UNIVERSIDAD NACIONAL
SISTEMA DE ESTUDIOS DE POSGRADO
POSGRADO REGIONAL EN CIENCIAS VETERINARIAS TROPICALES

Evaluación de la adherencia de la alimentación en la población urbana de ocho países de América Latina al patrón alimentario de referencia de EAT-Lancet

Rulamán Alejandro Vargas Quesada

Universidad Nacional, Heredia, octubre 2024

Tesis sometida a consideración del Tribunal Examinador del Posgrado Regional en Ciencias Veterinarias Tropicales, Maestría Académica en Epidemiología para optar al grado de *Magister Scientiae*

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RESUMEN GENERAL

Esta investigación aborda el contexto de los patrones alimentarios y la sostenibilidad ambiental en América Latina, evaluando cómo las dietas urbanas de ocho países latinoamericanos se adhieren a la "Dieta de Salud Planetaria" propuesta por la Comisión EAT-Lancet. El patrón alimentario propuesto por EAT-Lancet comprende un marco científico diseñado para promover la salud humana mientras se minimiza el impacto ambiental, y se caracteriza por un alto consumo de frutas, vegetales, granos enteros, leguminosas, nueces y semillas y aceites vegetales insaturados, con una reducción en el consumo de carnes rojas, azúcares añadidos y alimentos procesados.

Esta investigación utiliza datos del Estudio Latino Americano de Nutrición y Salud (ELANS 2016), un amplio estudio multinacional que recopiló información detallada sobre la dieta, el estado nutricional y los niveles de actividad física de 9218 participantes en Argentina, Brasil, Chile, Colombia, Costa Rica, Ecuador, Perú y Venezuela. Por medio del Índice de Dieta de Salud Planetaria (IDSP), desarrollado específicamente para medir la adherencia a las recomendaciones de EAT-Lancet, este estudio cuantifica el grado en que las dietas de estos países cumplen con los criterios de la Dieta de Salud Planetaria.

Los resultados del estudio muestran que la adherencia general al patrón de EAT-Lancet en América Latina es baja, con un promedio regional del 29.7%. Sin embargo, existe una variabilidad significativa entre países, siendo Costa Rica el país con la mayor adherencia (32.9%) y Argentina con la menor (25.8%). Algunos grupos demográficos, como los adultos de mayor edad, personas con mayor nivel educativo, de nivel socioeconómico más alto y aquellos con niveles más altos de actividad física, tienden a mostrar una mayor adherencia al patrón alimentario propuesto por EAT-Lancet.

Un hallazgo fundamental de esta investigación es que, mientras que una mayor adherencia al patrón alimentario de EAT-Lancet se asocia con mejoras en la ingesta de nutrientes como los

equivalentes de folato, la vitamina C, el magnesio y el zinc, también está vinculada a un mayor riesgo de ingesta inadecuada de micronutrientes esenciales como la vitamina D, el calcio y la vitamina B12. Esta paradoja se debe principalmente a la reducción en el consumo de productos lácteos y carnes, los cuales son fuentes ricas en estos nutrientes y cuyo consumo es desincentivado por el patrón de EAT-Lancet. Estos resultados resaltan la importancia de considerar las necesidades nutricionales específicas de la población al promover dietas basadas en principios globales de salud y sostenibilidad.

La investigación también aborda las limitaciones del patrón alimentario de EAT-Lancet en el contexto latinoamericano, señalando que las recomendaciones dietéticas globales pueden no ser fácilmente aplicables en regiones con tradiciones alimentarias y realidades socioeconómicas distintas. Por ejemplo, el costo y la disponibilidad de ciertos alimentos recomendados pueden ser prohibitivos para amplios sectores de la población, lo que dificulta la adopción generalizada de la Dieta de Salud Planetaria. Se destaca la necesidad de adaptar culturalmente las recomendaciones del patrón de EAT-Lancet para que sean más accesibles y aceptables en América Latina. Esto incluye la consideración de las preferencias alimentarias locales, la viabilidad económica y la posibilidad de implementar programas de fortificación de alimentos y suplementación para contrarrestar posibles deficiencias nutricionales.

Simultáneamente, esta investigación realiza un análisis detallado de la asociación entre la adherencia al patrón alimentario de EAT-Lancet y la prevalencia de sobrepeso y obesidad en América Latina. Este estudio no identificó una asociación significativa entre estos factores, lo que sugiere que seguir únicamente las pautas de EAT-Lancet podría no ser suficiente para reducir la alta prevalencia de exceso de peso en la región. La prevalencia elevada de esta condición, independientemente del nivel de adherencia al patrón alimentario, indica que otros factores (como

los hábitos alimentarios, los niveles de actividad física, las condiciones socioeconómicas y las predisposiciones genéticas) pueden tener un papel más determinante en los resultados relacionados con el exceso de peso que la simple adherencia a este patrón alimentario.

Además, se propone la hipótesis de que la baja adherencia promedio al patrón de EAT-Lancet observada en la muestra de este estudio probablemente contribuyó a la falta de una asociación significativa. Este resultado sugiere que cualquier beneficio potencial de la dieta de EAT-Lancet podría estar oculto o diluido en poblaciones donde la adherencia no es lo suficientemente alta. Por lo tanto, futuras investigaciones deberían examinar estas dinámicas con mayor profundidad, considerando intervenciones que busquen incrementar la adherencia y evaluar los resultados de salud asociados.

Aunque el patrón alimentario de EAT-Lancet proporciona un marco prometedor para una alimentación saludable y sostenible, su implementación efectiva en América Latina requiere una adaptación cuidadosa a las prácticas alimentarias locales y una comprensión más profunda de los múltiples factores que influyen en los desafíos de salud pública, como el exceso de peso. Es necesario realizar más estudios para ajustar estas recomendaciones dietéticas y evaluar su impacto a largo plazo en la salud de las diversas poblaciones latinoamericanas. Esta investigación proporciona una base sólida para futuras políticas públicas en América Latina que busquen promover un sistema alimentario más saludable y sostenible, en línea con los Objetivos de Desarrollo Sostenible y los compromisos internacionales en materia de cambio climático.

AGRADECIMIENTOS

A mis padres, familia y amigos, por su apoyo incondicional y por hacer de este proceso algo mucho más llevadero.

A Rafa, por ser siempre crítico y exigente, por ser un mentor y también un amigo en los momentos más difíciles.

A Geo, por creer en mí, confiarme los datos del ELANS y acompañarme en todo este proceso.

A Jotas, por todas sus enseñanzas durante la maestría, su paciencia infinita y su gran amistad.

A Leandro, por capacitarme y compartir generosamente sus valiosos aportes desde su experiencia.

DEDICATORIA

Dedico este proyecto a mi amada Tita Florita, quien, aunque ya no está con nosotros desde hace varios años, sé que habría estado muy orgullosa.

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INTRODUCCIÓN GENERAL

1. Cambio climático y producción de alimentos

La alimentación humana ha experimentado múltiples transformaciones en los últimos 50 años, producto de avances tecnológicos, globalización y cambios en los sistemas agrícolas (1,2). A nivel mundial, se estima que el aumento en el rendimiento de cultivos ha contribuido con una mejor esperanza de vida y una disminución general del hambre, la pobreza y las tasas de mortalidad infantil (3).

No obstante, estos beneficios han sido acompañados de cambios hacia patrones alimentarios poco saludables y sostenibles, caracterizados por un aumento en la producción de alimentos con alta densidad energética y alto grado de procesamiento. Lo anterior ha favorecido una amplia escala de desnutrición, aún existente en varias regiones del mundo, en conjunto con un aumento global en la prevalencia de exceso de peso y enfermedades no transmisibles (1).

La producción de alimentos se ha convertido en una de las principales causas de modificaciones ambientales, por su contribución al cambio climático. De forma recíproca, el cambio climático genera un impacto negativo en la productividad agrícola y ganadera, lo que representa una amenaza para la seguridad alimentaria (1). Estudios recientes sugieren que, en las próximas décadas, los cambios en los patrones climáticos conducirán a modificaciones en el contenido de nutrientes en los alimentos de consumo masivo, por ejemplo el arroz, la cebada, el trigo y las leguminosas. En algunos casos, estas modificaciones implican reducción en los aportes de nutrientes críticos, como la proteína, el hierro y el zinc (4–7).

