Cooperacion Cientifica en Ambiente y Salud), Buenos Aires, Argentina. ⁷⁴ICMR-National Institute of Nutrition, Hyderabad, India. ⁷⁵IRCCS Neuromed, Pozzilli, Italy. ⁷⁶University of Insubria, Varese, Italy. ⁷⁷Institut de Recherche pour le Developpement, Montpellier, France. ⁷⁸Institut de Veille Sanitaire, Bobigny, France. ⁷⁹Institute for International Investigation, NDRI-USA, New York, NY, USA. ⁸⁰Institute of Biomedical Sciences, Academia Sinica, Taipei, Taiwan. ⁸¹Institute of Nutrition and Food Technology (INTA), University of Chile, Santiago, Chile. ⁸²Institute of Nutrition in Central America and Panama (INCAP), Guatemala City, Guatemala. ⁸³Institute of Public Health of Federation of Bosnia and Herzegovina, Sarajevo, Bosnia and Herzegovina. ⁸⁴Institute of Studies in Public Health, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil. ⁸⁵Institutes of Biomedical Sciences, Academia Sinica, Taipei, Taiwan. ⁸⁶International Agency for Research on Cancer, Lyon, France. ⁸⁷International Food Policy Research Institute (IFPRI), Washington, DC, USA. ⁸⁸Interventional Cardiology Research Center, Cardiovascular Research Center, Isfahan University of Medical Sciences, Isfahan, Iran. ⁸⁹Intitut de Recherche en Sciences de la Sante, Bobo Dioulasso, Burkina Faso. ⁹⁰Isfahan Cardiovascular Research Center, Cardiovascular Research Center, Isfahan University of Medical Sciences, Isfahan, Iran. ⁹¹Israel Center for Disease Control, Tel-Hashomer, Israel. ⁹²Justus Liebig University Giessen, Giessen, Germany. ⁹³Jawaharlal Nehru Medical College, Belagavi, India. ⁹⁴Kenya Medical Research Institute, Nairobi, Kenya. ⁹⁵King Abdulaziz University, Jeddah, Saudi Arabia. ⁹⁶King Saud University, Riyadh, Saudi Arabia. ⁹⁷King's College London, London, UK. ⁹⁸Kinshasa School of Public Health, Kinshasa, Democratic Republic of Congo. ⁹⁹Korea Disease Control and Prevention Agency (KDCA), Cheongju, Korea. ¹⁰⁰Korea University, Seoul, Korea. ¹⁰¹Kuwait Institute for Scientific Research, Safat, Kuwait. ¹⁰²Lao Tropical and Public Health Institute, Vientiane Capital, Lao PDR. ¹⁰³Lausanne University Hospital (CHUV) and University of Lausanne, Lausanne, Switzerland. ¹⁰⁴Leibniz Centre for Agricultural Landscape Research, Müncheberg, Germany. ¹⁰⁵Loyola University Chicago, Chicago, IL, USA. ¹⁰⁶Mahidol University, Bangkok, Thailand. ¹⁰⁷Mahidol University, Pathom, Thailand. ¹⁰⁸Malaysian Palm Oil Council (MPOC), Kelana Jaya, Malaysia. ¹⁰⁹Medical Center Markovs, Sofia, Bulgaria. ¹¹⁰Menopause Andropause Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran. ¹¹¹Ministry of Health, Jakarta, Indonesia. ¹¹²Ministry of Health, Kuala Lumpur, Malaysia. ¹¹³Ministry of Health, Sungai Besar, Malaysia. ¹¹⁴Ministry of Health, Victoria, Seychelles. ¹¹⁵University Center for Primary Care and Public Health (Unisanté), Lausanne, Switzerland. ¹¹⁶NYU School of Medicine, New York, NY, USA. ¹¹⁷National Cancer Center Institute for Cancer Control, Tokyo, Japan. ¹¹⁸National Centre of Public Health and Analyses (NCPHA), Sofia, Bulgaria. ¹¹⁹National Food Agency, Uppsala, Sweden. ¹²⁰National Food and Nutrition Commission, Lusaka, Zambia. ¹²¹National Food and Nutrition Institute, Warsaw, Poland. ¹²²National Health Research Institutes, Zhunan Township, Taiwan. ¹²³Health and Environmental Risk Division, National Institute for Environmental Studies, Tsukuba, Japan. ¹²⁴National Institute of Nutrition, Hanoi, Vietnam. ¹²⁵National Institute of Nutrition, Hyderabad, India. ¹²⁶National Institute of Nutrition and Food Technology & SURVEN RL, Tunis, Tunisia. ¹²⁷National Institute of Public Health (INSP), Cuernavaca, Mexico. ¹²⁸National Institute of Public Health (INSP), Mexico City, Mexico. ¹²⁹National Institutes of Biomedical Innovation, Health and Nutrition, Tokyo, Japan. ¹³⁰National Nutrition Institute, Cairo, Egypt. ¹³¹National Nutrition and Food Technology Research Institute (NNFTRI): SBMU, Tehran, Iran. ¹³²National University of Malaysia (UKM), Kuala Lumpur, Malaysia. ¹³³Nestlé Research, Lausanne, Switzerland. ¹³⁴New England Complex Systems Institute, Cambridge, MA, USA. ¹³⁵North-West University, Potchefstroom, South Africa. ¹³⁶Oslo Metropolitan University (OsloMet), Oslo, Norway. ¹³⁷Perdana University–Royal College of Surgeons in Ireland, Puchong, Malaysia. ¹³⁸Pontificia Universidad Javeriana Seccional, Cali, Colombia. ¹³⁹Public Authority For Food and Nutrition, Sabah Al Salem, Kuwait. ¹⁴⁰Public Health Authority of the Slovak Republic, Bratislava, Slovak Republic. ¹⁴¹Qatar University and University of Jordan, Doha, Qatar. ¹⁴²Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

