

Micronutrient Intake and Dietary Patterns Associated with Cardiometabolic Health Outcomes of Overweight and Obese Pregnant Women in Dodoma, Tanzania

Jacktan J Ruhighira

jacktantz@gmail.com

University of Dodoma

Alexander M Tungu

Muhimbili University of Health and Allied Science

Costantine C Kamata

University of Dodoma

Elizabeth A John

University of Dodoma

Davis Ngarashi

Muhimbili University of Health and Allied Science

Evangelista Malindisa

Catholic University of Health and Allied Science

Fredirick L Mashili

Muhimbili University of Health and Allied Science

Research Article

Keywords: vitamin, micronutrients, pregnancy, dietary pattern, obesity, reduced rank regression

Posted Date: June 28th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9730977/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Historically, public health efforts in Tanzania have focused predominantly on addressing underweight and micronutrient deficiencies in pregnancy, but overweight and obesity are currently increasing. Context-specific data are essential to guide interventions for this high-risk group, but they are largely lacking. This study aimed to compare the micronutrient intake of overweight and obese pregnant women to their normal-weight counterparts and correlate their dietary patterns with cardiometabolic health outcomes.

Methods

A cross-sectional study looked at dietary micronutrient consumption of 242 pregnant women using contextualised 179-item FFQ and food composition tables. The micronutrient intake of overweight/obese participants was compared against normal-weight counterparts and the recommended intakes. Dietary patterns were determined by reduced rank regression (RRR).

Results

Although less common than normal-weight women, considerable portions of overweight and obese participants had intakes below recommended for key micronutrients, including vitamins A (6%), B12 (12%), and folate (12%); calcium (48%); iron (11%); and zinc (17%). Yet 57.8% were not taking iron supplements, 35.6% were not taking folate supplements, and none were taking calcium supplements. One dietary pattern, namely 'dysmetabolic' was identified and was characterised by high consumption of added sugars, boiled roots/tubers, plantains, meat, fried grain/roots/tubers, poultry, nuts/products and alcohol, but less consumption of boiled grain/cereals, and legumes/pulses. This pattern was associated with dyslipidaemia and glucose impairment, but better haemoglobin concentration.

Conclusion

Overweight and obese pregnant women exhibited dietary patterns linked to inconsistent cardiometabolic health outcomes by addressing some deficiencies, while creating new metabolic risks, and a higher tendency to neglect recommended micronutrient supplements.

1. Background

Overweight and obesity are recognised as significant chronic public health problems, with their prevalence continuing to rise globally, especially among women [1, 2]. In Africa, the prevalence of overweight among women increased from 31% in 2009 to 40% in 2019, while obesity rates rose from

12% to 19% and are projected to continue growing if no appropriate interventions are made [3]. Consequently, the prevalence of overweight and obesity among pregnant women is rising in parallel, reaching up to 50% in certain parts of Africa [4].

Tanzania, like many Low- and Middle-Income Countries (LMICs), is now experiencing the double burden of malnutrition (DBM), marked by the co-existence of undernutrition and the increasing rates of overweight and obesity. This transition, driven by sociocultural, lifestyle, and economic changes, presents a complex challenge for maternal healthcare [5, 6]. Given that 39% of pregnant women in Tanzania are now overweight or obese, this cohort represents a substantial and growing proportion of the antenatal population [7, 8]. Overweight and obesity are known to significantly increase the risk of vitamin and mineral malnutrition during pregnancy due to related factors such as poor-quality diets, higher nutrient requirements, and alterations in micronutrient metabolism [9]. Therefore, this population is susceptible to adverse maternal and neonatal outcomes stemming from both micronutrient deficiencies and potentially excessive intakes of certain nutrients [10, 11].

Micronutrients are vital for supporting physiological changes in pregnancy and fetal growth [12–16]. Consequently, deficiencies are concerns that lead to adverse maternal and infant outcomes. Micronutrient deficiencies in pregnancy are associated with increased risks of miscarriage, anaemia, premature rupture of the membranes (PROM), placental abruption, preeclampsia, urinary tract infections, and preterm births [17–20]. Furthermore, infants born to mothers with micronutrient deficiencies have an increased risk of low birth weight, vision impairments, impaired lung function, serious congenital defects and a higher likelihood of developing asthma, language difficulties, and autism [17–20].

Historically, public health efforts in LMICs have focused predominantly on addressing underweight and micronutrient deficiencies in pregnancy [21, 22]. However, the rising DBM necessitates a shift, as current maternal nutrition recommendations may be inadequate for the rapidly growing overweight and obese population [9, 23, 24]. Context-specific data are essential to guide interventions for this high-risk group, but they are largely lacking, meaning that current maternal nutrition counselling and supplementation guidelines may be inappropriate or suboptimal for them. This study aimed to compare the dietary intake of vitamins and minerals of overweight and obese pregnant women and their normal-weight counterparts and further correlate their dietary patterns with cardiometabolic health outcomes to inform targeted nutritional interventions that address the DBM in the antenatal care setting. We hypothesized that overweight and obese pregnant women would demonstrate: (1) distinct dietary patterns with different food group compositions than normal-weight women, (2) higher overall micronutrient intake, and (3) dietary patterns associated with adverse cardiometabolic outcomes.

2. Methods

2.1. Design and Sampling

This cross-sectional study examined the dietary micronutrient consumption of overweight and obese pregnant women. The study included 242 pregnant women recruited sequentially from prenatal clinics at Makole Health Centre in Dodoma, Tanzania, between February and March 2024. The sample size was calculated using the mean inter-trimester weight gain (6.3 kg) and variance (4.9) of a pregnant cohort in urban Tanzania [25]. The study group's average weight gain was estimated to be ± 1 kg, with a 95% level of significance, 80% power, and 25% non-response.

2.2. Inclusion and Exclusion Criteria

Participants aged 18–35 with a singleton pregnancy of 6–40 weeks' gestation were eligible for the study. Women on special diets and those who didn't know their body weight within three months prior to pregnancy were excluded. Also, women already diagnosed with any cardiometabolic disease were excluded. Underweight participants were not included in the final analysis.

2.3. Variables Measurement and Data Collection

Sociodemographic data were gathered using a specifically designed tool adapted from the WHO STEPS and Demographic Health Survey (DHS) questionnaires [26, 27]. Participants were categorised as normal-weight or overweight/obese based on body mass index (BMI) calculated using the weight recorded within three months before pregnancy. Dietary intake was assessed using a 179-item food frequency questionnaire (FFQ)[28], and the same portion sizes were used to estimate quantities consumed. The data collection tools were validated through expert consultations involving dietitians, physiologists, obstetricians/gynaecologists, and experienced midwives.

The Tanzanian food composition tables were utilised to calculate nutrient intake [29]. The recommended dietary intake for vitamins and minerals was established based on the Institute of Medicine (IOM) dietary reference intakes (DRI) [12–16]. Where the estimated average requirement (EAR) was not available, adequate intake (AI) was used if available. Mean nutrient adequacy ratios (MNAR) were calculated separately for vitamins and minerals from individual nutrient adequacy ratio (NAR) of each nutrient. NAR was obtained as ratio of absolute nutrient intake to corresponding EAR (or AI) value. $NAR > 1$ was truncated to limit the effect of highly consumed micronutrients on MNAR.