Las deficiencias de hierro y zinc constituyen un problema de salud pública global, principalmente en áreas geográficas donde las poblaciones vulnerables basan su dieta en cultivos fuente de estos nutrientes, como ocurre en el caso de mujeres y niños (as) de países de África subsahariana (8). No obstante, en el caso de América Latina, existen programas de fortificación de

alimentos con estos micronutrientes (9–11), los cuales podrían ayudar a contrarrestar el potencial efecto negativo del cambio climático en el contenido de micronutrientes de algunos cultivos.

A nivel global, se estima que la agricultura ocupa cerca del 40% de la tierra disponible (12) y que la producción de alimentos comprende aproximadamente 30% de la emisión de gases de efecto invernadero (GEI) (13,14) y 70% del uso del agua dulce del planeta (15). Existe una variedad de indicadores que pueden ser utilizados para evaluar el impacto que tiene la producción de alimentos en el ambiente, siendo los GEI los utilizados con mayor frecuencia en investigación (4,16).

Los distintos grupos de alimentos no solo difieren en su contenido nutricional, sino también en la cantidad de tierra, agua, energía y GEI implicados en su producción; lo que se conoce como huella ecológica (17). Según estimaciones basadas en la evidencia científica disponible, esta huella ecológica es mayor (por porción de alimento producido) en los productos de origen animal, especialmente en el caso de alimentos que provienen de rumiantes (1,18).

A raíz de estos hallazgos con respecto al impacto de la producción de alimentos en el ambiente, se ha establecido la necesidad de contar con objetivos científicos claros para guiar hacia una transformación del sistema alimentario que promueva dietas saludables y una producción de alimentos sostenible (1), en concordancia con los Objetivos de Desarrollo Sostenible (ODS) de las Naciones Unidas y el Acuerdo de París para el Cambio Climático (19,20). Considerando lo anterior, en los últimos años el concepto de "dieta saludable" ha sido modificado, con el propósito de incorporarle conceptos de salud planetaria y sostenibilidad (21). Según la Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO) y la Organización Mundial de la Salud (OMS), las dietas saludables y sostenibles son "aquellas que promueven todas las dimensiones de salud y bienestar en los individuos; tienen bajo impacto ambiental; son accesibles, asequibles, equitativas y culturalmente aceptables" (22).

2. Patrón alimentario de EAT-Lancet

Un patrón alimentario o patrón dietético se define como las cantidades, proporciones, variedades o combinaciones de alimentos y nutrientes presentes en la dieta, así como la frecuencia con la que son consumidos (13). Asociado a un modelo de producción y consumo de alimentos más saludable y con menor impacto ambiental, la Comisión EAT-Lancet para "Dietas Saludables a partir de Sistemas Alimentarios Sostenibles" propuso en 2019 un patrón alimentario que busca la salud humana y ambiental de forma simultánea bajo el principio de "una salud" (1,4,23). Este patrón se conoce como "Dieta de Salud Planetaria" y propone los primeros objetivos científicos para el consumo de una dieta saludable dentro de los límites ambientales de producción de alimentos (1,4).

El patrón alimentario de EAT-Lancet está basado en 2500 kcal diarias (con rangos posibles de consumo) y favorece el consumo de alimentos identificados como beneficiosos para la salud y cuya producción genera un menor impacto ambiental. De manera general, este patrón alimentario implica: 1) un alto consumo de vegetales, frutas, granos enteros, leguminosas, nueces, semillas y aceites vegetales insaturados, 2) un consumo bajo o moderado de lácteos, mariscos, pollo y huevo y 3) un consumo bajo o mínimo de carne roja, carne procesada, azúcar añadido, granos refinados y vegetales harinosos (1).

2.1. Patrón alimentario de EAT-Lancet y resultados de salud

El patrón alimentario de EAT-Lancet ha sido comparado con otras guías y patrones alimentarios saludables de distintas regiones del mundo (24–27). Asimismo, diversos estudios han encontrado resultados favorables al relacionar la adherencia al patrón alimentario de EAT-Lancet con distintos resultados de salud.

Por ejemplo, en 2022 Xu *et al.* encontraron una disminución de 19% de riesgo de presentar diabetes tipo 2 en personas con mayor adherencia al patrón de EAT-Lancet, al compararlo con la mínima adherencia, después de ajustar por variables sociodemográficas y factores relacionados con salud (HR: 0.81, IC 95% [0.72, 0.90]) (28). Además, Stubbendorff *et al.* (2022) encontraron que una mayor adherencia al patrón de EAT-Lancet se asoció con 25% menos riesgo de mortalidad por todas las causas (HR: 0.75, IC 95% [0.67, 0.85]), 24% menos riesgo de mortalidad por cáncer (HR: 0.76, IC 95% [0.63, 0.92]) y 32% menos riesgo de mortalidad por enfermedades cardiovasculares (ECV) (HR: 0.68, IC 95% [0.54, 0.84]), en comparación con la adherencia más baja al patrón (29).

También se ha asociado la adherencia al patrón alimentario de EAT-Lancet con la ingesta de nutrientes y parámetros de salud y sostenibilidad. Por ejemplo, los resultados obtenidos de la cohorte alemana del estudio DONALD (Diseño Longitudinal Nutricional y Antropométrico de Dortmund, por sus siglas en inglés) asociaron una mayor adherencia al patrón alimentario de referencia de EAT-Lancet (determinado mediante un índice dietético desarrollado por los investigadores) con una menor ingesta de proteína, azúcar añadido y colesterol dietético; mayor ingesta de fibra dietética; menor emisión de GEI y del uso de suelo; y un menor índice de masa corporal (IMC) (30).

2.2. Limitaciones del patrón alimentario de EAT-Lancet

El patrón alimentario de EAT-Lancet ha sido debatido con respecto a limitaciones de accesibilidad económica (31,32). Por ejemplo, un estudio realizado con los precios de venta de los alimentos en 159 países indicó que la forma más accesible de patrón alimentario de EAT-Lancet tiene un costo mediano global de $2.84 por día (RIC: 2.41–3.16), en el cual la mayor parte está

representada por frutas y vegetales (31.2%); leguminosas y semillas (18.7%); carne, huevos y pescado (15.2%) y productos lácteos (13.2%) (31).

Según Hirvonen *et al.* (2022) (31), a pesar de que el costo global del patrón alimentario de EAT-Lancet representa una mínima fracción del ingreso promedio en países de mediano y alto ingreso económico, no es una opción de fácil acceso en países de bajo ingreso. Los autores advierten que el costo estimado de este patrón alimentario a nivel global sobrepasa el ingreso per cápita de 1580 millones de personas, quienes para tener acceso a los alimentos requerirían una combinación de estrategias como un mayor ingreso económico, programas de asistencia nutricional y/o menores precios de mercado (31).

Otra de las limitaciones mencionadas es que, para algunas poblaciones, el patrón alimentario de EAT-Lancet podría parecer extremo o con poca adaptabilidad a los hábitos alimentarios locales. No obstante, según Willett *et al.* (1), desde una perspectiva global, las características de este patrón, las cuales incluyen dietas vegetarianas o con modestas cantidades de proteína animal, responden a tradiciones alimentarias bien establecidas en distintas regiones del mundo. Algunos ejemplos son la dieta mediterránea, con un bajo consumo de carnes rojas y un alto consumo de plantas y aceites vegetales; o dietas tradicionales de Indonesia, México, India, China y África Occidental, en la que las carnes rojas son consumidas principalmente en ocasiones especiales o como ingredientes menores de preparaciones mixtas. Por esta razón, la flexibilidad del patrón alimentario de EAT-Lancet y las experiencias culinarias de distintas regiones del mundo podrían aportar oportunidades para aprender nuevas formas de preparar alimentos de forma saludable (1).

Autores como Beal *et al.* (2023) han mencionado como una limitación del patrón alimentario de EAT-Lancet si la adherencia de la alimentación a este patrón permitiría un adecuado cumplimiento de los requerimientos de micronutrientes esenciales (33). Esto es de especial

importancia para aquellos nutrientes que, a pesar de los programas de fortificación implementados en América Latina, son reconocidos por su prevalencia de ingesta inadecuada en algunos estratos de los países de la región, como por ejemplo el hierro, el calcio y las vitaminas B12, A y D; los cuales podrían verse afectados al disminuir el consumo de alimentos de origen animal (34).

