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Original Research

Marked heterogeneity in micronutrient composition of multivitamin-mineral supplements

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Abstract: Background: Dietary research commonly assesses multivitamin (MVI) supplement use through broad categorical questions that assume products are compositionally similar. This study quantified the variability in micronutrient composition among best-selling MVI products to assess whether treating "multivitamin use" as a single exposure category is defensible. **Methods:** The 100 best-selling multivitamin products on Amazon, the dominant U.S. online supplement retailer, were screened on July 24, 2026. After excluding duplicate listings and products that were not general adult multivitamin supplements, 64 formulations remained. For each product, the labeled percent Daily Value (%DV) of 25 micronutrients was recorded directly from the Supplement Facts panel. Heterogeneity was characterized along three axes: composition breadth (number of nutrients included), per-nutrient content (inclusion rate, median, interquartile range, and range), and megadosing (defined a priori as ≥1,000% DV). **Results:** Composition breadth ranged from 7 to 24 of 25 nutrients (median 19.5). Only vitamin D, folate, and vitamin B12 were present in all 64 products, whereas choline, phosphorus, and iron were present in 22% or fewer. Labeled content varied widely; vitamin B12 ranged from 100% to 33,333% DV (median 408%). Thirty products (47%) contained at least one megadosed nutrient, concentrated in the B-complex vitamins and biotin. **Conclusion:** Best-selling multivitamins vary markedly in which nutrients they contain, in how much, and in whether they megadose. "Multivitamin use" is a compositionally heterogeneous exposure; studies should specify formulations or stratify by composition.

Keywords: Multivitamin supplements, Dietary supplements, Nutritional epidemiology, Research methodology, Micronutrients, Heterogeneity

1. Introduction

Multivitamin-mineral supplements are commonly used in the United States. National surveys indicate that over half of adults report using at least one dietary supplement during the preceding 30 days, whereas about a third report using a multivitamin-mineral product [1-4]. Evidence regarding the health effects of multivitamin-mineral supplementation is mixed and outcome-specific. Systematic reviews and large randomized trials have generally found little or no benefit for cardiovascular events or all-cause mortality [5-6]. A small reduction in cancer incidence has been reported [7-8]. Evidence for cognition in older adults is present in some studies

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but remains dependent on the population and outcome examined [9-11].

The prevailing evidence indicates that routine MVI supplementation provides little or no clinically important benefit for preventing cardiovascular disease, most cancer outcomes, or all-cause mortality in generally healthy adults without known nutritional deficiencies, although small benefits have been reported for overall cancer incidence and cognitive function in older adults [8, 11]. An alternative possibility also merits consideration: treating "multivitamin use" as a homogeneous intervention may obscure formulation-specific effects by pooling heterogeneous products [12]. These explanations are not mutually exclusive. Distinguishing them requires first establishing how much MVI formulations actually differ.

In epidemiological studies, self-reported dietary-supplement use may be assessed using structured questionnaires or 24-hour dietary recalls. Structured questionnaires commonly use predefined categories of supplement type and frequency, whereas 24-hour recalls are open-ended and can collect more detailed information when required by the study protocol [13-14]. Some studies nevertheless classify participants using a general multivitamin category or assign a default nutrient composition rather than incorporating the exact product formulation. Because multivitamin products vary substantially in nutrient content, this practice can misclassify formulation-specific exposure and produce inaccurate nutrient-intake estimates [15]. Such measurement error may attenuate formulation-specific associations under some conditions. While non-differential misclassification is expected to bias estimates toward the null, that expectation does not hold reliably when exposure has multiple categories or the underlying error structure is complex [16].

Prior work has established that multivitamin composition is not uniform. Methodologic analyses showed that allowing for variation in multivitamin composition improves nutrient intake estimates [15], that the method of supplement exposure assessment materially changes estimated nutrient intakes [17], and that the category itself lacks a consistent scientific or regulatory definition [12, 18]. Chemical analyses documented substantial between-product variability in measured content, including a wide range of vitamin D relative to the label [19-20]. What remains missing is a direct, current, cross-product quantification of how formulations differ in the nutrients they include and at what labeled %DV, expressed in the same terms in which exposure enters epidemiologic categorization.

The present study addresses this gap using a current (2026) sample of multivitamins ranked by sales volume in the dominant U.S. online marketplace, rather than a catalog or convenience sample. It quantifies compositional heterogeneity across 25 micronutrients along three explicit axes and assesses whether products sold and used as "multivitamins" are similar enough in composition to justify a single exposure category, or whether the category is intrinsically heterogeneous.