Data on cardiometabolic parameters were gathered using a customised checklist. Based on their pre-pregnancy BMI, participants were divided into two groups: normal-weight and overweight/obese. A digital upper arm sphygmomanometer (Omron 5 series®, BP7200, Japan) was used to measure blood pressure (BP) in mmHg and pulse rate (PR) in beats per minute [30]. The HemoCue® Hb 801 system was used to measure the haemoglobin concentration (Hb) in mg/dl. A digital glucometer (Accu-Check®, Roche Diabetes Care, Switzerland) was used to measure blood glucose in mg/dl [31]. An oral glucose tolerance test (OGTT) was done an hour after drinking a solution containing 50 g of pure glucose dissolved in 200 mL of water. An automatic analyser (Cobas® 6000, Roche, Germany) was used to quantify serum triglycerides, total, LDL, and HDL cholesterol in mg/dl [32]. All tests were done on venous blood drawn in the morning (between 8–11 am) following fasting of about 8 hours.

2.4. Data Analysis

All analyses were performed using STATA 19.5 software, and a p -value of 0.05 was considered significant. Mann–Whitney U test for independent analysis of medians was used to compare absolute nutrient intakes between overweight/obese and normal-weight participants for both absolute and per 1000 kcal values while t-test was used for NAR and MNAR. Intakes were further categorised according to EAR or AI, and categorical comparisons were conducted using chi-square tests.

Individual foods were further categorised into 17 food groups based on nutritional profile and culinary proximity, and then were modelled to derive dietary patterns using reduced rank regression (RRR). Response variables included in the RRR model were blood pressure, fasting blood glucose, 1-hour glucose tolerance, serum triglycerides, total cholesterol, HDL cholesterol and LDL cholesterol. We used Pearson's correlation to obtain factor loadings. Factors were extracted based on eigenvalues > 1 (Fig. 1), and each was considered a dietary pattern. Food groups were considered to contribute significantly to a given pattern if they had loadings ≥ 0.2 or ≤ -0.2 . Linear regression was used to assess whether pre-pregnancy weight predicted dietary pattern and whether dietary pattern predicted cardiometabolic outcomes while adjusting for maternal age, gestational age and parity.

Figure 1: *Scree Plot*

2.5. Ethical Consideration

The study was approved by Muhimbili University of Health and Allied Sciences (MUHAS) Research and Ethics Committee with reference number MUHAS-REC-02-2024-2016. The ethical clearance certificate is accessible at <https://irb.muhas.ac.tz/storage/Certificates/Certificate%20-%2015161.pdf>. The relevant authorities permitted the study to be conducted. All study protocols were carried out in alignment with Helsinki's declaration. Informed consent was offered in writing and signed by all participants.

3. Results

3.1. Characteristics of Study Participants

3.1.1. Sociodemographic Characteristics of Study Participants

The study involved 242 participants (Table 1), of whom 37.2% were overweight or obese, with the majority being in their third trimester (50.4%). Most participants were multigravida (60.3%), although the majority were nulliparous (50.8%). Most participants were married (77.6%), unemployed (40.1%) or self-employed (45%), with a family monthly income below 500,000 TZS ($\approx$ 200\$) (81.8%).

Table 1
Sociodemographic Characteristics of Study Participants (N = 242)

Characteristic	Frequency (%) or mean $\pm$ SD or median (range)
Age	
< 20	16 (6.6)
20–29	156 (64.5)
30+	70 (28.9)
Gravida	
1	96 (39.7)
2 or more	146 (60.3)
Parity	
0	123 (50.8)
1–3	111 (45.9)
4 or more	8 (3.3)
Gestational age	
1st trimester	25 (10.3)
2nd trimester	95 (39.3)
3rd trimester	122 (50.4)
Education level	
Illiterate	12 (5.0)
Primary	97 (40.1)
Secondary	77 (31.8)
College+	56 (23.1)
Marital status	
Married	187 (77.6)
Not married	54 (22.4)
Occupation	
Unemployed	97 (40.1)
*TZS: Tanzanian Shilling	

Characteristic	Frequency (%) or mean $\pm$ SD or median (range)
Self-employed	109 (45.0)
Employed	28 (11.6)
Student	8 (3.3)
Family income (TZS*)	
< 500,000	197 (81.8)
500,000–1,000,000	26 (10.7)
1,000,000+	18 (7.5)
*TZS: Tanzanian Shilling	

3.1.2. Cardiometabolic Health Characteristics of Study Participants

The cardiometabolic profile of study participants is summarised in Table 2.

Table 2
Cardiometabolic Health Characteristics of Study Participants (N = 242)

	normal weight	overweight/obese
	median (min–max)	
Systolic blood pressure (mmHg)	111 (82–158)	120 (95–177)
Diastolic blood pressure (mmHg)	65 (50–98)	70 (52–95)
Pulse rate (beats/minute)	73 (60–139)	76 (64–113)
Haemoglobin (g/dl)	11 (8–16)	12 (9–14)
Fasting blood glucose (mg/dl)	68 (52–86)	74 (61–94)
Oral glucose tolerance (mg/dl)	88 (70–155)	95 (65–121)
Triglycerides (mg/dl)	26 (7–52)	29 (6–73)
Total cholesterol (mg/dl)	84 (48–134)	84 (38–127)
HDL cholesterol (mg/dl)	27 (19–45)	27 (17–43)
LDL cholesterol (mg/dl)	41 (2–95)	43 (16–72)

3.2. Vitamin Intake of Study Participants

Compared to their normal-weight counterparts, overweight and obese participants had higher median absolute vitamin intakes for vitamins D [7 μ g/day (0–85) versus 10 (0–93), $z = 2$, $p = 0.047$], E [26 mg/day

(4–398) versus 42 (6–213), $z = 3.6, p < 0.001$], C [334 mg/day (25–1234) versus 422 (70–1395), $z = 2.709, p = 0.007$], B1 [3 mg/day (1–23) versus 4 (1–28), $z = 2.823, p = 0.005$], B5 [10 mg/day (2–42) versus 12 (5–50), $z = 2.351, p = 0.019$], B6 [5 mg/day (1–38) versus 6 (2–45) $z = 2.8, p = 0.005$] and folate [820 µg/day (238–5499) versus 925 (408–5734), $z = 2, p = 0.041$]. However, when intakes were described per energy intake only vitamin E was higher [5.3 mg/1000 kcal/day (2.2–90.7) versus 6.6 (2.3–42.7) as presented in Table 2.

Vitamins' MNAR was higher among overweight/obese [96% ± 5 versus 94% ± 8, $t(240) = 2.7, p = 0.004$] with individual NARs being higher for vitamins E [0.99 ± 0.07 versus 0.93 ± 0.17, $t(240) = 3.1, p = 0.002$], B1 [0.99 ± 0.03 versus 0.97 ± 0.06, $t(240) = 2.9, p = 0.004$], B5 [0.99 ± 0.03 versus 0.96 ± 0.13, $t(240) = 2.5, p = 0.011$], B6 [1 ± 0 versus 0.98 ± 0.08, $t(240) = 2.1, p = 0.039$], and folate [0.98 ± 0.05 versus 0.95 ± 0.12, $t(240) = 2.6, p = 0.011$]. Yet, a notable proportion of overweight and obese participants had dietary intakes below EAR, especially for vitamins A (5.6%), D (46.7%), B12 (12.2%) and folate (12.2%). Despite these deficiencies, only 1.7% of participants were taking multivitamin supplements, while 30.2% of all participants, including 35.6% of overweight and obese women, were not taking any folate-containing supplements.

