Vegan Diet and Bone Health

Cross-Sectional Study

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Introduction

- Vegan diet has become popular in Germany and other Western countries
- Not only due to ethical reasons but also for health benefits
- Prevents chronic conditions

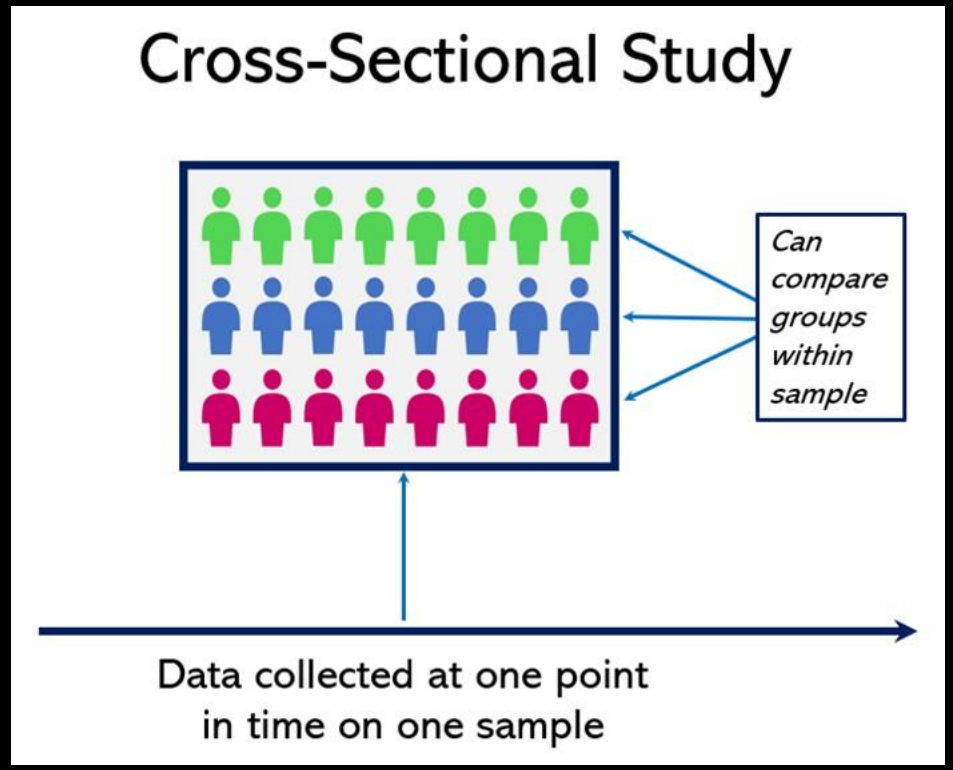
Associated Bone Health Impacts:

- Lower bone mineral density (BMD)
- Potential deficiencies:

1. Calcium and vitamin D
2. Vitamin B12
3. Long-chain n-3 fatty acids
4. Minerals (zinc, selenium, iodine)

- However, it provides vitamin K and folate

Method



- Cross-Sectional Study: analyzes at a single point in time, a measure of prevalence
- Time Period: January 2017- July 2017 (7 months)
- Criteria:

1. 30-60 years old
2. Being on a vegan diet for at least one year
3. BMI ≤ 30
4. No cardiovascular disease, type 2 diabetes, cancer, pregnancy, breastfeeding, current infection