¹⁴³Research Institute for Primordial Prevention of NCD, Isfahan University of Medical Sciences, Isfahan, Iran. ¹⁴⁴Risk and Benefit Assessment Department, Swedish Food Agency, Uppsala, Sweden. ¹⁴⁵Robert Koch Institute, Berlin, Germany. ¹⁴⁶Rutgers University, New Brunswick, NJ, USA. ¹⁴⁷Santé publique France, Saint Maurice, France. ¹⁴⁸Seoul National University, Seoul, Korea. ¹⁴⁹St John's Research Institute, Bangalore, India. ¹⁵⁰Statistics Canada, Ottawa, Ontario, Canada. ¹⁵¹Tabriz University of Medical Sciences, Tabriz, Iran. ¹⁵²Tallinn University, Tallinn, Estonia. ¹⁵³Taylor's University, Selangor, Malaysia. ¹⁵⁴Teesside University, Middlesbrough, UK. ¹⁵⁵Tehran University of Medical Sciences, Tehran, Iran. ¹⁵⁶The Technical University of Kenya, Nairobi, Kenya. ¹⁵⁷Utica University, Tehran, Iran. ¹⁵⁸The University of New Mexico, Albuquerque, NM, USA. ¹⁵⁹Tropical Diseases Research Centre, Ndola, Zambia. ¹⁶⁰Unidad de Nutricion Publica, Macul, Chile. ¹⁶¹Department of Biochemistry, Medical Sciences, University of Puerto Rico, San Juan, Puerto Rico. ¹⁶²Universidad San Sebastian, Providencia, Chile. ¹⁶³Universidad Tecnica del Norte, Ibarra, Ecuador. ¹⁶⁴Universidad de Antioquia, Medellin, Colombia. ¹⁶⁵Universidad de Cuenca, Cuenca, Ecuador. ¹⁶⁶Universiti Kebangsaan Malaysia Medical Centre, Kuala Lumpur, Malaysia. ¹⁶⁷Universiti Putra Malaysia, Serdang, Malaysia. ¹⁶⁸Universiti Sains Malaysia, Kubang Kerian, Malaysia. ¹⁶⁹University Dunarea de Jos, Galati, Romania. ¹⁷⁰University Kebangsaan Malaysia, Selangor, Malaysia. ¹⁷¹University of Aberdeen, Aberdeen, UK. ¹⁷²University of Alberta, Edmonton, Alberta, Canada. ¹⁷³University of Bergen, Bergen, Norway. ¹⁷⁴Department of Nutrition and Food Sciences, University of Bonn, Bonn, Germany. ¹⁷⁵University of California Davis, Davis, CA, USA. ¹⁷⁶University of Cincinnati, Cincinnati, OH, USA. ¹⁷⁷University of Colombo, Colombo, Sri Lanka. ¹⁷⁸University of Colorado School of Medicine, Aurora, CO, USA. ¹⁷⁹University of Dhaka, Dhaka, Bangladesh. ¹⁸⁰University of Goettingen, Goettingen, Germany. ¹⁸¹Department of Food and Nutrition, University of Helsinki, Helsinki, Finland. ¹⁸²University of Hohenheim, Stuttgart, Germany. ¹⁸³University of Iceland, Reykjavík, Iceland. ¹⁸⁴University of Las Palmas de Gran Canaria (ULPGC), Canary Islands, Las Palmas, Spain. ¹⁸⁵University of Malaya, Kuala Lumpur, Malaysia. ¹⁸⁶University of Manchester, Manchester, UK. ¹⁸⁷University of Mauritius, Reduit, Mauritius. ¹⁸⁸University of Medicine and Pharmacy Carol Davila, Bucharest, Romania. ¹⁸⁹University of North Carolina at Chapel Hill, Chapel Hill, NC, USA. ¹⁹⁰University of Otago, Dunedin, New Zealand. ¹⁹¹University of Sao Paulo, Sao Paulo, Brazil. ¹⁹²University of Saskatchewan, Saskatoon, Saskatchewan, Canada. ¹⁹³University of Vienna, Vienna, Austria. ¹⁹⁴University of the Southern Caribbean, Port-of-Spain, Trinidad and Tobago. ¹⁹⁵Wageningen University, Wageningen, Netherlands. ¹⁹⁶Washington University in St. Louis, St. Louis, MO, USA. ¹⁹⁷World Health Organization (WHO), Amman, Jordan. ¹⁹⁸World Health Organization (WHO), Geneva, Switzerland. ¹⁹⁹Yazd Cardiovascular Research Centre, Shahid Sadoughi University of Medical Sciences, Yazd, Iran. ²⁰⁰Ziauddin University Karachi, Karachi City, Pakistan.