Table 2
Vitamin intake of study participants (N = 242)

	Normal-weight	Overweight/obese	
	Median (min–max) or mean $\pm$ SD or n (%)		p-value
Vitamin A (μ g RAE*)	2385 (207–95306)	2484 (207–16982)	0.344
per 1000 Kcal	500 (20–26587)	546 (20–4827)	0.978
Animal Vitamin A	119 (15–7553)	194.5 (14–16122)	0.512
NAR	0.98 $\pm$ 0.09	0.98 $\pm$ 0.08	0.493
< EAR	13 (8.6)	5 (5.6)	0.925
Vitamin D (μ g)	7 (0–85)	10 (0–93)	0.047
per 1000 Kcal	1.7 (0–15.1)	2 (0–18.4)	0.352
NAR	0.67 $\pm$ 0.35	0.74 $\pm$ 0.34	0.133
< EAR	84 (55.3)	42 (46.7)	0.151
Vitamin E (mg)	26 (4–398)	42 (6–213)	< 0.001
per 1000 Kcal	5.3 (2.2–90.7)	6.6 (2.3–42.7)	0.001
NAR	0.93 $\pm$ 0.17	0.99 $\pm$ 0.07	0.002
< EAR	31 (20.4)	4 (4.4)	0.001
Vitamin C (mg)	334 (25–1234)	422 (70–1395)	0.007
per 1000 Kcal	82.2 (12.1–227.4)	79.7 (11.3–189)	0.728
NAR	0.99 $\pm$ 0.07	1 $\pm$ 0	0.276
< EAR	2 (1.3)	0 (0)	0.275
Vitamin B1 (Thiamin) (mg)	3 (1–23)	4 (1–28)	0.005
per 1000 Kcal	0.7 (0.3–3)	0.8 (0.2–3.5)	0.072
NAR	0.97 $\pm$ 0.06	0.99 $\pm$ 0.03	0.004
< EAR	23 (15.1)	3 (3.3)	0.004
Vitamin B2 (Riboflavin) (mg)	7 (1–27)	8 (2–30)	0.409
per 1000 Kcal	1.8 (0.2–10.4)	1.5 (0.2–10.6)	0.158
NAR	1 $\pm$ 0.01	1 $\pm$ 0	0.442

*RAE: Retinol Activity Equivalents; EAR: Estimated Average Requirement; AI: Adequate Intake NAR: Nutrient Adequacy Ratio; Bold: significant

	Normal-weight	Overweight/obese	
	Median (min–max) or mean $\pm$ SD or n (%)		p-value
< EAR	1 (0.7)	0 (0)	0.441
Vitamin B3 (Niacin) (mg)	28 (10–151)	28 (12–156)	0.400
per 1000 Kcal	7.2 (3.1–11.6)	7.1 (3.1–10.5)	0.377
NAR	0.99 $\pm$ 0.04	1 $\pm$ 0.02	0.223
< EAR	10 (6.6)	3 (3.3)	0.279
Vitamin B6 (Pyridoxine) (mg)	5 (1–38)	6 (2–45)	0.005
per 1000 Kcal	1.1 (0.1–5.7)	1.2 (0.1–7)	0.117
NAR	0.98 $\pm$ 0.08	1 $\pm$ 0	0.039
< EAR	7 (4.6)	0 (0)	0.039
Folic acid (B9) (μ g)	820 (238–5499)	925 (408–5734)	0.041
per 1000 Kcal	202 (88–436)	218 (90–375)	0.550
NAR	0.95 $\pm$ 0.12	0.98 $\pm$ 0.05	0.011
< EAR	34 (22.4)	11 (12.2)	0.050
Vitamin B12 (μ g)	12 (0–99)	16.5 (0–100)	0.074
per 1000 Kcal	2.9 (0–20.5)	3.3 (0–14.2)	0.326
NAR	0.93 $\pm$ 0.19	0.94 $\pm$ 0.21	0.712
< EAR	24 (15.8)	11 (12.2)	0.446
Vitamin B5 (Pantothenic) (mg)	10 (2–42)	12 (5–50)	0.019
per 1000 Kcal	2.5 (1.1–6.1)	2.7 (1.5–6.8)	0.193
NAR	0.96 $\pm$ 0.13	0.99 $\pm$ 0.03	0.011
< AI	19 (12.5)	4 (4.4)	0.039
*RAE: Retinol Activity Equivalents; EAR: Estimated Average Requirement; AI: Adequate Intake NAR: Nutrient Adequacy Ratio; Bold: significant			

3.3. Mineral Intake of Study Participants

Compared to normal-weight participants, those with obesity or overweight had higher median absolute intake for most minerals (Table 3), but only potassium was significant [7,741 mg/day (2,272–89,460) versus 6,321 (1,981–84,927), $z = 2.499$, $p = 0.013$], which was not significant after adjusting for daily energy intake. Similarly, neither minerals' MNAR nor individual NARs differed between the two groups

although overweight and obese participants were less likely to consume intakes below EAR for calcium ($p = 0.021$) and potassium ($p = 0.026$). Yet, a considerable proportion of overweight and obese participants had intakes below EAR for calcium (47.8%), sodium (7.8%), iron (11.1%), and zinc (16.7%). Yet, none of the overweight and obese participants took any calcium supplements, and 57.8% were not taking any iron supplements. Categorical analysis revealed that overweight and obese participants had more likelihood of neglecting iron supplements compared to normal-weight participants ($p = 0.046$).

Table 3
Mineral intake of pregnant women (N = 242)

Mineral	Normal-weight	Overweight/obese	p-value
	Median (min–max) or mean ± SD or n (%)		
Calcium (Ca) (mg)	839 (184–5712)	972 (191–6340)	0.064
per 1000 Kcal	199 (56–439)	189 (49–377)	0.697
NAR	0.82 ± 0.24	0.84 ± 0.22	0.471
< EAR	74 (48.7)	43 (47.8)	0.021
Phosphorus (P) (mg)	1992 (668–6779)	2192 (821–7102)	0.065
per 1000 Kcal	507 (271–899)	464 (267–788)	0.342
NAR	1 ± 0	1 ± 0	–
< EAR	0 (0)	0 (0)	–
Magnesium (Mg) (mg)	800 (318–6171)	897.5 (374–6375)	0.093
per 1000 Kcal	216 (75–383)	222 (72–343)	0.293
NAR	1 ± 0	1 ± 0	–
< EAR	0 (0)	0 (0)	–
Potassium (K) (mg)	6321 (1981–84927)	7741 (2272–89460)	0.012
per 1000 Kcal	1783 (441–3972)	1911 (456–3683)	0.556
NAR	0.99 ± 0.05	1 ± 0.03	0.288
< AI	14 (9.2)	4 (4.4)	0.026
Sodium (Na) (mg)	2183 (1277–52631)	2825 (1232–65946)	0.146
per 1000 Kcal	270 (67–2658)	311 (84–2575)	0.502
NAR	0.66 ± 0.33	0.7 ± 0.32	0.34
< AI	19 (12.5)	7 (7.8)	0.252
Iron (Fe) (mg)	26 (9–127)	29.5 (10–128)	0.074
per 1000 Kcal	6.3 (3.2–13.9)	5.9 (3.1–12.1)	0.202
MFP* iron	2 (0–7)	2 (0–8)	0.829
NAR	0.9 ± 0.17	0.93 ± 0.14	0.113
*Meat Fish Poultry Iron; EAR: Estimated Average Requirement; AI: Adequate Intake NAR: Nutrient Adequacy Ratio; Bold: significant			