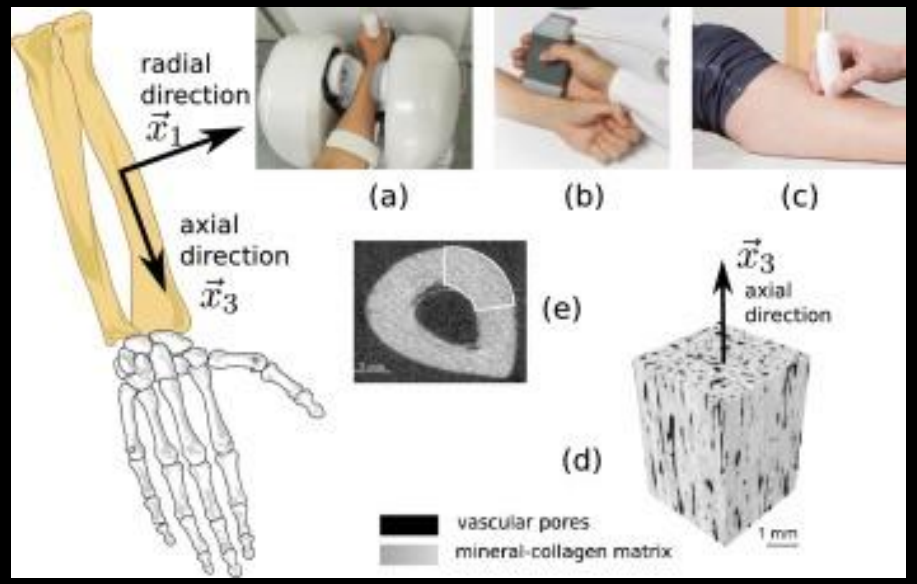
- Participants: 36 vegans and 36 omnivores (sex and age-matched).
- First visit: collected urine samples & 3-day weighed food protocol
- Second visit: fasting blood sample, anthropometric measurements, QUS measurements, lifestyle characteristics

Assessments

- **Quantitative Ultrasound Measurement**

❖ Evaluates tissue structure by measuring ultrasound attenuation and speed of sound

❖ BUA (broadband ultrasound attenuation) & SOS (speed of sound)



- **Lifestyle Characteristics**:

❖ Anthropometric measurements (weight, height, waist circumference)

❖ Educational level, smoking habits, supplement intake

❖ Physical activity

- **Blood and Urine Samples**

Study questions…

Will bone-health-related biomarkers show lower levels in vegans than omnivores relative to QUS findings? If yes, will it indicate impaired bone health?

Results

- Basic characteristics of 72 participants
- Vegans had a greater tendency to take supplements, especially vitamin B12

Table 1. Characteristics of the study population according to a vegan or omnivorous diet.

Characteristics	Vegans (n = 36)	Omnivores (n = 36)	p-Value
Duration vegan diet (years)	4.8 (3.1–8.7)		
Men	50.0% (18)	50.0% (18)	1.00
Age (years)	37.5 (32.5–44.0)	38.5 (32.0–46.0)	0.75
Anthropometry			
BMI (kg/m^2)	22.9 ± 3.2	24.0 ± 2.1	0.08
Fat mass (%)	24.1 ± 7.8	26.2 ± 7.7	0.27
Muscle mass (%)	33.9 ± 5.2	33.5 ± 5.2	0.72
Waist circumference (cm)			
Women	73.1 ± 6.9	77.2 ± 6.2	0.07
Men	84.5 ± 8.9	86.0 ± 6.1	0.56
Education (%)			0.60
Low	0.0% (0)	2.8% (1)	
Intermediate	30.6% (11)	30.6% (11)	
High	69.5% (25)	66.7% (24)	
Lifestyle			
Physical activity (h/week)	2.8 (0.88–3.75)	2.3 (1.2–4.1)	0.69
Walking (h/week)	7.0 (5.0–12.0)	5.5 (3.5–11.8)	0.15
Smoking status			0.30
Non-smoker	66.7% (24)	58.3% (21)	
Ex-smoker	22.2% (8)	16.7% (6)	
Smoker	11.1% (4)	25.0% (9)	
Alcohol consumption (g/d)			
Women	0.10 (0.00–4.69)	0.21 (0.02–4.88)	0.22
Men	0.04 (0.00–2.00)	3.85 (0.36–16.2)	0.09
Taking supplements	97.2% (35)	33.3% (12)	<0.0001
Vitamin B12	91.7% (33)	8.3% (3)	<0.0001
Vitamin D3	50.0% (18)	11.1% (4)	0.0003

Variables expressed as percentage (n), mean ± SD, or median (IQR). BMI: body mass index.