Otra potencial limitación del patrón alimentario de EAT-Lancet es el reemplazo en la ingesta de las proteínas de origen animal con otras de origen vegetal; las cuales contienen factores antinutricionales como glucosinolatos, inhibidores de tripsina, hemaglutininas, taninos, fitatos y gosipol, que podrían afectar la digestibilidad de la proteína (35,36). No obstante, a pesar de la presencia de estos factores antinutricionales, el consumo de una dieta balanceada basada en plantas, que incluya variedad en alimentos fuente de proteína vegetal, ha sido descrita por la Academia Americana de Nutrición y Dietética como nutricionalmente adecuada, ya que proporciona suficientes cantidades de los aminoácidos esenciales (35,37,38).

Finalmente, se ha mencionado como limitación metodológica del patrón alimentario de EAT-Lancet que los umbrales de consumo sugeridos para cada grupo de alimentos están basados principalmente en datos epidemiológicos que provienen de distintas fuentes (estudios transversales, de cohorte y metaanálisis) sin unificar las conclusiones de estos estudios (4). No obstante, hasta el momento no ha sido planteada una propuesta alternativa para un patrón alimentario de referencia que contemple el componente salud y sostenibilidad, similar al planteado por EAT-Lancet (4).

3. Índice de Dieta de Salud Planetaria (IDSP) / Planetary Health Diet Index (PHDI)

En 2021, un equipo interdisciplinario liderado por Cacau propuso la creación y validación de un índice de dieta basado en las recomendaciones de la Comisión EAT-Lancet para evaluar la calidad de la alimentación y su impacto en el ambiente mediante la adherencia al patrón

alimentario de referencia: el Índice de Dieta de Salud Planetaria (IDSP). Este equipo desarrolló y validó el índice utilizando datos del Estudio Longitudinal de Salud de Adultos (ELSA-Brasil), con una cohorte multicéntrica compuesta por 15105 hombres y mujeres entre los 35 y 74 años (23).

El IDSP está basado en 16 grupos de alimentos distribuidos en 4 componentes, los cuales tienen puntaje proporcional a la energía que aportan. Los grupos de alimentos fueron propuestos como proporciones de la ingesta energética, con una puntuación de 0 a 150 puntos, tomando en cuenta el patrón de EAT-Lancet. Los 16 grupos del índice incluyen (23):

- Componente de adecuación: nueces y maní, leguminosas, frutas, total de vegetales, cereales de grano entero.
- Componente óptimo: huevos, pescado y mariscos, tubérculos, lácteos, aceites vegetales.
- Componente de razón: razón de vegetales de hoja verde oscuro al total de vegetales, razón de vegetales rojos y anaranjados al total de vegetales.
- Componente de moderación: carnes rojas, pollo y sustitutos, grasas animales y azúcares añadidos.

Cada grupo de alimentos es puntuado y ponderado según si pertenece a la categoría de componente de adecuación, óptimo, de razón o de moderación; de acuerdo con un sistema previamente desarrollado en 2015 para el Índice de Dieta Saludable Holandesa (DHDI: Dutch Healthy Eating Index) (4,39). Una de las principales ventajas del IDSP es que permite evaluar la adherencia individual al patrón alimentario de EAT-Lancet, ya que los puntajes de los componentes del índice son asignados de forma proporcional con respecto a la ingesta energética, basados en una dieta de 2500 kcal. Esto significa que la ingesta intermedia de los grupos de alimentos sí tiene un efecto en la determinación del puntaje del IDSP (4,40,41).

3.1. Asociación del IDSP con calidad de la dieta y huella ecológica

Cacau *et al.* (23) validaron la capacidad del IDSP para identificar patrones alimentarios saludables y sostenibles, identificando la asociación del IDSP con la calidad de la dieta y la huella ecológica de la siguiente manera:

- Asociación positiva del IDSP con la calidad de la dieta: determinada mediante el Índice de Alimentación Brasileña Saludable (BHEI-R: Brazilian Healthy Eating Index Revised). Este análisis determinó que a mayor puntaje de IDSP, mayor puntaje del índice de calidad de la dieta (β: 0.47, IC 95% [0.45, 0.49], valor-*p* <0.001) (23,42,43).
- Asociación negativa del IDSP con la huella ecológica: calculada como la emisión de GEI (en equivalentes de dióxido de carbono - CO2eq) correspondiente al total de alimentos consumidos por cada sujeto (44). Este análisis determinó que a mayor puntaje del IDSP, menor emisión de GEI y menor huella ecológica (β: -1.30, IC 95% [-1.56, -1.05], valor-*p* <0.001) (23).

3.2. Adherencia al IDSP y resultados de salud

Al utilizar el IDSP como instrumento para medir la adherencia al patrón alimentario de EAT-Lancet en la cohorte del ELSA-Brasil, Cacau *et al.* (2021) encontraron dietas más saludables y sostenibles (identificadas como puntajes del IDSP significativamente mayores) en personas adultas mayores, en los no fumadores y en aquellas personas con actividad física de moderada a intensa (23,40).

Los análisis posteriores del mismo estudio determinaron que los sujetos con mayor adherencia al IDSP (quintil 5) presentaron 24% menos probabilidad de presentar exceso de peso (OR: 0.76, IC 95% [0.67, 0.85]) y 27% menos probabilidad de tener circunferencia de cintura aumentada (OR: 0.73, IC 95% [0.64, 0.83]), en comparación con individuos con baja adherencia al IDSP

(quintil 1) (45). Estos resultados sugieren que una mayor adherencia al IDSP, y por ende mayor adherencia al patrón alimentario de EAT-Lancet, podría favorecer una disminución en los indicadores antropométricos de exceso de peso como el índice de masa corporal y la circunferencia de cintura. Por otro lado, un estudio posterior, también realizado en Brasil con datos de la Encuesta Nacional de Hogares 2017-2018 no encontró asociación entre una mayor adherencia al IDSP y el exceso de peso (46).

4. Justificación del estudio

El cambio climático tiene consecuencias económicas que pueden favorecer un aumento de la inseguridad alimentaria y afectar la calidad de la dieta. Actualmente más de 820 millones de personas a nivel mundial no cuentan con suficiente cantidad de alimentos para satisfacer sus demandas nutricionales y una cantidad mayor presenta un patrón alimentario de baja calidad, que contribuye a un aumento de la prevalencia de obesidad y enfermedades no transmisibles (1). Una forma de mitigar estas consecuencias del cambio climático es modificar la forma en que se producen y consumen los alimentos (4).

Muchos sistemas y procesos ambientales están sobrepasando los límites de seguridad para cumplir con la producción de alimentos, por lo que autores como Willett *et al.* (1) proponen una urgente transformación global del sistema alimentario, es decir, del conjunto de actividades involucradas en la producción, procesamiento, transporte, consumo y gestión de los residuos de los alimentos (13,47). De esta forma se ha propuesto la adopción de un sistema alimentario sostenible que garantice la seguridad alimentaria y la nutrición para todos, pero que al mismo tiempo no comprometa las bases económicas, sociales y ambientales para las futuras generaciones (47).

A raíz de la ausencia de objetivos científicos claros para alcanzar dietas saludables a partir de sistemas alimentarios sostenibles, en 2019 se crea la Comisión EAT-Lancet, conformada por un grupo de 37 científicos de 16 países con experiencia en salud, agricultura, ciencias políticas y sostenibilidad ambiental (1). Esta comisión tuvo como propósito desarrollar objetivos científicos globales basados en la evidencia disponible, para proponer un patrón alimentario saludable dentro de los límites ambientales de producción de alimentos. Como producto del trabajo de esta comisión se creó el patrón alimentario de EAT-Lancet, también conocido como "Dieta de Salud Planetaria" (1,23). En general el patrón de EAT-Lancet contiene recomendaciones basadas en el consumo de vegetables, frutas y granos enteros; así como un consumo reducido de carne, pescado, huevos, cereales refinados y tubérculos (1).