2. Materials and methods

2.1 Sample selection

Multivitamin products were identified from the Amazon "Best Sellers in Multivitamins" list (Health & Household › Vitamins, Minerals & Supplements › Multivitamins), accessed on July 24, 2026. Amazon was selected as the sampling frame because it is the dominant U.S. online retailer of vitamin, mineral, and supplement products and aggregates warehouse-club private labels and legacy direct-sales brands alongside mainstream retail brands, functioning as a de facto comprehensive marketplace for the category. Its best-seller list is public, sales-ranked, and date-stamped, making the frame reproducible, and the ranking weights the sample toward frequently purchased formulations rather than toward obscure catalog entries. This weighting is channel-specific. The ranking reflects sales volume within a single online retailer, and e-commerce accounted for an estimated 26.9% of U.S. dietary supplement sales in 2025 [21]. The sample is therefore weighted by online sales rather than by total category consumption, and formulations distributed mainly through brick-and-mortar retail, clinics, or direct sales may be under-represented.

The 100 top-ranked listings were screened in rank order against pre-specified criteria. Products labeled and marketed as adult multivitamins were included regardless of mineral content. Excluded were children's and adolescent formulations, which use age-specific Daily Value references that are not comparable to the adult (18 years and older) values; prenatal products; single- or dual-nutrient products; condition-specific or specialty products, such as bariatric, stress, or organ-targeted formulations; whole-food fruit and vegetable blends not labeled as multivitamins; products that were not dietary supplements, such as over-the-counter drugs appearing in the ranked list; and duplicate listings of an identical formulation. Screening the top 100 listings yielded 64 unique adult multivitamin formulations for analysis. Supplementary Table S1 provides the complete product-level dataset: all 100 screened listings with their Amazon rank, brand, ASIN, dosage form, and individual screening disposition, followed by the 64 included formulations with the extracted percent Daily Value for each of the 25 micronutrients. The same file is permanently archived in the Zenodo Repository (DOI: 10.5281/zenodo.18050899).

2.2 Data collection

For each product, the labeled %DV of 25 micro-

nutrients was recorded directly from the printed Supplement Facts panel shown in the product listing. When the panel image was not legible in the listing, the value was taken from the manufacturer's website or the National Institutes of Health Dietary Supplement Label Database. When a nutrient was absent, 0% DV was recorded. All products were sampled in July 2026, well after the U.S. Food and Drug Administration final rule revising the Nutrition and Supplement Facts labels, which established the current Daily Value references, including a Daily Value for choline of 550 mg [22], had taken full effect. Compliance with that rule was required by January 1, 2020 for manufacturers with $10 million or more in annual food sales and by January 1, 2021 for smaller manufacturers [23]. Accordingly, all labels used the current Daily Value references, and %DV values were compared directly across products without recalculation. The 25 micronutrients assessed were vitamin A, vitamin C, vitamin D, vitamin E, vitamin K, thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, biotin, pantothenic acid, calcium, iron, phosphorus, iodine, magnesium, zinc, selenium, copper, manganese, chromium, molybdenum, and choline.

2.3 Statistical analysis

Analyses were descriptive and characterized heterogeneity along three axes rather than testing causal or efficacy hypotheses. First, composition breadth was defined as the number of the 25 nutrients present in a product at greater than 0% DV. Second, per-nutrient content was summarized for each nutrient by its inclusion rate (the percentage of products containing it) and, across all 64 products, its median, interquartile range, and full range; because absent nutrients were coded as 0% DV, these summaries describe the exposure distribution faced by a consumer selecting from the category. For each nutrient, the median with interquartile range and the mean %DV among products that contained it were also reported, so that typical dosing among users of a nutrient is visible alongside the category-wide distribution. Because these distributions were right-skewed, the median is the preferred summary of typical content, and the mean is retained for comparability with prior reports. Third, megadosing was defined a priori as a labeled content of at least 1,000% of the Daily Value, or tenfold the recommended intake; this threshold is a suggested convention adopted for this analysis, not a validated clinical cutoff. The number of megadosed nutrients per product, the proportion of products containing at least one megadosed nutrient, and the frequency of megadosing by nutrient were calculated.

Two additional analyses assessed whether the observed heterogeneity was driven by a few outlier products. Composition breadth was re-examined after excluding all products containing any megadosed nutrient, and breadth and megadosing were compared across dosage forms. Percent Daily Value values are reported as integers. Analyses were conducted in Python (version 3) with the pandas library. Reporting of statistical methods and numerical results follows the SAMPL guidelines [24].