Mineral	Normal-weight	Overweight/obese	p-value
	Median (min–max) or mean ± SD or n (%)		
< EAR	30 (19.7)	10 (11.1)	0.104
Zinc (Zn) (mg)	15 (5–51)	16 (7–52)	0.097
per 1000 Kcal	3.7 (1.5–7)	3.3 (1.4–5.7)	0.189
NAR	0.96 ± 0.1	0.98 ± 0.07	0.084
< EAR	35 (23.0)	15 (16.7)	0.303
Copper (Cu) (mg)	5 (1–22)	5 (2–24)	0.384
per 1000 Kcal	1.1 (0.5–3.9)	1 (0.6–2.6)	0.188
NAR	1 ± 0	1 ± 0	–
< AI	0 (0)	0 (0)	–
Manganese (Mn) (mg)	9 (2–39)	10 (3–45)	0.06
per 1000 Kcal	2 (1.2–4.3)	2 (1.3–4.5)	0.83
NAR	1 ± 0	1 ± 0	–
< AI	0 (0)	0 (0)	–
*Meat Fish Poultry Iron; EAR: Estimated Average Requirement; AI: Adequate Intake NAR: Nutrient Adequacy Ratio; Bold: significant			

3.4. Dietary Patterns of Study Participants and Their Association with Cardiometabolic Factors

One dietary pattern was identified, as shown in Table 4. This pattern which explained 38.2% of the variation, had high factor loadings on added sugars, boiled roots/tubers, plantains, meat, fried grain/roots/tubers, poultry, nuts/products and alcohol, but more negative loadings on boiled grain/cereals and legumes/pulses. Pre-pregnancy weight classification was associated with the identified dietary pattern, whereby participants classified as overweight or obese had 0.67 times more scores of adherence to this pattern [$\beta = 0.67$ (0.07–1.3), $p = 0.028$] than those classified as normal-weight. However, pre-pregnancy weight explained only 6.4% of the variation in the dietary pattern.

Table 4: Dietary patterns of pregnant women (N=242)

	Factor loadings
Food group	Pattern 1
Grain and cereals	-0.219
Roots and tubers	0.336
Fried grain roots and tubers	0.309
Plantains	0.335
Legumes and pulses	-0.349
Nuts and products	0.274
Fruits	0.125
Vegetables	0.007
Meat	0.334
Fish and seafoods	-0.045
Poultry	0.295
Eggs	0.072
Milk and dairy	0.143
Added sugar	0.436
Added fats	-0.076
Alcohol	0.274
Sweetened beverages	0.059
Variance explained	38.2%
Redder: more positive; Bluer: more negative; Bold: loadings ≥ 0.2 or ≤ -0.2	

For every unit increase in adherence to this pattern (Fig. 2), there was an increase in systolic blood pressure by 3.4 mmHg [$\beta = 3.4$ (1.1–5.7), $p = 0.004$], explaining 9.5% of the variation. Adherence to the same pattern was associated with a higher haemoglobin concentration by 0.26 g/dl [$\beta = 0.26$ (0.07–0.46), $p = 0.009$], explaining 7.8% of the variation. Fasting blood glucose was higher by 3.1 mg/dl [$\beta = 3.1$ (1.9–4.4), $p < 0.001$] and oral glucose tolerance was higher by 7.3 mg/dl [$\beta = 7.3$ (4.5–10.1), $p < 0.001$] every time adherence to this pattern increased, which explained 24–26% of the variations. This pattern was also associated with an elevated lipid profile whereby an increase in a score of adherence had a 2.4 mg/dl increase in serum triglycerides [$\beta = 2.4$ (1.4–3.3), $p < 0.001$], which explained 26% of variation; a 7.1 mg/dl increase in total cholesterol [$\beta = 7.1$ (4.2–9.9), $p < 0.001$] explaining 23% of variation; and a 6.1 mg/dl increase in LDL cholesterol [$\beta = 6.1$ (4.1–8.1), $p < 0.001$], explaining 33% of variation. Therefore, this pattern was termed the ‘dysmetabolic’ pattern.

Figure 2: *Forrest Plot for Association between dietary pattern factor score and cardiometabolic parameters of pregnant women (n = 242, linear regression, linear scale)*

4. Discussion

This study provides a context-specific assessment of dietary micronutrient intake among overweight and obese pregnant women in Dodoma, Tanzania, addressing a critical data gap in the context of the rapidly rising double burden of malnutrition (DBM) in Low- and Middle-Income Countries (LMICs). Despite exhibiting relatively higher absolute micronutrient intakes, the overweight and obese cohort displays a considerable proportion of inadequate intakes of several key micronutrients. Yet, they were comparably more likely to overlook recommended supplements. Moreover, overweight and obese women show high adherence to ‘dysmetabolic’ dietary pattern, which was associated with both

undesirable cardiometabolic outcomes, such as dyslipidaemia and glucose impairment, and desirable outcomes, such as better haemoglobin concentration.

Overweight and obese women had higher absolute micronutrient intakes than their normal-weight counterparts, but the difference was no longer significant when intakes were adjusted for energy intake. This means that higher micronutrient intake was merely due to overall food consumption, which does not alleviate micronutrient deficiencies indicating that simply managing caloric intake is insufficient for addressing malnutrition [33, 34]. Consequently, a substantial proportion of overweight and obese women had dietary intakes below the estimated average requirement (EAR) for crucial micronutrients such as vitamins A, B12, folic acid, calcium, iron, and zinc. This trend, which mirrors deficiencies seen in normal-weight counterparts, highlights a regional nutritional pattern characterised by calorie density over nutrient quality [35–38]. It should be noted that the highest deficiency was observed for vitamin D, but lower serum vitamin D levels have been not commonly observed in tropical regions, possibly due to ample sunlight aiding dermal synthesis and compensating dietary deficiencies [39–41].

The observed low adherence to micronutrient supplementation, particularly iron and folate, which are highly recommended during pregnancy, is a public health concern previously noted in overweight and obese pregnant women [42]. This may arise from cultural perceptions equating obesity with health, leading to a perceived lack of need for supplements [43]. The Tanzanian healthcare system tends to address underweight issues predominantly, leaving overweight and obese women with insufficient, non-tailored counselling about diet and supplementation needs [44, 45]. Findings from this study emphasise the call for efforts that recognise that overweight and obese pregnant women are also prone to micronutrient deficiencies.

The study further employed reduced rank regression (RRR) to identify a dietary pattern that explained about 38% of the variance in a panel of cardiometabolic health outcomes. RRR is considered unique as compared to conventional factor analysis because it maximises the correlation between dietary patterns and disease markers, establishing a direct etiological link [46]. The pattern, namely 'dysmetabolic', was characterised by high consumption of added sugars, boiled roots and tubers, plantains, meat, fried grain/roots/tubers, poultry, nuts/products and alcohol, but less consumption of boiled grain/cereals, and legumes/pulses. This points to a nutrition transition pattern currently growing in low- and middle-income countries, moving away from traditional high-fibre, plant-based diets [5, 47]. The negative loadings on boiled grains and legumes reflect not only what is consumed but also which protective staples are displaced [48].