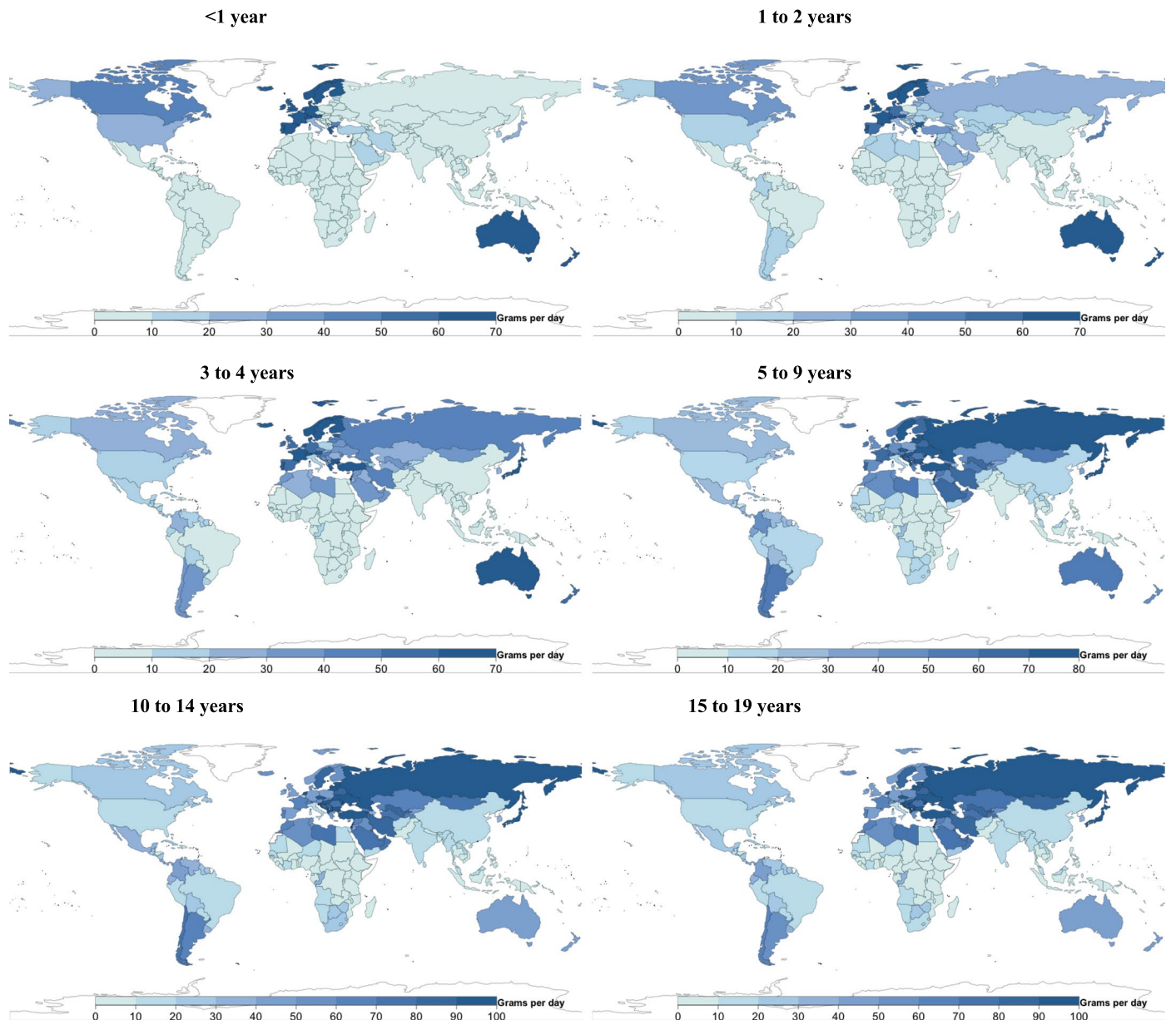


Extended Data Fig. 1 | National milk intake (g/d) from 185 countries, by age. Of 185 countries, 20, representing 867 million or 34.0%, had intakes <1 serving per day. Of 185 countries, 22 had mean intakes of at least one serving of