Some Bone Health Related Micronutrients Functions

- Bone turnover marker **CTX (C-telopeptide of type I collagen):** plays a role in bone resorption when Ca is released from bone storage. CTX is high when there is insufficient intake of Ca from the diet.
- **Long chain n-3 fatty acids** (DHA & EPA): associated with better BMD and lower risk of hip fracture
- **SePP** (selenium-transport protein): constitutes the majority of selenium in blood, and transports selenium to bones. Selenium decreases bone turnover.
- **Lysine**: osteoblast growth and differentiation.
- **Zinc**: osteoblast differentiation and mineralization.
- **Vitamin A & B2**: protects & promotes bone health

Table 2. Characteristics of bone parameters and biomarkers according to a vegan or omnivorous diet.

Characteristics	Vegans (n = 36)	Omnivores (n = 36)	p-Value
Quantitative ultrasound			
BUA (dB/MHz) [a]	111.8 ± 10.7	118.0 ± 10.8	0.02
SOS (m/s) [a]	1581.7 ± 28.3	1592.3 ± 9.27	0.20
SI [a]	97.3 ± 13.3	104.3 ± 16.9	0.05
Bone turnover			
CTX (ng/mL) [a]	0.45 ± 0.19	0.36 ± 0.16	0.03
Osteocalcin (ng/mL)	20.8 ± 5.49	18.2 ± 6.83	0.08
PINP (µg/L)	60.7 ± 17.0	52.7 ± 18.2	0.06
Alkaline phosphatase (U/L)	64.5 (57.0–80.0)	59.5 (50.5–79.5)	0.13
Calcium homeostasis			
PTH (pg/mL)	52.3 ± 21.0	44.1 ± 19.0	0.09
Vitamin D3 (nmol/L)	63.2 (21.5–88.1)	45.4 (34.6–68.6)	0.49
Urinary calcium (mg/L)	55.5 (36.5–73.0)	86.0 (49.0–165.5)	0.004
FGF23–α-klotho axis			
α-Klotho (pg/mL)	780.3 (621.1–976.2)	640.1 (520.8–770.2)	0.01
FGF23 (RU/mL)	64.5 (54.4–83.2)	63.6 (57.7–72.5)	0.75
Vitamin B12 status			
Vitamin B12 (pmol/L)	337.9 (218.0–559.1)	267.6 (227.2–364.5)	0.12
Holotranscobalamin (pmol/L)	89.4 (58.9–205.0)	84.3 (67.6–100.4)	0.35
Total homocysteine (µmol/L)	8.60 (6.70–11.3)	8.75 (7.25–10.5)	0.90
Methylmalonic acid (µmol/L)	0.17 (0.15–0.22)	0.18 (0.16–0.21)	0.62
4cB12	0.54 (0.07–1.24)	0.42 (0.19–0.70)	0.47
Vitamins			
Vitamin A (µmol/L)	1.80 (1.56–1.92)	2.07 (1.80–2.33)	0.004
Vitamin B2 (nmol/L)	6.00 (4.39–10.70)	9.05 (6.82–11.8)	0.03
Vitamin B6 (nmol/L)	67.2 (49.1–89.4)	78.8 (47.1–99.7)	0.62
Vitamin K1 (nmol/L)	1.55 (1.30–2.23)	0.78 (0.54–1.13)	<0.0001
Folate (ng/mL)	10.9 (7.71–12.8)	7.82 (6.36–11.2)	0.03
Amino acids			
Alanine (µmol/L)	373.2 ± 98.1	348.7 ± 66.2	0.22
Arginine (µmol/L)	64.1 (52.7–74.4)	69.1 (59.0–76.0)	0.35
Glutamine (µmol/L)	629.4 ± 83.2	546.9 ± 64.3	<0.0001
Leucine (µmol/L)	117.5 (103.6–137.0)	120.0 (114.4–143.8)	0.07
Lysine (µmol/L)	128.5 (119.0–147.7)	171.4 (152.3–189.3)	<0.0001
Proline (µmol/L)	174.7 (146.5–244.4)	174.6 (139.2–195.7)	0.24
Iodine and thyroid			
Urinary iodine (µg/L)	28.1 (17.1–41.6)	74.1 (41.5–101.7)	<0.0001
TSH (µg/L)	2.13 ± 0.92	2.35 ± 1.05	0.34
Other bone-related biomarkers			
Zinc (µg/dL)	79.3 ± 11.6	87.3 ± 13.3	0.008
Selenium (µg/L)	67.7 (59.8–82.1)	76.2 (68.4–83.5)	0.11
SePP (mg/L)	3.26 (2.61–4.47)	4.97 (4.22–5.46)	<0.0001
hsCRP (mg/L)	0.39 (0.21–0.88)	0.63 (0.24–1.74)	0.25
Total n-3 fatty acids (%)	3.07 (2.66–3.53)	5.11 (4.22–5.77)	<0.0001
Urinary magnesium (mg/L)	57.0 (44.8–66.9)	56.4 (43.5–81.9)	0.88