Desde entonces han sido creados distintos índices o instrumentos para evaluar la adherencia del consumo de alimentos al patrón alimentario de EAT-Lancet. En el 2021, Cacau *et al.* (23) propusieron el Índice de Dieta de Salud Planetaria (IDSP o PHDI por sus siglas en inglés), el cual está basado en el consumo de 16 grupos de alimentos y su aporte a la ingesta energética total, permitiendo evaluar de forma indirecta la calidad de la alimentación y su impacto en el ambiente, de acuerdo con el patrón saludable propuesto por EAT-Lancet. Este índice fue validado en Brasil utilizando datos del Estudio Longitudinal de Salud del Adulto (ELSA-Brasil 2010-2011), mostrando alta validez y confiabilidad para identificar patrones alimentarios saludables y sostenibles (23).

Hasta el momento, se han realizado pocos estudios para evaluar la adherencia de la alimentación de la población al patrón alimentario de EAT-Lancet en países de la región latinoamericana (23,45). Utilizando datos del Estudio Latinoamericano de Nutrición y Salud (ELANS, 2016) recolectados en 8 países (Argentina, Brasil, Chile, Perú, Colombia, Costa Rica,

Ecuador y Venezuela), esta investigación realizará un acercamiento sobre el tema. La ejecución de un estudio de esta índole representa un insumo oportuno para determinar el impacto potencial de la alimentación de la población urbana latinoamericana sobre el ambiente y la calidad de la dieta.

Esta propuesta de investigación resulta oportuna, pues permitirá evidenciar si la adherencia al patrón alimentario de referencia de EAT-Lancet es una alternativa para conducir el planteamiento de políticas de salud pública y producción de alimentos en beneficio de un sistema alimentario más saludable y sostenible en los países de América Latina, procurando la seguridad alimentaria de la región, de acuerdo con los ODS de las Naciones Unidas y el Acuerdo de París para el Cambio Climático (19,20).

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ARTÍCULO 1

Adherence to the EAT-Lancet Diet and its Association with Micronutrient Inadequacy in the Urban Population of Eight Latin American Countries: Results from the Latin American Study of Nutrition and Health

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Abstract

The EAT-Lancet Commission proposed a dietary framework aimed at reducing the ecological footprint of diets worldwide, but research on adherence to this diet in Latin America is limited. This study aimed to describe the adherence of urban diets in eight Latin American countries to the EAT-Lancet diet and its association with micronutrient intake inadequacy. This cross-sectional study analyzed baseline data from the Latin American Study of Nutrition and Health, involving 6835 participants from Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, and Venezuela. Data collection included two 24-hour recalls, alongside socio-demographic variables. Usual dietary intake was estimated via the Multiple Source Method and micronutrient inadequacy was evaluated with the Nutrient Adequacy Ratio. The Planetary Health Diet Index (PHDI; which ranged between 0 to 150) assessed adherence to the EAT-Lancet diet. Adherence was low (29.7%) across the region, with an average PHDI score of 44.6 ± 9.2 points. Costa Rica had the highest adherence (32.9%), while Argentina had the lowest (25.8%). Older participants, those overweight/obese, and those with higher socioeconomic status, education, and physical activity had higher adherence. Higher adherence was associated with increased inadequacy risks for cobalamin, vitamin D, and calcium, but decreased risks for folate, vitamin C, magnesium, and zinc. The study suggests that low adherence may stem from a disconnect between culturally ingrained dietary habits and the EAT-Lancet recommendations, which are primarily informed by nutritional epidemiology and environmental considerations. Recognizing and honoring diverse food cultures is crucial for promoting dietary practices that support human health and environmental sustainability.

Keywords

EAT-Lancet diet, PHDI, Latin America, ELANS, sustainable diets, micronutrient inadequacy

1. Introduction

Global food systems significantly contribute to harmful effects on the environment (1,2) and the development of non-communicable diseases related to poor diet globally (3,4). Therefore, over recent decades, there has been increasing recognition of the importance of a radical transformation of food systems to ensure that nutritious, safe, affordable, and sustainable diets are available to all (5,6,4,7). This transformation represents a crucial pathway to decreasing mortality rates associated with the food system (3), as well as reducing greenhouse gas emissions, and water and land use (1,8,9).

To promote a model of production and consumption of healthier food with lower environmental impact, the EAT-Lancet Commission on "Healthy Diets from Sustainable Food Systems" proposed in 2019 a dietary pattern that seeks human and environmental health simultaneously under the principle of "One Health" (1,10,11). This pattern is known as the "Planetary Health Diet" and proposes the first scientific targets for consuming a healthy diet within the environmental limits of food production (1,10). Overall, this dietary pattern involves 1) high consumption of vegetables, fruits, whole grains, legumes, nuts, seeds, and unsaturated vegetable oils; 2) low to moderate consumption of dairy, seafood, chicken, and eggs; and 3) low to minimal consumption of red meat, processed meat, added sugar, refined grains, and starchy vegetables (1).

The dietary pattern proposed by EAT-Lancet has been compared with other healthy eating guidelines and patterns from different regions of the world (12–15). These comparisons have shown that, depending on the country and culture, compliance with the EAT-Lancet reference diet may require significant changes to an individual's eating habits. Furthermore, the nutritional quality of the diet is not always guaranteed in different contexts (16).

Various studies have found favorable results when associating adherence to the EAT-Lancet dietary pattern with lower risks of type 2 diabetes (17,18), cardiovascular disease morbidity and mortality (18–21), overweight/obesity (22,23), and cancer (24); as well as better global cognitive functioning and slower cognitive decline among cognitively healthy older adults (25), among others. Some studies (16,26), but not all (27,28), have shown a lower risk of iron, fiber, potassium, folate equivalents, and vitamin C inadequacy in participants with higher adherence to the reference diet. Since the EAT-Lancet diet includes large amounts of pulses, dark green leafy vegetables, and vitamin A-rich fruits and vegetables, it has been evidenced that the estimated intakes of folate and vitamin A are essentially adequate for adults and women of reproductive age. However, the estimated cobalamin, calcium, iron, and zinc intakes are below the recommended nutrient intakes. This could be because the EAT-Lancet diet involves limited consumption of dairy and meat products, which are rich sources of these nutrients (27). In addition, iron and zinc inadequacies and deficiencies are common among populations consuming high amounts of phytates and few animal-sourced foods (28,29).

Limited research has been conducted to assess adherence to the EAT-Lancet dietary pattern in Latin America thus far. The primary investigations in this area have focused on Brazil, utilizing the Planetary Health Diet Index (PHDI) (11,30–32), and in Mexico, employing the Healthy and Sustainable Dietary Index (HSDI) (33). Despite the utilization of distinct indexes and methodologies to evaluate adherence to the EAT-Lancet dietary pattern, findings from both studies suggest a low level of adherence to this dietary pattern among populations in both countries.

Latin America faces an epidemiological panorama characterized by a double burden of communicable and non-communicable diseases (34). Adding to this challenge is the region's vulnerability to the impacts of global warming, which puts even more pressure on health systems

and threatens the sustainability of food production. To address these pressing issues, it is imperative to implement strategies that strengthen resilience and sustainability within Latin American food systems. Among these strategies, adherence to the EAT-Lancet dietary pattern stands out. By studying adherence to the EAT-Lancet diet, valuable insights can be gained to improve health, mitigate environmental degradation resulting from food production, and pave the way for lasting sustainability in Latin America. However, it has been suggested that it should not necessarily be assumed that a planet-healthy diet provides an adequate intake of nutrients, particularly minerals such as iron, calcium, and zinc, to meet the nutritional demands of the population over two years of age (27).

This study aimed to describe the adherence of the urban population's diet in eight Latin American countries to the EAT-Lancet reference dietary pattern and to determine if there is an association between this adherence and micronutrient intake inadequacy. This research introduces a new perspective on the topic in the Latin American region, using data from the Latin American Study of Nutrition and Health/Estudio Latinoamericano de Nutrición y Salud (ELANS) conducted in eight countries (35).