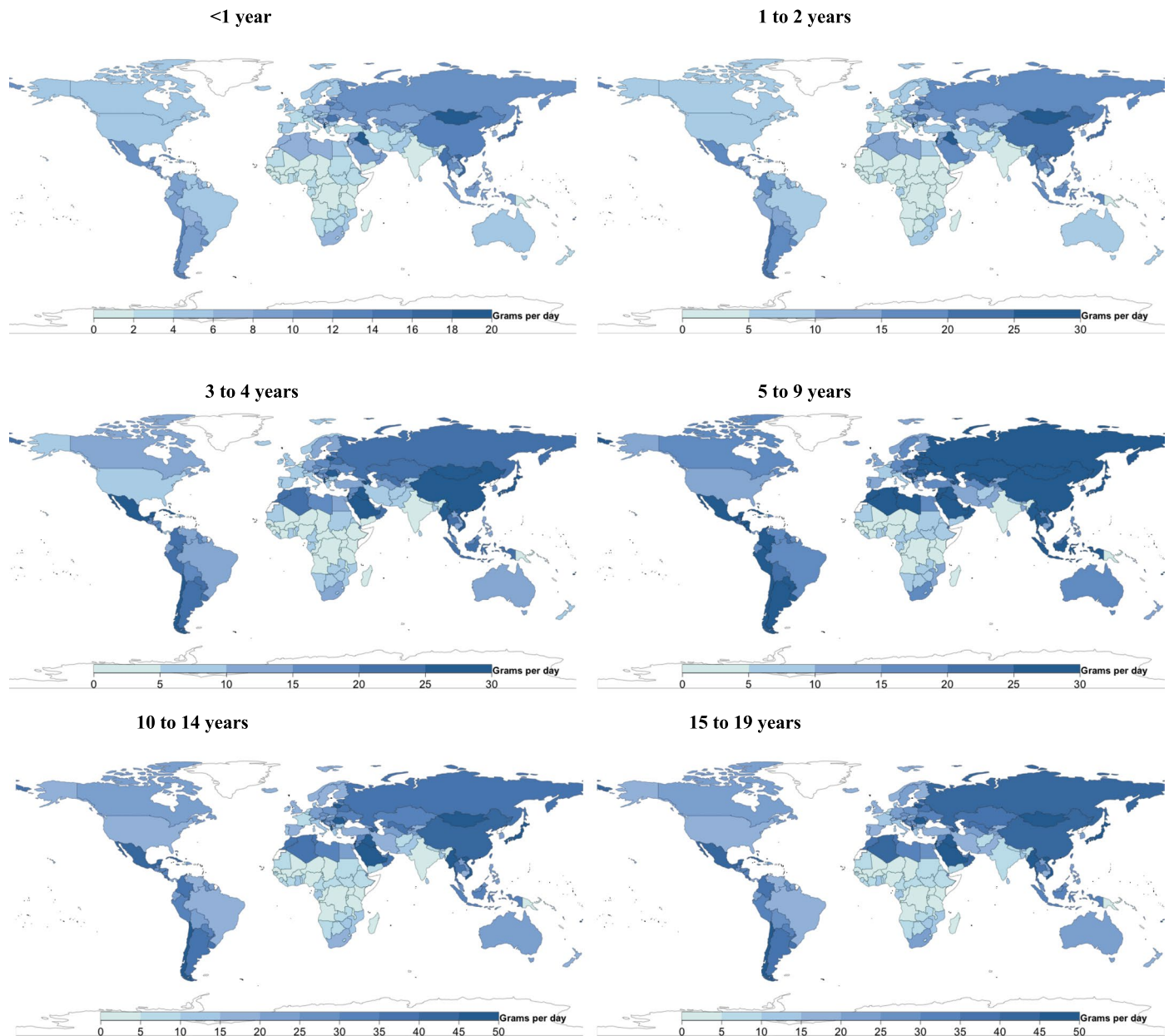
milk (245 g) daily (representing 7.7% of the global child population), and 21 of 185 (representing 10.7% of the global child population) had mean intakes of <1 serving per week.