The pattern was associated with increased Hb concentration, which is desirable, and with a simultaneous increase in fasting blood glucose, poor oral glucose tolerance, triglycerides, total cholesterol, and LDL cholesterol, all of which are undesirable. Poor metabolic outcomes have been attributed to high sodium, reduced insulin sensitivity, and an atherogenic drive from processed meats, fried foods, saturated fats, added sugars, and alcohol's pressor effect [49–52]. The consumption of animal foods, a good source of heme iron, could explain the higher haemoglobin levels observed among

participants adhering to this pattern. It should be noted that, while cardiometabolic parameters are affected by many factors, this study considered diet alone.

The finding that pre-pregnancy overweight or obesity was associated with significantly higher pattern adherence scores is consistent with the bidirectional relationship between adiposity and dietary behaviour [53]. Excess adiposity can reinforce preference for energy-dense, palatable foods through hedonic reward pathways and dysregulation of leptin and ghrelin signalling [54]. However, the low explained variance underlines that body weight is only one of many determinants of dietary behaviour. These mixed metabolic effects highlight the complexity of the impacts of dietary patterns in pregnancy.

4.1. Limitations of the Study

The findings of this study should be interpreted with consideration of potential limitations. Although dietary intake was assessed, we did not measure micronutrient bioavailability in the body, which is relevant in obesity due to altered metabolism of micronutrients. Particularly, the sparse distribution of fat-soluble vitamins in increased body fat may result in lower bioavailability despite apparently excessive dietary intake. Furthermore, administering the Food Frequency Questionnaire (FFQ) during pregnancy means the dietary intakes observed may be influenced by physiological changes and may not entirely reflect usual pre-pregnancy patterns. The cross-sectional design prevented the establishment of causality between dietary patterns and cardiometabolic outcomes.

5. Conclusion and Recommendations

This study suggests a complex nutritional landscape among overweight and obese pregnant women in Tanzania, characterised by calorie-rich but micronutrient-poor dietary patterns with distinct cardiometabolic implications. Although less common than normal weight counterparts, many overweight and obese women present with micronutrient deficiencies and yet they are likely to ignore supplements recommended during pregnancy. The 'dysmetabolic' pattern demonstrates the classic nutrition transition dilemma whereby diets address some deficiencies, such as haemoglobin concentration, while creating new metabolic risks, including elevated blood pressure, atherogenic drive, and poor glycaemic control. Addressing maternal nutrition in LMICs requires moving beyond the traditional focus on underweight to adopt a comprehensive approach that acknowledges the potential of deficiencies among overweight and obese women.

6. Abbreviations

AI

Adequate Intake

BMI

Body Mass Index

BP

Blood Pressure
dl
decilitre
DRI
Dietary Recommended Intakes
EAR
Estimated Average Requirement
FFQ
Food Frequency Questionnaire
Hb
Haemoglobin
HDL
High-Density Lipoprotein
Kg
Kilogram
LDL
Low-Density Lipoprotein
LMIC
Low and Middle-Income Countries
mg
milligram
OGTT
Oral Glucose Tolerance Test
µg
microgram

7. Declarations

7.1 Ethical Consideration

The study was approved by Muhimbili University of Health and Allied Sciences (MUHAS) Research and Ethics Committee with reference number MUHAS-REC-02-2024-2016. The ethical clearance certificate is accessible at <https://irb.muhas.ac.tz/storage/Certificates/Certificate%20-%2015161.pdf>. The relevant authorities permitted the study to be conducted. Informed consent was offered in writing and signed by all participants.

7.2 Consent for Publication

Not applicable

7.3 Authors' Contributions

JJR and AMT equally contributed to the study conceptualisation, data collection, analysis, and authored the first manuscript draft. CCK, EM and EAJ contributed to manuscript writing and critical review of the paper. DN contributed to the study's data collection and manuscript writing. FLM conceptualised and supervised the study, oversaw data collection, and critically reviewed the manuscript. All authors actively participated in the final version's approval.

7.4 Funding

The study received funding from the University of Dodoma (UDOM) and the International Society of Behavioral Nutrition and Physical Activity (ISBNPA) Pioneer Program scholarship for 2023-2024. The funders took no part in the study conceptualisation, designing, data collection, analysis, decision to publish results, or manuscript preparation.

7.5 Competing Interests

The authors declare that they have no competing interests

7.6 Acknowledgements

Not applicable

7.7 Availability of Data and Materials

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

7.8 Declaration of generative AI use

For grammar improvement, the text was created, and then artificial intelligence (Claude AI) was asked for improvement using the prompt 'rewrite with improved grammar, coherence and clarity without changing the core meaning'. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

8. References

1. World Obesity Federation. World Obesity Atlas 2023 [Internet]. 2023. <https://data.worldobesity.org/publications/?cat=19>. Accessed 9 July 2025.
2. James SL, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392:1789–858. [https://doi.org/10.1016/S0140-6736\(18\)32279-7](https://doi.org/10.1016/S0140-6736(18)32279-7).

3. Gona PN, Kimokoti RW, Gona CM, Ballout S, Rao SR, Mapoma CC, et al. Changes in body mass index, obesity, and overweight in Southern Africa development countries, 1990 to 2019: Findings from the Global Burden of Disease, Injuries, and Risk Factors Study. *Obes Sci Pract.* 2021;7:509–24. <https://doi.org/10.1002/osp4.519>.
4. Onubi OJ, Marais D, Aucott L, Okonofua F, Poobalan AS. Maternal obesity in Africa: a systematic review and meta-analysis. *J Public Health.* 2016;38:e218–31. <https://doi.org/10.1093/pubmed/fdv138>.
5. Keding G. Nutrition Transition in Rural Tanzania and Kenya. In: Biesalski HK, Black RE, World Rev Nutr Diet [Internet]. S., Karger AG. 2016 [cited 2023 June 26]. pp. 68–81. <https://doi.org/10.1159/000442073>
6. Wang D, Wang M, Darling AM, Perumal N, Liu E, Danaei G, et al. Gestational weight gain in low-income and middle-income countries: a modelling analysis using nationally representative data. *BMJ Glob Health BMJ Specialist Journals.* 2020;5:e003423. <https://doi.org/10.1136/bmjgh-2020-003423>.
7. Ministry of Health [Tanzania Mainland], Ministry of Health [Zanzibar], National Bureau of Statistics (NBS). Office of the Chief Government Statistician (OCGS), ICF. Tanzania demographic and health survey 2022 - final report [Internet]. Rockville, Maryland, USA: ICF; 2023. <https://www.dhsprogram.com/pubs/pdf/FR382/FR382.pdf>.
8. Mwanamsangu AH, Mahande MJ, Mazuguni FS, Bishanga DR, Mazuguni N, Msuya SE, et al. Maternal obesity and intrapartum obstetric complications among pregnant women: Retrospective cohort analysis from medical birth registry in Northern Tanzania. *Obes Sci Pract.* 2020;6:171. <https://doi.org/10.1002/osp4.395>.
9. Guardiola-Márquez CE, Santos-Ramírez MT, Segura-Jiménez ME, Figueroa-Montes ML, Jacobo-Velázquez DA. Fighting Obesity-Related Micronutrient Deficiencies through Biofortification of Agri-Food Crops with Sustainable Fertilization Practices. *Plants.* 2022;11:3477. <https://doi.org/10.3390/plants11243477>.
10. Wanaditya GK, Putra IWA, Aryana MBD, Mulyana RS. Obesity in Pregnant Women and Its Impact on Maternal and Neonatal Morbidity. *Eur J Med Health Sci.* 2023;5:17–21. <https://doi.org/10.24018/ejmed.2023.5.3.1625>.
11. Melchor I, Burgos J, Campo A, del, Aiartzaguena A, Gutiérrez J, Melchor JC. Effect of maternal obesity on pregnancy outcomes in women delivering singleton babies: a historical cohort study. *J Perinat Med De Gruyter.* 2019;47:625–30. <https://doi.org/10.1515/jpm-2019-0103>.
12. National Academies of Sciences, Engineering, and Medicine. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline [Internet]. Washington, D.C.: National Academies; 1998. p. 6015. [cited 2026 May 7]. <https://doi.org/10.17226/6015>.
13. National Academies of Sciences, Washington DC. Engineering, and Medicine. Dietary Reference Intakes for Calcium and Vitamin D [Internet]. National Academies; 2011. p. 13050. [cited 2026 May