2. Methods and Materials

2.1. Sample and setting

This cross-sectional study used the baseline data from the ELANS, whose design and sampling are described in detail elsewhere (35–37). The ELANS is an urban representative household-based multinational study conducted from September 2014 to August 2015; involving 9218 participants from eight Latin American countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, and Venezuela. The ELANS was designed to assess anthropometric measures,

nutritional intakes, and physical activity levels. It used a random complex multistage sample, stratified by geographical region, sex, age, and socioeconomic status (37). Misreported energy intake (EI) was previously calculated for the ELANS study by Previdelli *et al.* (38), following the methodology used by McCrory *et al.* (39). After excluding cases of misreported EI from the overall ELANS sample, the final plausible sample of this study comprised 6835 men and women, including adolescents (aged 15-18 years) and adults aged 19 to 65 years.

The ELANS protocol received approval from the Western Institutional Review Board (#20140605) and was registered on clinicaltrials.gov (#NCT02226627). Additionally, it was approved by the local ethics committees in each respective country. Before participating in the survey, all participants provided their informed consent/assent. Moreover, this study protocol was approved on June 21st, 2023, by the Scientific and Ethics Committee of the Costa Rican Institute for Research and Education on Nutrition and Health (INCIENSA) (IC-2023-02).

2.2. Data collection

2.2.1. Demographic and socioeconomic status variables

A questionnaire was used to collect data on sex, age, and years of education. A standardized 3-level system was established to classify educational levels: basic for non-formal and complete/incomplete primary school; medium for complete/incomplete secondary school; and high for university studies or superior (40). The socioeconomic status (SES) was evaluated through a questionnaire utilizing a format specific to each country, designed to adhere to national legislative standards or recognized local layouts. It was classified as low, middle, and high status, based on the national indexes of each country (35,40).

2.2.2. Anthropometric assessment

Height and weight measurements, conducted by trained nutritionists adhering to standardized protocols (41), were used to calculate the body mass index (BMI). For participants under 18 years old, the BMI was categorized based on z-score cut-off criteria for age and sex as recommended by the World Health Organization (WHO) (42). For individuals aged 18 years and older, BMI was categorized as follows: underweight, BMI <18.5 kg/m²; normal weight, BMI 18.5-24.9 kg/m²; overweight, BMI 25.0-29.9 kg/m²; and obese, BMI ≥30.0 kg/m² (43).

2.2.3. Physical activity level assessment

The International Physical Activity Questionnaire (IPAQ) was used to assess participants' physical activity level (PAL) (35). IPAQ data helped estimate each participant's total energy expenditure (TEE) from physical activities. TEE was calculated using age, height, weight, and overall activity level, based on a predictive equation from the Institute of Medicine; and was also required for the EI misreporters identification (37,44). PAL was determined by summing PAL values from individual activities. Walking, moderate, and vigorous physical activities (measured in min/week) were evaluated using IPAQ's standardized methods to classify PAL as low, moderate, or high (37,45).

2.2.4. Dietary assessment

The ELANS dietary assessment included two household visits, with an interval of ≤8 days between visits. Trained interviewers conducted a 24-hour dietary recall (24HR) during each visit to record all food and beverage consumption from the prior day, including both weekdays and weekends with a proportional distribution across the sample, ensuring representation of day-to-day intake variations. Trained nutritionists supervised the recalls and converted the recorded measures into grams and milliliters (37).

All locally sourced and traditional foods documented were standardized using a USDA composition table, accounting for nutritional equivalency. Mandatory food fortification regulations in each respective country were also considered (37,40). Energy and micronutrient values were derived using the Nutrition Data System for Research (NDS-R) software version 2013 (46).

2.2.4.1. Usual dietary intake

The Multiple Source Method (http://mss.dife.de/tps/en) (47,48) was employed to estimate the usual intake of the 16 components of the Planetary Health Diet Index (PHDI), energy, and various nutrients for the plausible ELANS sample, including: carbohydrates, added sugars, dietary fiber, protein, total fat, monounsaturated fat, polyunsaturated fat, saturated fat, trans fat, cholesterol, nine vitamins (thiamin [vitamin B1], riboflavin [vitamin B2], niacin [vitamin B3], pyridoxine [vitamin B6], folate equivalents [vitamin B9], cobalamin [vitamin B12], vitamin C, vitamin A, and vitamin D), and five minerals (calcium, iron, magnesium, zinc, and sodium). Furthermore, usual nutrient intakes were energy-adjusted using the nutrient residual model proposed by Willett *et al.* (49). This adjustment aimed to mitigate bias in estimating nutrient intake due to its significant association with energy intake.

2.2.4.2. Nutrient adequacy

The Nutrient Adequacy Ratio (NAR) was computed for protein and 13 micronutrients based on the individual's usual intake compared to the Estimated Average Requirement (EAR) for their corresponding sex and age group, following guidelines from the National Academy of Medicine of the United States (50). Nutritional adequacy for a specific nutrient was determined as adequacy, NAR value ≥1; inadequacy, NAR value <1. The EAR served as the appropriate reference intake for evaluating group adequacy since all the criteria outlined by the Institute of Medicine (IOM) to

assess nutrient adequacy by the cut-point method were met (51). Therefore the equation (1) was applied (52):

$$NAR = \left(\frac{Usual\ dietary\ intake_{nutrient}}{EAR_{nutrient}}\right) \times 100 \quad (1)$$

2.3. Planetary Health Diet Index assessment

The Planetary Health Diet Index (PHDI) was used to assess adherence to the EAT-Lancet dietary recommendations. This diet index includes all EAT-Lancet food groups and employs a gradual scoring system, assessing components based on consumption quantity (11,31). Scores in the PHDI are derived from a caloric intake ratio, computed by dividing the sum of calories from all foods within a PHDI component by the total calories from all foods (except alcoholic beverages, given their exclusion in the reference diet) (1,11).

The PHDI includes 16 components into four categories: adequacy (nuts and peanuts, fruits, legumes, vegetables, whole grain cereals), optimum (eggs, dairy products, fish and seafood, tubers and potatoes, vegetable oils), ratio (dark green vegetables/total vegetables, red-orange vegetables/total vegetables), and moderation (red meat, poultry, animal fats, added sugars). Adequacy, optimum, and moderation categories score from 0 to 10 points, while components in the ratio category score from 0 to 5 (11). The score for each component is determined based on the relative energy intake provided by that component according to the EAT-Lancet dietary pattern and the PHDI index (11).

To illustrate the relative contribution of each component, we used the following criteria to classify them: high relative contribution, ≥50% of available points by component; intermediate relative contribution, 20 – 49% of available points by component; low relative contribution, <20% of available points by component. Total PHDI score ranges from 0 to 150, with higher scores indicating greater adherence to the EAT-Lancet dietary pattern (11,53), and adherence to the

reference diet can be estimated from the PHDI score divided by the total possible PHDI points (32). Detailed information on PHDI development, scoring criteria, cutoff points, validity, and reliability can be found elsewhere (11).

All foods consumed by the ELANS plausible sample were initially disaggregated to their ingredient level, before classifying the ingredients into the 16 PHDI components, following the methodology outlined by Cacau *et al.* for extracting PHDI components from food consumption data (11). Furthermore, highly processed foods underwent careful disaggregation to estimate their content of added sugar, vegetable oils, and animal (saturated) fat using the USDA composition table. This ensures that each of these components was accurately placed within the corresponding categories of the PHDI, thus avoiding under or overestimation. This process underwent review by four trained nutritionists.

2.4. Statistical analyses

Continuous variables were presented as means ± standard deviations (SD) with 95% confidence intervals (95% CI), while categorical variables were expressed as frequencies (%). The Shapiro-Wilk test was employed to assess the normal distribution of continuous variables. Comparisons of PHDI scores among groups based on sex, age group, country, SES, educational level, PAL, and weight status were conducted using the Mann-Whitney test or Kruskal-Wallis test, followed by the Bonferroni procedure for multiple-comparison correction.

Generalized linear regression models (GLM) with gamma distribution and Log link function were utilized to evaluate the association between relative adherence to the PHDI and usual energy and nutrient intakes. The gamma distribution with the Log link function was preferred since energy and nutrient intakes can only take positive values (54). Furthermore, multivariate Poisson regression models with robust variance were employed to examine the association between relative

adherence to the PHDI and intake inadequacy of protein and 13 micronutrients with EAR. This choice was made over logistic regression to avoid the usual overestimation of the risk product of the logistic regression's odds ratio, particularly in cross-sectional studies and high-prevalence events (≥10%) (55–58).