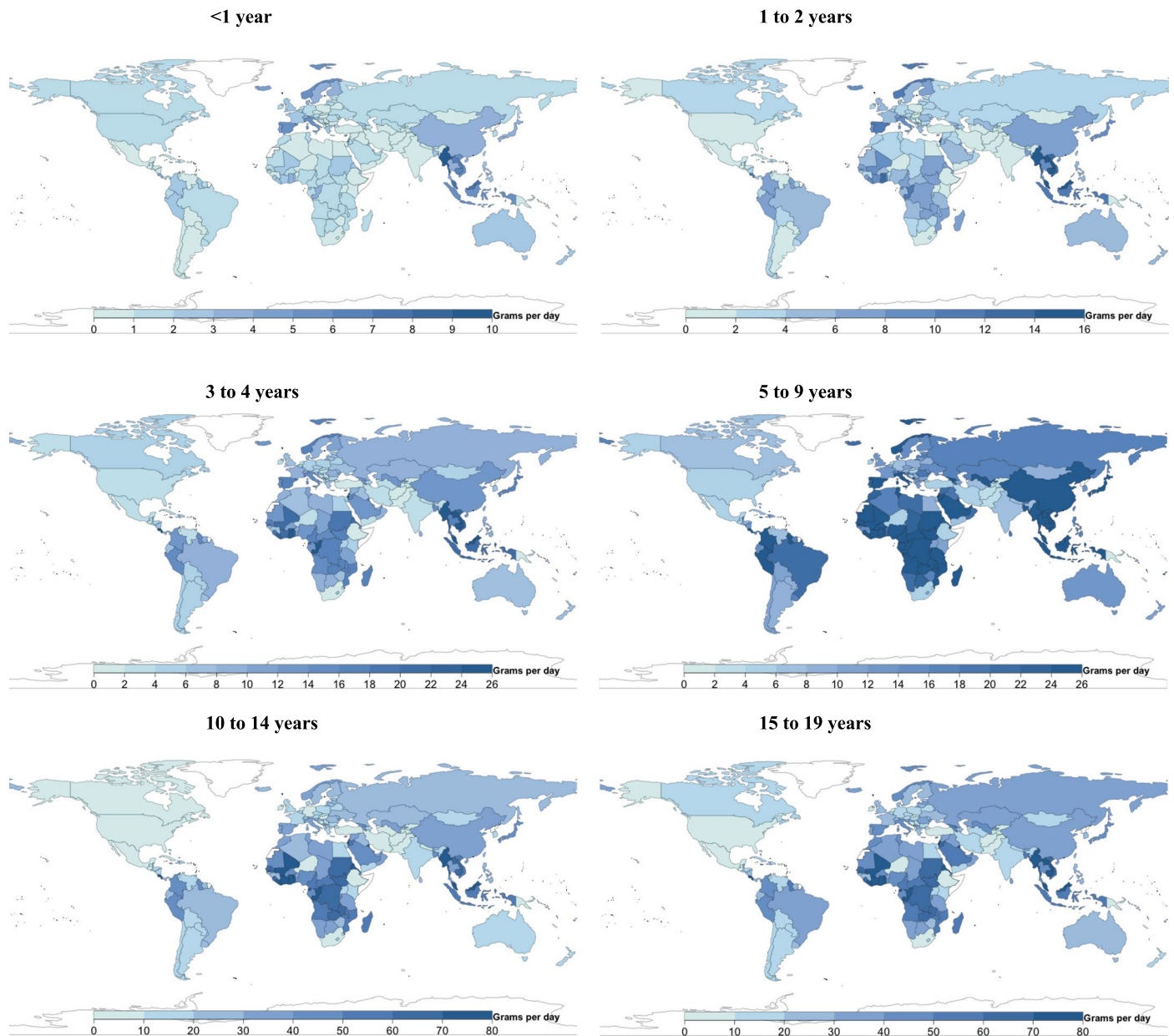
Extended Data Fig. 2 | National cheese intake (g/d) from 185 countries, by age. Of 185 countries, 8 had mean intakes of at least one serving of cheese (42 g) daily (representing <1% of the global child population), and 88 of 185 (representing 75.7% of the global child population) had mean intakes of <1 serving per week.