Variables expressed as percentage or mean ± SD or median (IQR); [a] n = 71 (vegan n = 36, omnivores n = 35). BUA (ultrasound attenuation), SOS (speed of sound), SI (stiffness index), CTX (b-CrossLaps), PINP (procollagen type-1), PTH (parathyroid hormone), FGF23 (fibroblast growth factor 23), 4cB12 (four markers combined vitamin B12 indicator), TSH (thyroid-stimulating hormone), SePP (selenoprotein P), hsCRP (high-sensitivity C-reactive protein).

Evaluation of QUS and Biomarkers

Concerning for vegans	Beneficial for vegans
SePP, n-3 FA are lower in vegans	**Vitamin K** is higher in vegans
CTX & **α- Klotho** are higher in vegans	**Folate** is higher in vegans
Urinary Ca & I are lower in vegans	**Glutamine** is higher in vegans
Vitamin A, B2, Zinc are lower in vegans	
Lysine is lower in vegans	

Exploratory RRR

- Reflects the score of how biomarkers relate to bone health evaluation (BUA and SOS)
- Factor Loading ≥ 0.20
- Black bars ≥ 0.20
- Grey bars < 0.20
- **Contribute to bone health:**

❖ FGF23

❖ TSH

❖ Vitamin B6

❖ **Urinary Mg, Ca, I**

❖ **n-3 FA**

❖ α- Klotho

❖ Leucine, **Lysine**

❖ **Vitamin A**

❖ **SePP**

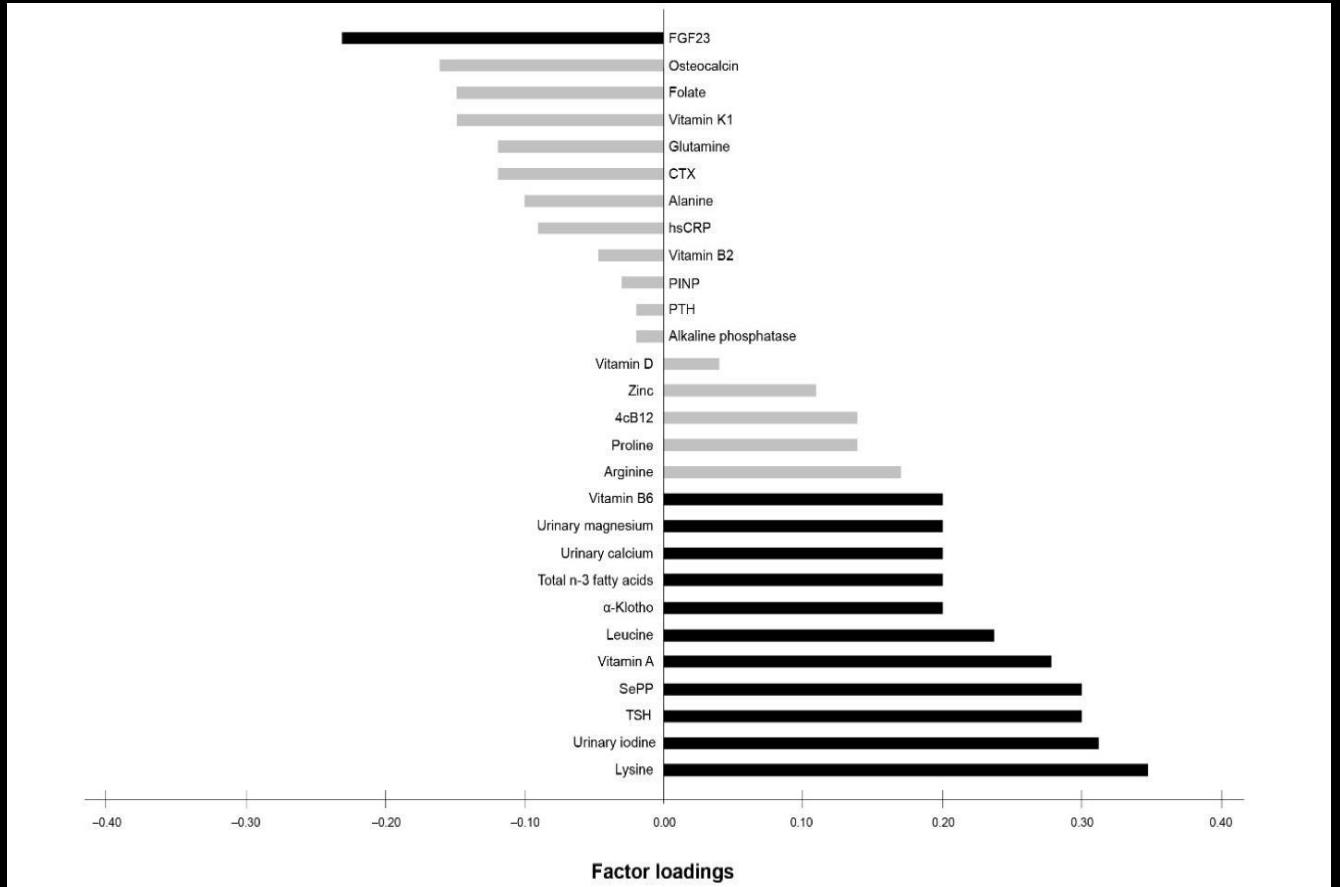
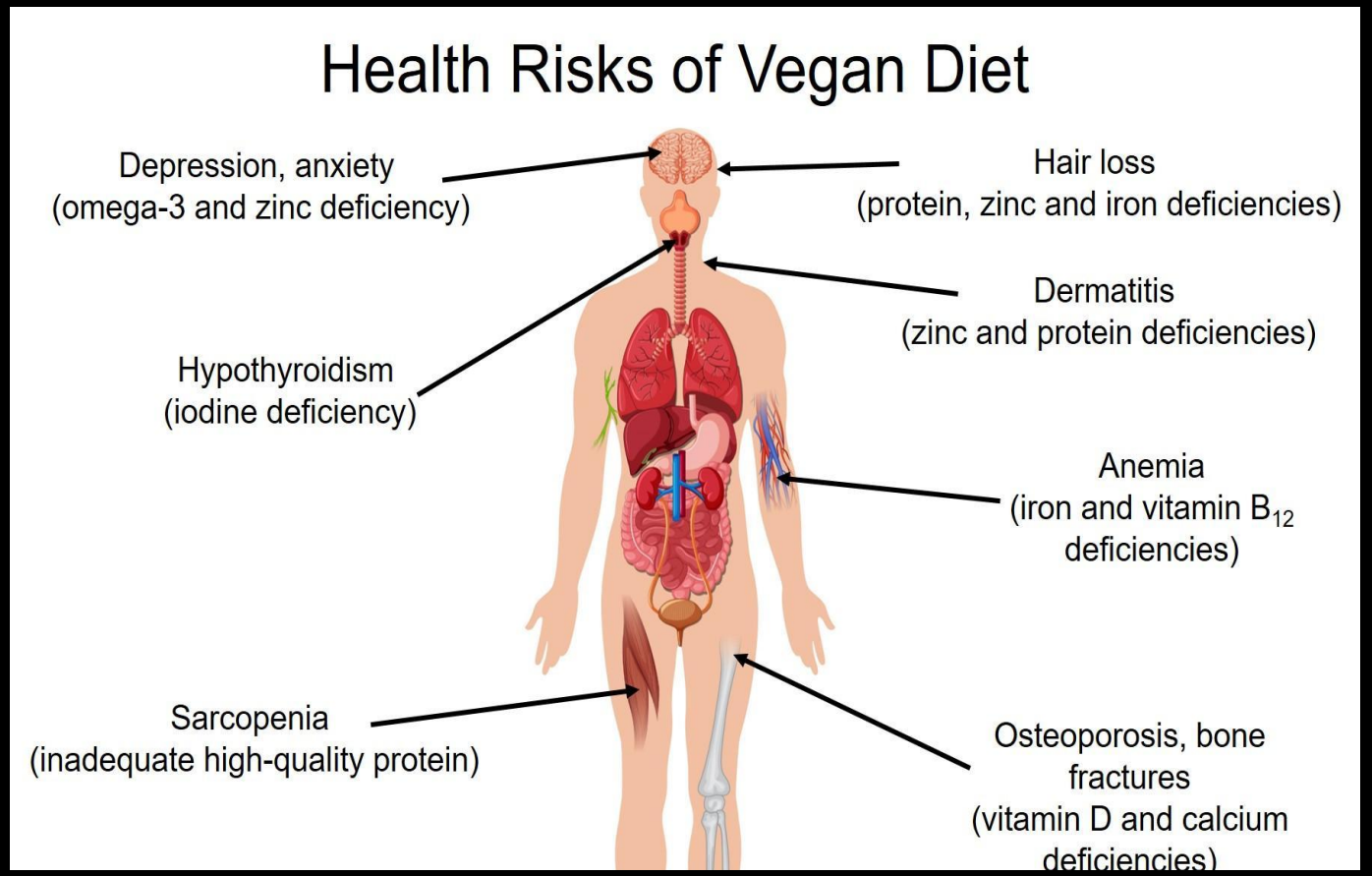