2.4 Ethics

This study analyzed publicly available product label information and involved no human subjects, identifiable private information, or biospecimens. Under 45 CFR 46, it does not constitute human subjects research, and institutional review board approval was not required.

3. Results

The 64 multivitamin formulations varied along three distinct dimensions: the number of nutrients each product contained, the labeled amount of each nutrient, and the frequency of megadoses. Each dimension is reported in turn.

3.1 Composition breadth

Formulations differed first in breadth, defined as the number of the 25 target micronutrients present in a product. Breadth ranged from 7 to 24 nutrients, with a median of 19.5 (interquartile range 14 to 22). A product labeled as a multivitamin therefore supplied anywhere from roughly one-quarter to nearly all of the assessed micronutrients.

3.2 Per-nutrient content

Table 1 reports the labeled content of each nutrient across the 64 products. Only three nutrients appeared in every product: vitamin D, folate, and vitamin B12. Others were frequently absent, including choline, present in 9 products (14%); phosphorus, present in 10 products (16%); and iron, present in 14 products (22%). Among products that contained a given nutrient, labeled amounts varied widely. Vitamin B12 content ranged from 100% to 33,333% of the Daily Value, with a median of 408% (interquartile range 250% to 2,083%). Thiamin reached 6,250%, biotin 33,333%, and vitamin E 1,787%. For most nutrients, the median approximated the conventional label target of near 100% of the Daily Value, while the maximum values exceeded the medians by one to two orders of magnitude. The resulting distributions were right-skewed, combining a cluster of products near the label target with a long tail of high-dose formulations. The effect of this skew on summary statistics was substantial for the most heavily dosed nutrients: among products containing them, the median and mean %DV were 133% and 935% for thiamin, 133% and 995% for biotin, and 408% and 3,073% for vitamin B12, respectively.

Table 1. Micronutrient content across 64 best-selling adult multivitamin formulations

Nutrient	Inclusion, n/64 (%)	Median %DV, all 64 products (Q1-Q3)	Range (min-max)	Median %DV when present (Q1-Q3)	Mean %DV when present
Vitamin A	63/64 (98%)	100 (54-117)	0-292	100 (56-117)	102
Vitamin C	62/64 (97%)	100 (54-133)	0-1,000	100 (67-133)	163
Vitamin D	64/64 (100%)	125 (108-250)	30-500	125 (108-250)	158
Vitamin E	63/64 (98%)	100 (88-131)	0-1,787	100 (90-132)	167
Vitamin K	31/64 (48%)	0 (0-67)	0-333	67 (46-100)	83
Thiamin (B1)	47/64 (73%)	120 (0-375)	0-6,250	133 (104-666)	935
Riboflavin (B2)	47/64 (73%)	119 (0-277)	0-3,846	150 (104-500)	602
Niacin (B3)	54/64 (84%)	110 (50-125)	0-1,000	125 (100-144)	167
Vitamin B6	61/64 (95%)	200 (100-500)	0-4,412	206 (106-500)	545
Folate	64/64 (100%)	100 (100-167)	20-425	100 (100-167)	134
Vitamin B12	64/64 (100%)	408 (250-2,083)	100-33,333	408 (250-2,083)	3,073
Biotin	61/64 (95%)	122 (100-512)	0-33,333	133 (100-550)	995
Pantothenic acid	53/64 (83%)	130 (50-300)	0-8,260	200 (100-300)	586
Calcium	40/64 (62%)	6 (0-12)	0-38	10 (8-16)	12
Iron	14/64 (22%)	0 (0-0)	0-100	44 (31-100)	57
Phosphorus	10/64 (16%)	0 (0-0)	0-4	2 (2-4)	2
Iodine	52/64 (81%)	100 (27-100)	0-200	100 (50-100)	85
Magnesium	37/64 (58%)	7 (0-24)	0-43	20 (12-25)	19
Zinc	62/64 (97%)	91 (35-136)	0-273	96 (35-136)	96
Selenium	47/64 (73%)	91 (0-107)	0-364	100 (62-196)	145
Copper	33/64 (52%)	56 (0-100)	0-244	100 (61-222)	129
Manganese	41/64 (64%)	82 (0-100)	0-261	100 (87-130)	113
Chromium	47/64 (73%)	100 (0-286)	0-2,857	100 (93-346)	296
Molybdenum	34/64 (53%)	10 (0-100)	0-222	100 (92-154)	109
Choline	9/64 (14%)	0 (0-0)	0-10	4 (2-6)	4