- 7]. <https://doi.org/10.17226/13050>.
14. National Academies of Sciences, Engineering, and, Medicine, Panel on Dietary Antioxidants and Related Compounds. Subcommittee on Upper Reference Levels of Nutrients, Subcommittee on Interpretation and Uses of Dietary Reference Intakes, Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board. et al. Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids [Internet]. Washington, D.C.: National Academies; 2000. p. 9810. [cited 2026 May 7]. <https://doi.org/10.17226/9810>.
 15. National Academies of Sciences. In: Stallings VA, Harrison M, Oria M, editors. Engineering, and Medicine, Committee to Review the Dietary Reference Intakes for Sodium and Potassium, Food and Nutrition Board, Health and Medicine Division, National Academies of Sciences, Engineering, and Medicine. Washington, D.C.: National Academies; 2019. p. 25353. [cited 2026 May 7]. <https://doi.org/10.17226/25353>. Dietary Reference Intakes for Sodium and Potassium [Internet].
 16. National Academies of Sciences, Engineering, and Medicine. Dietary Reference Intakes for. In: Vitamin A, Vitamin K, Arsenic, editors. Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc [Internet]. Washington, D.C.: National Academies; 2001. p. 10026. [cited 2026 May 7]. <https://doi.org/10.17226/10026>.
 17. WHO. WHO Antenatal Care Recommendations for a Positive Pregnancy Experience. Nutritional Interventions Update: Multiple Micronutrient Supplements During Pregnancy. Geneva: World Health Organization; 2020.
 18. Khayat S. Minerals in Pregnancy and Lactation: A Review Article. J Clin Diagn Res [Internet]. 2017 [cited 2025 Jan 10]; <https://doi.org/10.7860/JCDR/2017/28485.10626>.
 19. Adams JB, Kirby JK, Sorensen JC, Pollard EL, Audhya T. Evidence based recommendations for an optimal prenatal supplement for women in the US: vitamins and related nutrients. Matern Health Neonatol Perinatol. 2022;8:4. <https://doi.org/10.1186/s40748-022-00139-9>.
 20. Gernand AD, Schulze KJ, Stewart CP, West KP, Christian P. Micronutrient deficiencies in pregnancy worldwide: health effects and prevention. Nat Rev Endocrinol. 2016;12:274–89. <https://doi.org/10.1038/nrendo.2016.37>.
 21. Bhutta ZA, Das JK, Rizvi A, Gaffey MF, Walker N, Horton S, et al. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? The Lancet. Elsevier. 2013;382:452–77. [https://doi.org/10.1016/S0140-6736\(13\)60996-4](https://doi.org/10.1016/S0140-6736(13)60996-4).
 22. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet Elsevier. 2013;382:427–51. [https://doi.org/10.1016/S0140-6736\(13\)60937-X](https://doi.org/10.1016/S0140-6736(13)60937-X).
 23. Hasan MM, Ahmed S, Soares Magalhaes RJ, Fatima Y, Biswas T, Mamun AA. Double burden of malnutrition among women of reproductive age in 55 low- and middle-income countries: progress achieved and opportunities for meeting the global target. Eur J Clin Nutr. 2022;76:277–87. <https://doi.org/10.1038/s41430-021-00945-y>.

24. Seferidi P, Hone T, Duran AC, Bernabe-Ortiz A, Millett C. Global inequalities in the double burden of malnutrition and associations with globalisation: a multilevel analysis of Demographic and Health Surveys from 55 low-income and middle-income countries, 1992–2018. *Lancet Glob Health Elsevier*. 2022;10:e482–90. [https://doi.org/10.1016/S2214-109X\(21\)00594-5](https://doi.org/10.1016/S2214-109X(21)00594-5).
25. Yang J, Wang M, Tobias DK, Rich-Edwards JW, Darling AM, Abioye AI, et al. Gestational weight gain during the second and third trimesters and adverse pregnancy outcomes, results from a prospective pregnancy cohort in urban Tanzania. *Reprod Health BioMed Cent Ltd*. 2022;19:1–11. <https://doi.org/10.1186/s12978-022-01441-7>.
26. STEPwise. approach to NCD risk factor surveillance (STEPS) [Internet]. [cited 2023 July 9]. <https://www.who.int/teams/noncommunicable-diseases/surveillance/systems-tools/steps>. Accessed 9 July 2023.
27. The DHS Program - DHS Model Questionnaire. - Phase 8 (English, French) [Internet]. [cited 2023 July 9]. <https://dhsprogram.com/publications/publication-dhsq8-dhs-questionnaires-and-manuals.cfm>. Accessed 9 July 2023.
28. Zack RM, Irema K, Kazonda P, Leyna GH, Liu E, Gilbert S, et al. Validity of an FFQ to measure nutrient and food intakes in Tanzania. *Public Health Nutr*. 2018;21:2211–20. <https://doi.org/10.1017/S1368980018000848>.
29. Lukmanji Z, Hertzmark E, Nicolas Mlingi V, Assey G, Ndossi, Wafaie Fawzi. Tanzania Food Composition Tables [Internet]. MUHAS- TFNC, HSPH; 2008. https://nutritionsource.hsph.harvard.edu/wp-content/uploads/2023/09/Tanzania-Food-Composition-Tables_Sept-2023-Update.pdf. Accessed 4 Aug 2024.
30. Meng L, Zhao D, Pan Y, Ding W, Wei Q, Li H, et al. Validation of Omron HBP-1300 professional blood pressure monitor based on auscultation in children and adults. *BMC Cardiovasc Disord*. 2016;16:9. <https://doi.org/10.1186/s12872-015-0177-z>.
31. Landberg E, Nevander S, Hadi M, Blomberg M, Norling A, Ekman B, et al. Evaluation of venous plasma glucose measured by point-of-care testing (Accu-Chek Inform II) and a hospital laboratory hexokinase method (Cobas c701) in oral glucose tolerance testing during pregnancy – a challenge in diagnostic accuracy. *Scand J Clin Lab Invest Taylor Francis*. 2021;81:607–14. <https://doi.org/10.1080/00365513.2021.1980224>.
32. Supak Smolcic V, Bilic-Zulle L, Fisic E. Validation of methods performance for routine biochemistry analytes at Cobas 6000 analyzer series module c501. *Biochem Med*. 2011;21:182–90. <https://doi.org/10.11613/bm.2011.028>.
33. Karlsson T, Andersson L, Hussain A, Bosaeus M, Jansson N, Osmancevic A, et al. Lower vitamin D status in obese compared with normal-weight women despite higher vitamin D intake in early pregnancy. *Clin Nutr*. 2015;34:892–8. <https://doi.org/10.1016/j.clnu.2014.09.012>.
34. Dubois L, Diasparra M, Bédard B, Colapinto CK, Fontaine-Bisson B, Tremblay RE, et al. Adequacy of nutritional intake during pregnancy in relation to prepregnancy BMI: results from the 3D Cohort Study. *Br J Nutr*. 2018;120:335–44. <https://doi.org/10.1017/S0007114518001393>.