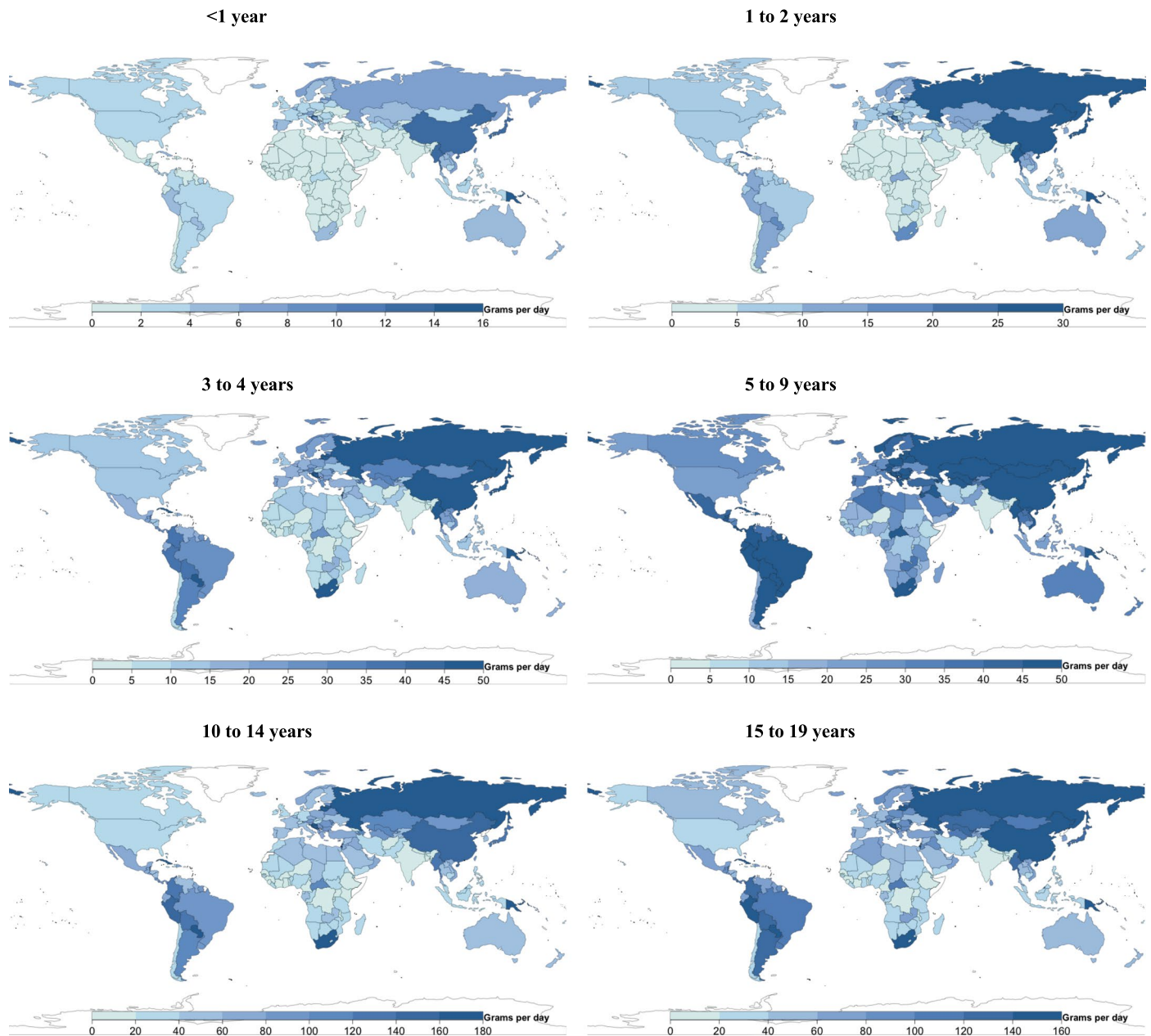
Extended Data Fig. 3 | National yogurt intake (g/d) from 185 countries, by age. Of 185 countries, 25 had mean intakes of ≥ 2 servings of yogurt (245 g) per week (representing 5.2% of the global child population).



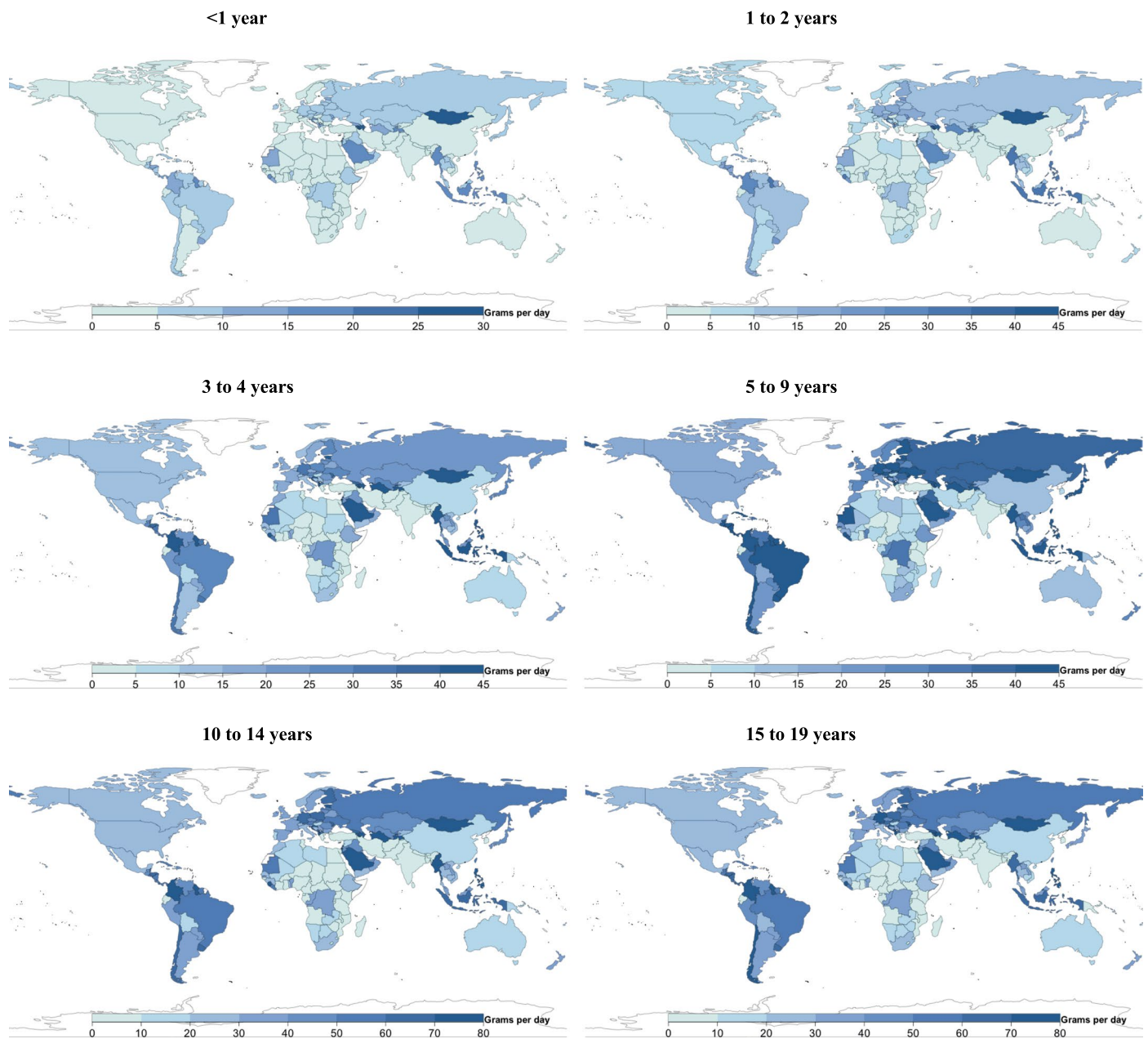
Extended Data Fig. 4 | National egg intake (g/d) from 185 countries, by age. Only 5 of 185 countries consumed ≥ 1 egg (55 g) daily, representing 0.9% of the global child population, and 41 of 185 (representing 41.3% of the global child population) consumed < 1 serving per week.