GLM and Poisson models were adjusted for sex, age, total energy intake, SES, and country. The association trend was evaluated using orthogonal polynomial contrast for linear trend among PHDI quintiles within each model. Non-multicollinearity within each model was assessed using the variance inflation factor. Additionally, over-dispersion was evaluated in the Poisson models.

All tests were conducted with a two-tailed approach, and p-values < 0.05 were considered statistically significant. Data analysis was performed using Stata software version 14.1 (2015, College Station, TX, USA) (59) and IBM SPSS® (version 27, IBM Corp) (60).

3. Results

3.1. General characteristics and Planetary Health Diet Index (PHDI) score of the study participants

The average age of the sample was 36.0 ± 14.1 y (data not shown). The majority of the study sample was 51.8% female, 83.0% aged 19-59 y, 52.2% with low SES, 60.6% with a basic education level, 58.9% with low PAL, and 60.0% of the participants were classified as overweight/obese (Table 1).

The average PHDI score of the sample was 44.6 ± 9.2 points (out of 150), and the distribution of the PHDI can be found in the Supplementary materials (Figure S1). The PHDI score was significantly higher in the 19-59 y and the 60-65 y age groups compared to the adolescents' group (44.7 ± 9.2 and 45.6 ± 9.4 vs 43.7 ± 9.4 points, respectively, p=0.006). There were significant

differences in PHDI scores among countries (p<0.001). Costa Rica had the highest score (49.3 ± 9.0), followed by Brazil (47.6 ± 9.1), Ecuador (46.5 ± 8.2), and Venezuela (45.1 ± 8.6). Chile (44.0 ± 8.8) and Peru (43.9 ± 8.4) had similar scores (p>0.05) and both ranked fifth place. Colombia came sixth (42.0 ± 8.6), while Argentina had the lowest score (38.7 ± 8.6) (Table 1, Figure S2).

Regarding SES and educational level, participants with high SES (45.9 ± 8.9 points) and with medium (45.2 ± 9.2 points) and high (45.3 ± 9.0 points) educational levels had significantly slightly higher PHDI scores (p<0.001), compared to participants with middle (44.9 ± 9.6 points) and low (44.2 ± 9.0 points) SES and with basic education (44.3 ± 9.3 points) (Table 1). Participants with high PAL had significantly higher PHDI scores than participants with low or moderate PAL (45.4 ± 9.8 vs 44.4 ± 9.1 and 44.45± 9.1 points, respectively; p=0.037). Also, participants with overweight/obesity showed a significantly higher PHDI score than those non-overweight/obese (44.9 ± 9.1 vs 44.2 ± 9.4 points, respectively; p=0.005). There were no significant differences in the PHDI between men and women (p=0.558) (Table 1).

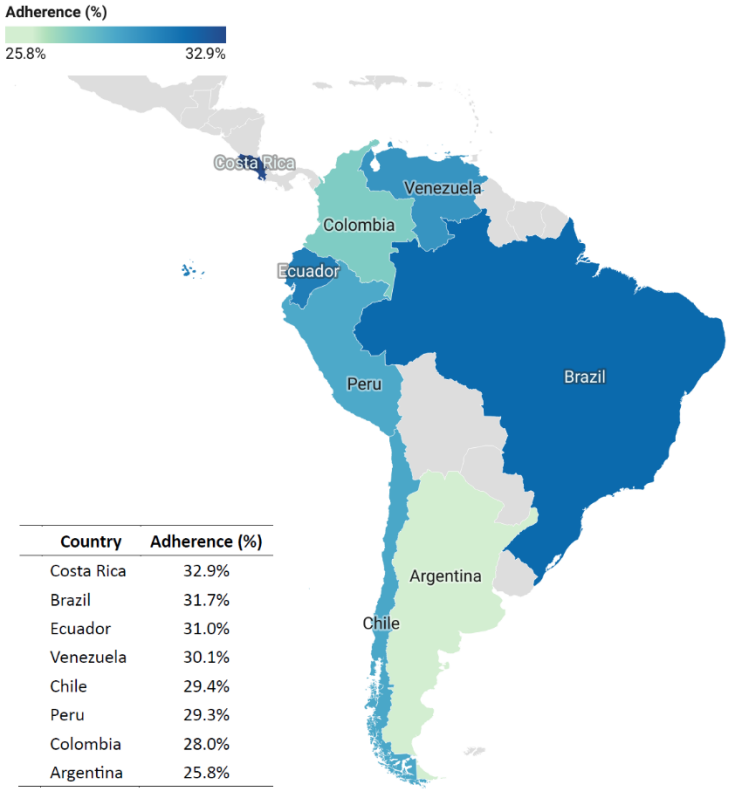
Table 1. Planetary Health Diet Index (PHDI) among subgroups of participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6835).

Characteristic	Total		PHDI score			
	n	%	Mean	SD	95% CI	*p*-value[1]
Overall	6835	100.0	44.6	9.2	44.4 – 44.8	-
Sex						
Men	3294	48.2	44.7	9.5	44.4 – 45.0	0.558
Women	3541	51.8	44.6	9.0	44.3 – 44.9	
Age group						
15 – 18 y	698	10.2	43.7[a]	9.4	43.0 – 44.4	0.006
19 – 59 y	5675	83.0	44.7[b]	9.2	44.4 – 44.9	
60 – 65 y	462	6.8	45.6[b]	9.4	44.7 – 43.4	
Country						
Argentina	896	13.1	38.7[a]	8.6	38.2 – 39.3	<0.001
Brazil	1471	21.5	47.6[b]	9.1	47.1 – 48.1	
Chile	629	9.2	44.0[c]	8.8	43.3 – 44.7	
Colombia	901	13.2	42.0[d]	8.6	41.4 – 42.5	
Costa Rica	570	8.3	49.3[e]	9.0	48.6 – 50.1	
Ecuador	582	8.5	46.5[f]	8.2	45.9 – 47.2	
Peru	890	13.0	43.9[c]	8.4	43.4 – 44.5	
Venezuela	896	13.1	45.1[g]	8.6	44.6 – 45.7	
Socioeconomic status						
Low	3565	52.2	44.2[a]	9.0	43.9 – 44.5	<0.001
Middle	2597	38.0	44.9[b]	9.6	44.5 – 45.2	
High	673	9.8	45.9[c]	8.9	45.2 – 46.6	
Educational level						
Basic	4145	60.6	44.3[a]	9.3	44.0 – 44.5	<0.001
Medium	2041	29.9	45.2[b]	9.2	44.8 – 45.6	
High	649	9.5	45.3[b]	9.0	44.6 – 45.9	
Physical activity level						
Not reported	152	2.2	45.4	10.2	43.7 – 47.0	-
Low	4024	58.9	44.5[a]	9.1	44.2 – 44.8	0.037
Moderate	1832	26.8	44.5[a]	9.1	44.1 – 44.9	
High	827	12.1	45.4[b]	9.8	44.7 – 46.1	
Weight status[2]						
Non-overweight/obese	2731	40.0	44.2	9.4	43.9 – 44.6	0.005
Overweight/obese	4104	60.0	44.9	9.1	44.6 – 45.2	

[1]*p*-value corresponds to the Mann-Whitney or Kruskal-Wallis tests comparing groups. Labeled mean values within the same variable and without a common letter differ ($p<0.05$). [2]Weight status according to BMI categories. SD: standard deviation.

The average adherence to the EAT-Lancet dietary pattern in the urban population of the 8 Latin American countries was 29.7%, and the adherence by country ranged from 32.9% in Costa Rica to 25.8% in Argentina (Figure 1).

Figure 1. Adherence[1] to the EAT-Lancet dietary pattern in the urban population of eight Latin American countries. Latin American Study of Nutrition and Health (ELANS, 2016) (n=6835).



Country	Adherence (%)
Costa Rica	32.9%
Brazil	31.7%
Ecuador	31.0%
Venezuela	30.1%
Chile	29.4%
Peru	29.3%
Colombia	28.0%
Argentina	25.8%

[1]Adherence is expressed by the percentage of maximum achievable in the Planetary Health Diet Index (PHDI) score. Map created with ©2024 Datawrapper.