35. Mbwana HA, Kinabo J. Nutrient intake of Women of Child Bearing Age from Two Agro-climatic zones of Rural Areas in Tanzania. *Tanzan J Agric Sci.* 2020;19:92–116.
36. Ngassa NJ, Masumo RM, Hancy A, Kabula EJ, Killel E, Nusrupia J et al. Food and nutrient intake among non-pregnant, non-lactating women of reproductive age of Mbeya in Tanzania: A repeated 24-hour dietary recall. Robinson J, editor. *PLOS Glob Public Health.* 2024;4:e0004010. <https://doi.org/10.1371/journal.pgph.0004010>
37. Lee SE, Talegawkar SA, Merialdi M, Caulfield LE. Dietary intakes of women during pregnancy in low- and middle-income countries. *Public Health Nutr.* 2013;16:1340–53. <https://doi.org/10.1017/S1368980012004417>.
38. Ruhighira JJ, Dionis I, Munyogwa M, Tungu AM, Mashili FL. High-calorie low-protein dietary pattern among overweight and obese pregnant women in Tanzania. *Clin Nutr Open Sci.* 2025;60:89–100. <https://doi.org/10.1016/j.nutos.2025.01.014>.
39. Luxwolda MF, Kuipers RS, Kema IP, Janneke Dijck-Brouwer DA, Muskiet FAJ. Traditionally living populations in East Africa have a mean serum 25-hydroxyvitamin D concentration of 115 nmol/l. *Br J Nutr.* 2012;108:1557–61. <https://doi.org/10.1017/S0007114511007161>.
40. Kagotho E, Omuse G, Okinda N, Ojwang P. Vitamin D status in healthy black African adults at a tertiary hospital in Nairobi, Kenya: a cross sectional study. *BMC Endocr Disord.* 2018;18:70. <https://doi.org/10.1186/s12902-018-0296-5>.
41. Vearing RM, Hart KH, Darling AL, Probst Y, Olayinka AS, Mendis J, et al. Global Perspective of the Vitamin D Status of African-Caribbean Populations: A Systematic Review and Meta-analysis. *Eur J Clin Nutr.* 2022;76:516–26. <https://doi.org/10.1038/s41430-021-00980-9>.
42. Masho SW, Bassyouni A, Cha S. Pre-pregnancy obesity and non-adherence to multivitamin use: findings from the National Pregnancy Risk Assessment Monitoring System (2009–2011). *BMC Pregnancy Childbirth.* 2016;16:210. <https://doi.org/10.1186/s12884-016-1002-0>.
43. Sumińska M, Podgórski R, Bogusz-Górna K, Skowrońska B, Mazur A, Fichna M. Historical and cultural aspects of obesity: From a symbol of wealth and prosperity to the epidemic of the 21st century. *Obes Rev.* 2022;23:e13440. <https://doi.org/10.1111/obr.13440>.
44. Radimer K. *Am J Epidemiol.* 2004;160:339–49. <https://doi.org/10.1093/aje/kwh207>. Dietary Supplement Use by US Adults: Data from the National Health and Nutrition Examination Survey, 1999–2000.
45. Tenorio-Guerrero LK, Puente-Alejos R, Chavez Sosa JV, Newball-Noriega EE, Huancahuire-Vega S. Factors Associated with the Health-Related Self-Care Capacity of Overweight and Obese People. *Healthcare.* 2024;12:1226. <https://doi.org/10.3390/healthcare12121226>.
46. Zhao J, Li Z, Gao Q, Zhao H, Chen S, Huang L, et al. A review of statistical methods for dietary pattern analysis. *Nutr J.* 2021;20:37. <https://doi.org/10.1186/s12937-021-00692-7>.
47. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev.* 2012;70:3–21. <https://doi.org/10.1111/j.1753-4887.2011.00456.x>.

48. Venn B, Thies F, O'Neil C. Whole Grains, Legumes, and Health. *J Nutr Metab.* 2012;2012:903767. <https://doi.org/10.1155/2012/903767>.
49. Fung TT, Rimm EB, Spiegelman D, Rifai N, Tofler GH, Willett WC, et al. Association between dietary patterns and plasma biomarkers of obesity and cardiovascular disease risk. *Am J Clin Nutr.* 2001;73:61–7. <https://doi.org/10.1093/ajcn/73.1.61>.
50. Schulze MB, Hoffmann K, Manson JE, Willett WC, Meigs JB, Weikert C, et al. Dietary pattern, inflammation, and incidence of type 2 diabetes in women. *Am J Clin Nutr.* 2005;82:675–84. <https://doi.org/10.1093/ajcn/82.3.675>.
51. Heidemann C, Hoffmann K, Spranger J, Klipstein-Grobusch K, Möhlig M, Pfeiffer AFH, et al. A dietary pattern protective against type 2 diabetes in the European Prospective Investigation into Cancer and Nutrition (EPIC)--Potsdam Study cohort. *Diabetologia.* 2005;48:1126–34. <https://doi.org/10.1007/s00125-005-1743-1>.
52. Bank TC, Grasch JL, Chung J, Mercer BM, McNeil RB, Parry S, et al. Sodium intake and the development of hypertensive disorders of pregnancy. *Am J Obstet Gynecol MFM.* 2023;5:101166. <https://doi.org/10.1016/j.ajogmf.2023.101166>.
53. Paradis A-M, Godin G, Périusse L, Vohl M-C. Associations between dietary patterns and obesity phenotypes. *Int J Obes.* 2005; 2009;33:1419–26. <https://doi.org/10.1038/ijo.2009.179>
54. Spinelli S, Monteleone E. Food Preferences and Obesity. *Endocrinol Metab.* 2021;36:209–19. <https://doi.org/10.3803/EnM.2021.105>.