Note: Only 3 of 25 nutrients (vitamin D, folate, and vitamin B12) were present in all 64 formulations. Columns 3 and 4 are computed across all 64 products, including 0% DV for absent nutrients, and describe the exposure distribution faced by a consumer selecting from the category. Columns 5 and 6 are computed only among products that contained the nutrient. Because these distributions are right-skewed, the median is the preferred summary of typical content; the mean is retained for comparability with prior reports. %DV = percent Daily Value; Q1 = 25th percentile; Q3 = 75th percentile. Inclusion is defined as %DV > 0. Product-level values for every nutrient are provided in Supplementary Table S1.

3.3 Megadosing

Megadosing, defined a priori as labeled content of at least 1,000% of the Daily Value, was common. Of the 64 products, 30 (47%) contained at least one megadosed nutrient. The number of megadosed nutrients per product ranged from 0 to 7, with a median of 0. Megadosing was concentrated in the water-soluble B-complex vitamins and

biotin: vitamin B12 was megadosed in 24 products, biotin in 14, vitamin B6 in 10, thiamin in 10, pantothenic acid in 7, riboflavin in 6, and niacin in 2. Megadosing was not confined to the B vitamins; vitamin E was megadosed in 2 products, chromium in 2, and vitamin C in 1.

3.4 Structure of the heterogeneity

This heterogeneity was not attributable to a few outlier products. After excluding all 30 products that contained any megadosed nutrient, composition breadth among the remaining 34 products still ranged from 7 to 24 nutrients (median 16). Heterogeneity was also structured by dosage form. Capsule and tablet products (n = 43) were broader (median 21 nutrients) and more often megadosed (58%) than gummy products (n = 19; median 12 nutrients; 16% megadosed). There was one liquid product containing 15 nutrients (two megadosed) and one powder product containing 22 nutrients (three megadosed). Compositional heterogeneity therefore persisted across the sample rather than arising solely from a small number of high-dose formulations.

4. Discussion

Best-selling multivitamins varied markedly along all three axes examined: breadth, ranging from 7 to 24 of 25 nutrients; per-nutrient dose, with vitamin B12 alone spanning 100% to 33,333% of the Daily Value; and megadosing, present in nearly half of products. "Multivitamin use," as recorded in most dietary research, therefore does not correspond to a single, well-defined exposure.

Prior work has established that multivitamin composition varies, with chemical analyses documenting substantial between-product variability [19-20], and methodological work showing that composition-aware modeling improves intake estimates [12, 15, 18]. The present study extends this literature in three specific ways. It draws on a current sample defined by online sales rank rather than by convenience or catalog listing, targeting formulations people actually buy, albeit within a single retail channel; it quantifies heterogeneity across 25 nutrients simultaneously using label %DV, the exact form in which exposure enters most epidemiologic categorization; and it introduces two simple, reportable indices, composition breadth and megadose prevalence, that make the heterogeneity legible to researchers designing exposure definitions.

Because a single "multivitamin user" category can contain a product supplying 7 nutrients and one supplying 24, or 100% DV of vitamin B12 alongside 33,333% DV, pooling such products under one exposure label plausibly introduces substantial measurement error. The direction of the resulting bias cannot be assumed. Non-differential misclassification is often expected to attenuate associations toward the null, but that expectation does not hold reliably when exposure has multiple categories or the error structure is complex [16], and correcting such error is a recognized challenge in nutritional epidemiology [25-26]. Whether this mechanism materially contributes to the persistently null findings of major multivitamin trials and cohorts [3, 5-6, 8] cannot be determined from compositional data alone. The present findings support this as a testable hypothesis rather than an established explanation. Distinguishing this from the competing possibility that micronutrient supplementation has little effect on hard endpoints across the entire compositional range will require studies that link specific formulations or composition strata to outcomes. Because the direction of bias is unknown, null findings from studies using a pooled multivitamin category cannot be read as conservative estimates of a true effect.