3.2. Planetary Health Diet Index (PHDI) components score

The overall descriptive analysis of the PHDI components score showed the average contribution of each component to the EAT-Lancet dietary pattern adherence (Table 2). While there were components with high relative contribution (≥50% of available points by component) to the adherence, as ReV/total ratio (74.6%), fruits (72.0%), vegetable oils (64.0%), and vegetables

(57.8%); other components showed low relative contribution (<20% of available points by component) to the adherence, as nuts and peanuts (3.1%), whole cereals (3.4%), and DGV/total ratio (9.6%), among others. Most PHDI components had an intermediate relative contribution (20 – 49% of available points by component) to adherence (Table 2).

Table 2. Descriptive analysis of the Planetary Health Diet Index (PHDI) components score among participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6835).

PHDI Components	Maximum points	Score		Relative contribution by component (%)
		Mean	SD	
Adequacy components				
Nuts and peanuts	10	0.31	1.04	3.1
Legumes	10	2.39	2.32	23.9
Fruits	10	7.20	3.00	72.0
Vegetables	10	5.78	2.60	57.8
Whole cereals	10	0.34	0.68	3.4
Optimum components				
Eggs	10	2.28	3.36	22.8
Fish and seafood	10	3.67	2.08	36.7
Tubers and potatoes	10	3.02	3.56	30.2
Dairy	10	4.88	3.14	48.8
Vegetable oils	10	6.40	1.71	64.0
Ratio components				
DGV / Total ratio[1]	5	0.48	0.80	9.6
ReV / Total ratio[2]	5	3.73	1.01	74.6
Moderation components				
Red meat	10	0.02	0.21	0.2
Chicken and substitutes	10	2.11	2.50	21.1
Animal fats	10	1.82	2.71	18.2
Added sugars	10	0.19	0.96	1.9
Total score	0-150	44.62	9.24	29.7

[1]DGV/total ratio: dark green vegetables/total ratio multiplied by 100. [2]ReV/total ratio: red and orange vegetables/total ratio multiplied by 100. SD: standard deviation.

Additional details regarding the descriptive analysis of the average PHDI component scores by country are available in the Supplementary materials (Table S1). All 16 PHDI components showed significant score differences among countries, with some components exhibiting higher

variability. For instance, in the adequacy components Costa Rica had the highest score for legumes (4.76 ± 2.84), while Argentina had the lowest (0.78 ± 0.80). All countries scored less than 80% of available points for fruits and vegetables. Chile and Colombia had the highest fruit scores (7.91 ± 2.76 and 7.73 ± 2.86, respectively), while Argentina had the lowest (6.14 ± 3.12). For vegetables, scores ranged from 7.52 ± 2.20 in Ecuador to 4.62 ± 2.50 in Brazil. Regarding the moderation components, all countries showed low scores for red meat, chicken and substitutes, animal fats, and added sugars; indicating that typical consumption of these food groups highly exceeds the EAT-Lancet dietary pattern recommendations (Table S1).

3.3. Association between adherence to the Planetary Health Diet Index (PHDI) and usual energy/nutrient intakes

Overall, after for sex, age, SES, and country, the high adherence to the PHDI (5th PHDI quintile) showed a positive and significant association with the intake of carbohydrates, dietary fiber, polyunsaturated fat, thiamin, pyridoxine, folate equivalents, vitamin C, vitamin A, iron, magnesium, and zinc (p-trend<0.05) (Table 3). On the other hand, it had a negative and significant association with protein, total fat, saturated fat, trans fat, cholesterol, riboflavin, niacin, cobalamin, vitamin D, and calcium intakes (p-trend<0.05). There were no significant associations between the high adherence to the PHDI and the intake of energy, added sugars, monounsaturated fat, and sodium intakes (p-trend>0.05) (Table 3). Additional graphs, illustrating the association between the high adherence to the PHDI and the intake of energy and some nutrients, are shown in the Supplementary materials (Figure S3 and S4).

Table 3. Association between high adherence to the Planetary Health Diet Index (PHDI) and usual energy/nutrient intakes among participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6835).

Nutrient	β[1]	95% CI	*p*-value[2]	*p*-trend[3]
Energy (kcal)	-0.0158	-0.0318 – 0.0003	0.054	0.087
Macronutrients				
Carbohydrates (g)	0.0313	0.0213 – 0.0414	<0.001	<0.001
Added sugars (%TEI)	-0.0014	-0.0031 – 0.0004	0.124	0.177
Dietary fiber (g)	0.2495	0.2273 – 0.2717	<0.001	<0.001
Protein (g)	-0.0279	-0.0403 – -0.0156	<0.001	<0.001
Total fat (g)	-0.0203	-0.0331 – -0.0076	0.002	0.011
Saturated fat (g)	-0.0989	-0.1161 – -0.0818	<0.001	<0.001
Monounsaturated fat (g)	-0.0081	-0.0234 – 0.0073	0.304	0.689
Polyunsaturated fat (g)	0.0691	0.0516 – 0.0866	<0.001	<0.001
Trans fat (g)	-0.0324	-0.0610 – -0.0039	0.026	0.008
Cholesterol (mg)	-0.2025	-0.2247 – -0.1809	<0.001	<0.001
Micronutrients				
Vitamins				
Thiamin (mg)	0.0530	0.0398 – 0.0661	<0.001	<0.001
Riboflavin (mg)	-0.0634	-0.0798 – -0.0470	<0.001	<0.001
Niacin (mg)	-0.0133	-0.0273 – -0.0007	0.041	0.039
Pyridoxine (mg)	0.0434	0.0268 – 0.0601	<0.001	<0.001
Folate equivalents (µg)	0.1100	0.0937 – 0.1264	<0.001	<0.001
Cobalamin (µg)	-0.0364	-0.0682 – -0.0046	0.025	0.010
Vitamin C (mg)	0.4308	0.3731 – 0.4885	<0.001	<0.001
Vitamin A (µg)	0.0481	0.0094 – 0.0869	0.015	0.036
Vitamin D (µg)	-0.2205	-0.2623 – -0.1788	<0.001	<0.001
Minerals				
Calcium (mg)	-0.1092	-0.1355 – -0.0829	<0.001	<0.001
Iron (mg)	0.0781	0.0634 – 0.0929	<0.001	<0.001
Magnesium (mg)	0.1249	0.1119 – 0.1378	<0.001	<0.001
Zinc (mg)	0.0547	0.0139 – 0.0954	0.009	0.027
Sodium (mg)	0.0154	-0.0052 – 0.0360	0.144	0.106

Generalized linear regression model: [1]Coefficient of energy/nutrient intake for the 5th PHDI quintile vs the 1st PHDI quintile (baseline); adjusted for sex, age, socioeconomic status, and country (gamma distribution with Log link function). [2]*p*-value corresponds to the Wald test for the 5th PHDI quintile as a category of the PHDI within each model. [3]*p*-value for trend corresponds to the linear trend among PHDI quintiles within each model.

PHDI quintiles: min–max score / 1st: 13.4–36.7; 2nd: 36.8–42.0; 3rd: 42.1–46.8; 4th: 46.9–52.3; 5th: 52.4–82.8. Usual nutrient intakes were energy-adjusted by the nutrient residual model. %TEI: Percentage of Total Energy Intake.

3.4. Association between adherence to the Planetary Health Diet Index (PHDI) and nutrient inadequacy

Regarding nutrient inadequacy, after adjusting for sex, age, total energy intake, SES, and country, individuals in the 5th PHDI quintile (with high adherence to the EAT-Lancet dietary pattern) had 95.9%, 1.0%, and 11.6% significantly higher risks of nutrient inadequacy of cobalamin, vitamin D, and calcium, respectively (p-trend<0.05); compared to those participants in the 1st PHDI quintile (with low adherence). At the same time, individuals in the 5th PHDI quintile also had 56.9%, 52.1%, 12.0%, and 17.4% significantly lower risks of nutrient inadequacy of folate equivalents, vitamin C, magnesium, and zinc, respectively (p-trend<0.05); compared to those participants in the 1st PHDI quintile. There was no significant association between the high relative adherence to the PHDI and the nutrient inadequacy of protein, thiamin, riboflavin, niacin, pyridoxine, vitamin A, and iron (Table 4).

Table 4. Association between high adherence to the Planetary Health Diet Index (PHDI) and nutrient inadequacy of protein and 13 micronutrients among participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6835).