Extended Data Fig. 5 | National seafood intake (g/d) from 185 countries, by age. Only 8 of 185 countries consumed a mean of ≥ 2 servings of seafood (100 g each) per week, representing 2.0% of the global child population, while 56 countries representing 1.2 billion children (45.3% of the global child population) had mean intakes of < 1 serving per week.



Extended Data Fig. 6 | National unprocessed red meat intake (g/d) from 185 countries, by age. Of 185 countries, 14 (representing 17.9% of the global child population) had mean consumption of ≥ 1 serving of unprocessed red meat (100 g) per day, and 24 of 185 (representing 33.5% of the global child population) had mean consumption of < 1 serving per week.



Extended Data Fig. 7 | National processed meat intake (g/d) from 185 countries, by age. Of 185 countries, 28 (representing 9.2% of the global child population) had mean intakes of ≥ 1 serving of processed meat (50 g) daily, and 37 of 185 (representing 44.6% of the global child population) had mean intakes of <1 serving per week.

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

- | | |
|-------------------------------------|---|
| n/a | Confirmed |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> The statistical test(s) used AND whether they are one- or two-sided
<i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i> |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> A description of all covariates tested |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals) |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> For null hypothesis testing, the test statistic (e.g. F , t , r) with confidence intervals, effect sizes, degrees of freedom and P value noted
<i>Give P values as exact values whenever suitable.</i> |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes |
| <input type="checkbox"/> | <input checked="" type="checkbox"/> Estimates of effect sizes (e.g. Cohen's d , Pearson's r), indicating how they were calculated |

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection

Data analysis

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

The modelled estimates are available for download from the Global Dietary Database (<https://www.globaldietarydatabase.org/>). Survey-level information and original data download weblinks are also provided for all public surveys; and survey-level microdata or stratum-level aggregate data are provided for direct download for all non-public surveys granted consent for public sharing by the data owner. Data on national food and nutrient supplies are available for download from the United Nations Food and Agriculture Organization (<https://www.fao.org/faostat/en/#data>) and the Global Expanded Nutrient Supply (GENUS) model

Human research participants

Policy information about [studies involving human research participants and Sex and Gender in Research](#).

Reporting on sex and gender

Our study reports animal source food consumption by sex. Data on gender was not collected or reported.

Population characteristics

GDD 2018 incorporated 1,248 dietary surveys from 188 countries, comprising 99.0% of the world's population. Data on ASF consumption (milk, cheese, yogurt, eggs, seafood, unprocessed red meat, processed red meat) was reported in 498 surveys, including 429 with data on children, defined as between age 0 to 19 years. These 429 surveys included 3.3 million children from 125 countries, representing 93.1% of the global child population. Most surveys were nationally representative (88.1%), collected at the individual-level (78.1%), and included data by rural and/or urban residence (71.1%) and by parental education (53.4%).

Recruitment

Not applicable.