Figures

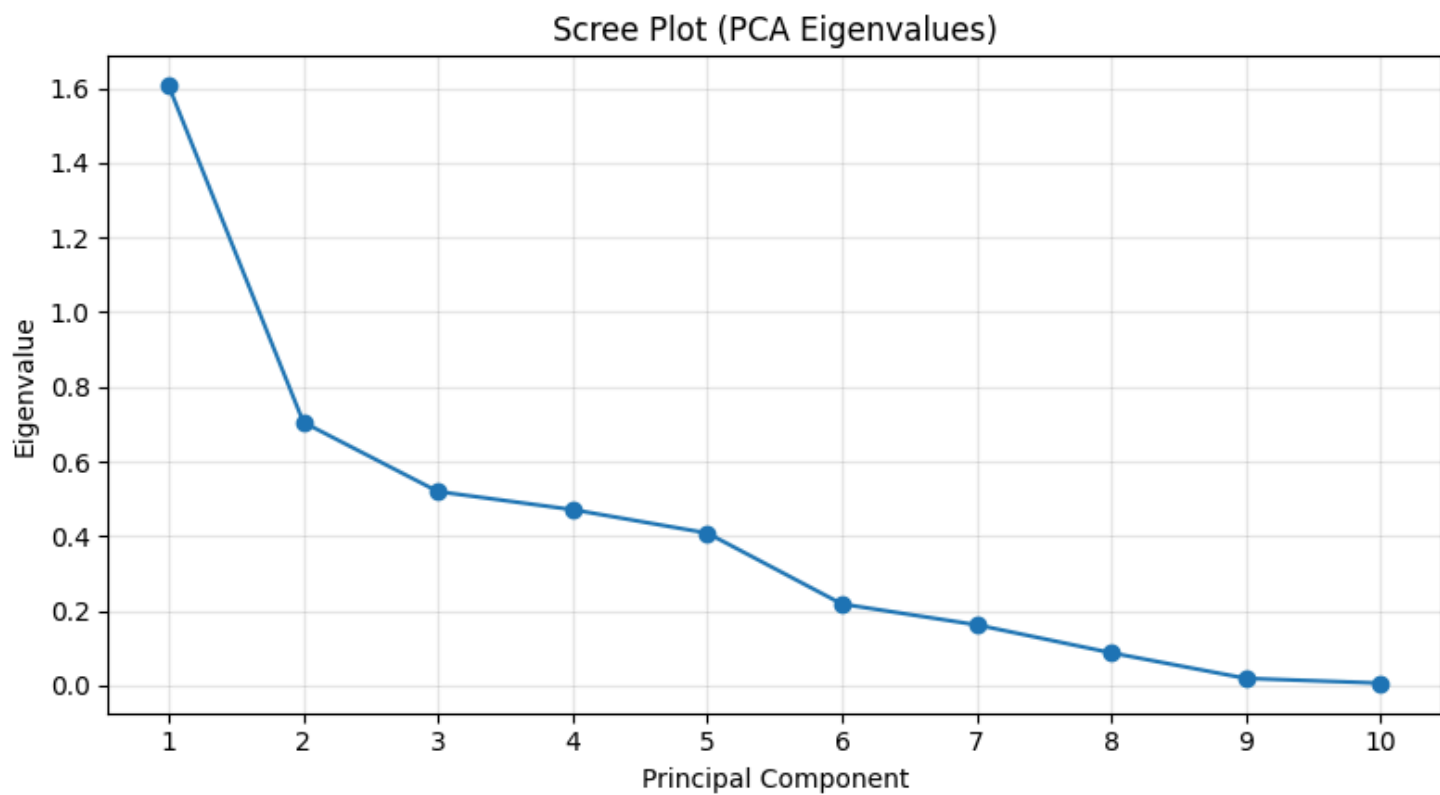


Figure 1

Scree Plot

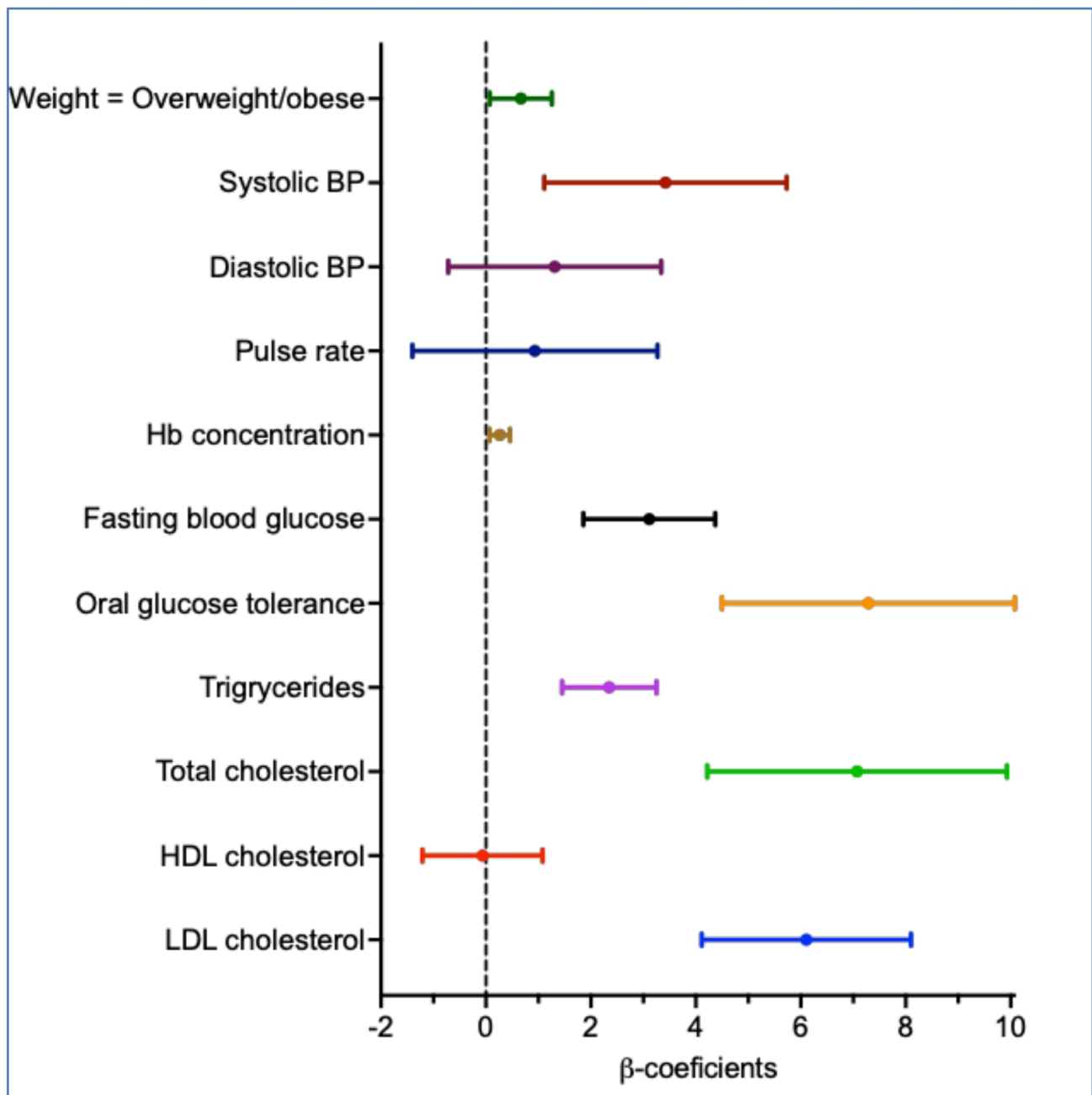


Figure 2

Forrest Plot for Association between dietary pattern factor score and cardiometabolic parameters of pregnant women (n=242, linear regression, linear scale)