Figure 1. Factor loadings of all 28 biomarkers according to the biomarker pattern score explaining the maximum variation in BUA and SOS. Factor loadings are correlations between biomarkers and the biomarker pattern score. Black bars indicate biomarkers with factor loadings ≥ 0.20, which are considered as major contributors to the score. Grey bars indicate biomarkers with factor loadings < 0.20. FGF23 (fibroblast growth factor 23), CTX (b-CrossLaps), hsCRP (high-sensitivity C-reactive protein), PINP (procollagen type-1), PTH (parathyroid hormone), 4cB12 (four markers combined vitamin B12 indicator), SePP (selenoprotein P), TSH (thyroid-stimulating hormone).

Discussion/ Conclusion

- The study investigated the connection between a vegan diet and impaired bone health.
- Bone-focused QUS parameters and bone health-related biomarkers for individuals consuming an entirely plant-based diet generally reflected bone health below that of their animal-consuming counterparts.
- Values generally appeared below the mean for the plant-based sample population and, in some cases, significantly differed, which can explain lower bone health in vegans compared to omnivores.



Limitations of the study:

- Small study
- Used QUS measurements instead of DEXA
- Cross-sectional study limitations
- Very specific population (only in Berlin)

Follow-up Research:

- Research plant-based population that is not on vitamin B12 and D3 supplementation.
- Conduct a medical history questionnaire to see if a family history indicates bone health conditions.

Thank you!