The megadoses observed were concentrated in water-soluble B-complex vitamins and biotin. Several of these nutrients, including thiamin, riboflavin, vitamin B12, biotin, and pantothenic acid, have no established Tolerable Upper Intake Level because of low toxicity [27]. For these nutrients, extreme label %DV values exaggerate differences in biologically delivered dose, because absorption of large oral boluses is limited; the heterogeneity is real at the level of labeled exposure but attenuated at the level of physiologic exposure. The exceptions are informative. Vitamin E, megadosed in two products at up to 1,787% DV, is fat-soluble and has a defined upper intake level, and chromium is a mineral with accumulation potential; for such nutrients, label heterogeneity tracks biologically meaningful differences more closely. Even among the water-soluble vitamins, safety is not unlimited. For example, regulatory agencies have revisited the upper intake level for vitamin B6 [28], with reports of neuropathy associated with routine vitamin B6 supplement use [29-30]. These reports underscore that megadosing is not uniformly benign, at least for the water-soluble vitamin B6.

Labeled %DV also does not capture nutrient form, which alters bioavailability. Folate, for example, appears as folic acid in some products and as 5-methyltetrahydrofolate in others, and these forms differ in absorption and metabolism; two products listing an identical folate %DV may deliver different physiologic exposures. A study that pools such products mixes not only doses but chemical forms, compounding exposure misclassification beyond what the %DV heterogeneity alone implies.

Exposure misclassification is a recognized source of bias in pharmacoepidemiology, and the magnitude of the resulting distortion depends on which aspect of exposure is misclassified [31]. The same reasoning applies to nutrient exposure: treating compositionally distinct formulations as equivalent obscures dose-response relationships and formulation-specific effects. Accordingly, nutritional research examining multivitamin

supplementation should record specific products and doses, or stratify by composition, rather than rely on a single categorical exposure.

5. Limitations

This study has several limitations. First, the analysis relied on labeled %DV rather than laboratory assay; however, labeled composition is precisely the information available to consumers and to the questionnaire-based instruments the study critiques, so it is the operative exposure in epidemiologic research. Independent laboratory analyses have shown that labeled and measured supplement content can diverge substantially [32-35], reinforcing that label-based composition should be interpreted as declared, rather than verified content. Second, the sample was drawn from a single online retailer; however, Amazon's dominance of U.S. online supplement sales [36] and its aggregation of warehouse-club and direct-sales brands make it a broad and reproducible frame. That frame is nonetheless partial, since e-commerce accounted for an estimated 26.9% of U.S. supplement sales in 2025 [21]. Best-seller ranking therefore weights the sample toward the products most purchased online rather than across all retail channels, and the findings describe the online segment of the category rather than the whole. Third, the data capture a single time point; however, the date-stamped, sales-ranked frame makes the snapshot exactly reproducible and anchors it to the current market rather than to historical formulations. Fourth, 64 products is a modest number, and the sample is not a census of adult multivitamin formulations. It is a complete enumeration of the qualifying products within the top 100 listings on a single best-seller list on a single date; formulations ranked below that cutoff and those sold only through other channels were not assessed. The direction of this limitation is nonetheless favorable to the study's aim, because a truncated sample can only understate compositional heterogeneity: adding formulations can widen the observed range of breadth and dose but cannot narrow it. Documenting that the category is heterogeneous, and by how much at minimum, therefore does not require exhaustive coverage. These features make the sample well suited to the study's aim of characterizing, rather than explaining, compositional heterogeneity.

6. Conclusions

Best-selling multivitamins vary markedly in how many nutrients they contain, from 7 to 24 of 25; in the labeled amount of each nutrient; and in whether they megadose, with 47% containing at least one nutrient at 1,000% of the Daily Value or more. "Multivitamin use" is therefore a compositionally heterogeneous exposure rather than a single intervention. Studies of the health effects of multivitamin supplementation should specify exact formulations, record brand and dosage information, or stratify analyses by nutrient composition. Whether this heterogeneity contributes to the inconsistent findings of the existing literature is a hypothesis these data motivate but do not test; examining it will require linking specific formulations to outcomes. For clinicians, broad statements that multivitamins are effective or ineffective are difficult to interpret without specifying which formulations and doses were studied.

Supplementary materials

Supplementary materials associated with this article are available at the following link: https://file.luminescience.cn/FNDS-604%20Supplementary%20Table%20S1.xlsx.

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Data availability

The full product list, ASINs, dosage forms, screening dispositions, and extracted %DV data are provided as Supplementary Table S1 and are permanently archived in the Zenodo Repository (DOI: 10.5281/zenodo.18050899). No other data were generated or analyzed.

Conflicts of interest

The author declares no conflicts of interest.

AI usage

Large language models were used for language editing, tabulation, and formatting assistance; the author reviewed, verified, and is fully responsible for all content.

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