Ethics oversight

Not applicable.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

Life sciences

Behavioural & social sciences

Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://www.nature.com/documents/nr-reporting-summary-flat.pdf)

Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description

We conducted a Bayesian hierarchical modeling study. First, we systematically searched, identified, extracted and harmonized publicly available and privately-held dietary surveys. To account for differences in survey methods, representativeness, time trends, input data, and uncertainty, a Bayesian model estimated the log-means of dietary intake (mean and standard deviation) within a nested hierarchical structure. The model included random effects by country, region, and globally; sex, education, urban/rural residence, and non-linear age effects; survey-level indicator data for dietary assessment method (24-hr recall, FFQ, Demographic Health Survey (DHS) questionnaire, household budget survey) and type of dietary metric (optimal or suboptimal definition); and national year-specific covariate data relevant to each dietary factor. The model included overdispersion of study-level variance for surveys that were not nationally representative or not stratified by sex, education, urbanicity, or small age groups (≤ 10 years). The model estimated mean intake of each ASF and its statistical uncertainty for each of the 72 population strata from 185 countries, for 1990 and 2018.

Research sample

The research sample consists of dietary surveys identified through systematic searches and personal communication with survey owners. The GDD incorporated 1,248 dietary surveys from 188 countries, comprising 99.0% of the world's population. Data on ASF consumption (milk, cheese, yogurt, eggs, seafood, unprocessed red meat, processed red meat) was reported in 498 surveys, including 429 with data on children, defined as between age 0 to 19 years. These 429 surveys included 3.3 million children from 125 countries, representing 93.1% of the global child population. Most surveys were nationally representative (88.1%), collected at the individual-level (78.1%), and included data by rural and/or urban residence (71.1%) and by parental education (53.4%).

Sampling strategy

We systematically searched for individual-level national surveys for dietary intakes worldwide, with additional data obtained through communication with researchers and government authorities. We prioritized nationally and sub-nationally representative surveys, and surveys collected at the individual level using standardized 24-hr recalls, food frequency questionnaires (FFQ), or short standardized questionnaires (e.g., Demographic Health Survey [DHS] questionnaire). Surveys from large cohort studies or household budget surveys in populous countries were selected when nationally or sub-nationally representative individual-level surveys were not identified. Surveys focused on special populations (e.g., pregnant women, lactating women, individuals with a specific disease) were excluded.

Data collection

Standardized protocols were used to identify, extract, and analyze data in a systematic and comparable manner. For privately owned surveys, survey characteristics were retrieved using a standardized electronic form, including data on survey name, country, years performed, sampling methodology, response rate, national representativeness, level of data collection (individual- or household-level), dietary assessment method and validation, sample size, population demographics (age, sex, education, urban/rural residence, pregnancy/lactation status), and definitions and measurement units of dietary factors. Individual-level microdata were retrieved as SAS, or STATA files. Aggregate stratum-level dietary intake data were collected using standardized electronic spreadsheets, including data on stratum sample size and means, standard deviations, and 10th, 25th, 50th, 75th, and 90th percentiles of intake for each

dietary factor, jointly stratified by age, sex, education and urban/rural strata, as available. Data from publicly available surveys were retrieved using a similar standardized electronic spreadsheet as for the privately owned surveys. For each survey in the GDD, we assessed the credibility of information obtaining relating to survey characteristics, including survey name, country, years performed, sampling methods, response rate, national representativeness, level of data collection (individual or household), dietary assessment method and validation, sample size, population demographics (age, sex, education, urban/rural residence, pregnancy/lactation status), and definitions and units of dietary factors. We evaluated dietary intakes adjusted to age-standardized energy intakes to assess dietary composition independently of quantity, account for estimated age-specific average requirements, and reduce measurement error within and across surveys. The research team was not blinded to the study hypothesis.

Timing	Systematic searches were conducted between May 2008-September 2010 and November 2014-May 2017 to identify dietary surveys. We included surveys conducted between 1980 and 2016.
Data exclusions	Surveys focused on special populations (e.g., pregnant women, lactating women, individuals with a specific disease), conducted prior to 1980 or after 2016 were excluded.
Non-participation	The study is an analysis of existing observational studies.
Randomization	The study is an analysis of existing observational studies and randomization is not applicable.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Included in the study
<input checked="" type="checkbox"/>	<input type="checkbox"/> Antibodies
<input checked="" type="checkbox"/>	<input type="checkbox"/> Eukaryotic cell lines
<input checked="" type="checkbox"/>	<input type="checkbox"/> Palaeontology and archaeology
<input checked="" type="checkbox"/>	<input type="checkbox"/> Animals and other organisms
<input checked="" type="checkbox"/>	<input type="checkbox"/> Clinical data
<input checked="" type="checkbox"/>	<input type="checkbox"/> Dual use research of concern

Methods

n/a	Included in the study
<input checked="" type="checkbox"/>	<input type="checkbox"/> ChIP-seq
<input checked="" type="checkbox"/>	<input type="checkbox"/> Flow cytometry
<input checked="" type="checkbox"/>	<input type="checkbox"/> MRI-based neuroimaging