Nutrient	PR[1]	95% CI	*p*-value[2]	*p*-trend[3]
Protein	1.000	0.638 – 1.567	1.000	0.813
Vitamins				
Thiamin	0.833	0.316 – 2.193	0.712	0.823
Riboflavin	1.394	0.969 – 2.005	0.074	0.059
Niacin	0.255	0.047 – 1.374	0.112	0.054
Pyridoxine	0.758	0.552 – 1.040	0.086	0.040
Folate equivalents	0.431	0.254 – 0.730	0.002	<0.001
Cobalamin	1.959	1.327 – 2.894	0.001	0.002
Vitamin C	0.479	0.434 – 0.528	<0.001	<0.001
Vitamin A	0.982	0.914 – 1.056	0.624	0.459
Vitamin D	1.010	1.001 – 1.019	0.030	0.023
Minerals				
Calcium	1.116	1.087 – 1.146	<0.001	<0.001
Iron	0.441	0.159 – 1.224	0.116	0.189
Magnesium	0.880	0.856 – 0.906	<0.001	<0.001
Zinc	0.826	0.695 – 0.983	0.031	0.013

Multivariate Poisson regression with robust variance analysis: [1]Prevalence ratio of nutrient inadequacy for the 5th PHDI quintile vs the 1st PHDI quintile (baseline); adjusted for sex, age, total energy intake, socioeconomic status, and country. [2]*p*-value corresponds to the Wald test for the 5th PHDI quintile as a category of the PHDI within each model. [3]*p*-value for trend corresponds to the linear trend among PHDI quintiles within each model.

PHDI quintiles: min–max score / 1st: 13.4–36.7; 2nd: 36.8–42.0; 3rd: 42.1–46.8; 4th: 46.9–52.3; 5th: 52.4–82.8. Nutrient inadequacy was defined as a Nutrient Adequacy Ratio (NAR) <1.

4. Discussion

This study aimed to assess the adherence of urban populations in eight Latin American countries to the EAT-Lancet dietary pattern and the association between this adherence and the inadequacy of micronutrient intake. As a result, we observed a low average adherence to the EAT-Lancet reference pattern in urban areas of Latin America, which aligns with the evidence found in previous studies in the Latin American region, specifically in Brazil (32) and Mexico (33); as well as studies in the United States (26), Europe (16,17,19,61,62), and Africa (63). Despite the variation in tools used to determine adherence in most studies (except those conducted in Brazil, which also

used the PHDI), the evidence consistently shows low adherence to the EAT-Lancet reference diet. This information provides valuable insights into adherence to healthy and sustainable dietary patterns in the Latin American region.

In our study, higher adherence to the EAT-Lancet dietary pattern, defined as higher PHDI scores, was observed in individuals of older age, higher education, better socioeconomic status, and greater physical activity, as well as in participants who were overweight or obese. Some of these findings are consistent with the first study conducted by Cacau *et al.* in Brazil, which also used the PHDI on data from the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil) (11). This study found that participants with higher adherence to the reference diet were older, more physically active, and without excess weight (30). However, another subsequent study involving a representative sample from all Brazilian regions found a lower average adherence (30.6%) than the previous study (32). The authors suggested that this discrepancy could be attributed to the initial study's sample having higher income, educational level, and overall living conditions (32).

In contrast to our results, a study in Mexico using data from the National Health and Nutrition Survey (ENSANUT 2018-2019) found that men had lower adherence to the EAT-Lancet dietary pattern than women (33). However, the methodology used to evaluate adherence in the Mexican study (HDSI) differs notably from the one used in this study (PHDI).

The low adherence to the EAT-Lancet dietary pattern in the urban population of the Latin American region could be associated with economic limitations. Analyses indicate that the daily cost of this diet surpasses the income of at least 1.58 billion people globally, rendering it unaffordable (10,64–66). In Latin America, urban poverty is increasingly prevalent in developing countries, exceeding 50% (67). This phenomenon is more pronounced in urban areas due to

accelerated urbanization and rural-to-urban migration, potentially limiting access to certain food groups essential for higher adherence to the EAT-Lancet pattern.

On the other hand, the low adherence to the EAT-Lancet reference diet likely stems from the region's dietary habits diverging significantly from the EAT-Lancet recommendations. Even countries with higher adherence, like Costa Rica, Brazil, Ecuador, and Venezuela, fall short in many PHDI components. The ELANS group has highlighted insufficient daily consumption of health-beneficial, low-environmental-impact foods, which are adequacy components in the PHDI, such as nuts and seeds (1.6 ± 12.9 g/d), legumes (41.6 ± 65.3 g/d), fruits (75.3 ± 25.2 g/d), vegetables (86.7 ± 87.3 g/d), and whole grains (13.1 ± 31.3 g/d) (68). Conversely, moderation components of the PHDI, which negatively impact health and the environment, are consumed excessively, including red meat (61.3 ± 68.0 g/d) (68), animal-origin saturated fats (9.7 ± 2.6 %TEI/d) (69), and added sugars (13.2 ± 5.8 %TEI/d) (70).

When examining the consumption of both adequacy and moderation components of the PHDI, it becomes clear that a significant gap exists between real-world dietary practices and the theoretical reference model proposed by EAT-Lancet. Prioritizing foods with established epidemiological benefits and health advantages is highly desirable (10), especially when formulating dietary guidelines and food public policies. However, global directives that emphasize specific food categories based solely on nutritional epidemiology, without considering the diverse food cultures at national and regional levels, can result in a clash of cultural identities and create challenges for their adoption. Implementing such recommendations becomes complex and requires significant adjustments (71). Therefore, it is essential to move beyond a narrow focus solely on nutrition and embrace a more anthropological perspective, recognizing the pivotal role of food culture in human development (72).

Future adaptations of the dietary pattern should include food groups that guarantee the intake of nutrients of public health interest. Our results show that higher adherence to the EAT-Lancet dietary pattern is associated with a higher risk of inadequate intakes of cobalamin, vitamin D, and calcium—nutrients primarily found in animal-based foods. Dairy products, important sources of these nutrients (73), obtained an intermediate relative contribution in their PHDI component score (4.88 ± 3.14 points, out of 10). This is particularly important considering the high prevalence of inadequate calcium and vitamin D intake in the ELANS participating countries, at 85.7% and 98.2%, respectively (40).

According to a United Nations report, the restrictive nature of the EAT-Lancet dietary pattern concerning several food groups may lead to nutritional deficiencies and could be harmful to human health in the long term, especially for populations with increased nutritional requirements (10,74). Alexandropoulou *et al.* (10) suggest that the nutritional inadequacy of this pattern might require increased use of dietary supplements or the fortification of staple foods. The latter is already widely practiced in Latin America, a region with a strong history of food fortification policies and programs aimed at eradicating nutritional deficiencies (75,76).

The fortification of wheat flour with thiamine, riboflavin, niacin, and folate is mandatory in all eight ELANS participating countries (77). Additionally, some countries fortify other staple foods with these nutrients, such as corn flour in Costa Rica and rice in Costa Rica, Peru, and Venezuela (40). This could explain why low adherence to the EAT-Lancet dietary pattern does not currently reflect a risk of inadequate intake of thiamine, riboflavin, niacin, and folate in the participating countries, as the intake of these nutrients might be primarily supplied by refined flours (73), despite not being part of the reference pattern.

While the authors of the EAT-Lancet reference diet suggest adjustments to suit sociocultural contexts, the current dietary pattern does not include the option to replace the consumption of whole grains with refined grains. However, some refined grains, like rice, have an equivalent environmental footprint between their white and whole versions (78) and are widely consumed in its fortified refined version in Latin America. Additionally, as has been observed in Costa Rica, including white rice alongside beans in the reference pattern in specific proportions could reduce the risk of diabetes while it is part of the country's dietary pattern (79).

This study has several strengths and limitations to consider when interpreting its results. Strengths include: 1) The 24-hour dietary recall method for food intake data collection is more accurate than the food frequency questionnaire used in similar studies. 2) Micronutrient intake adequacy was evaluated using usual intake from two complete days, reducing methodological bias from intrapersonal variability. 3) The large plausible sample size provided precise mean values, identified outliers, and reduced the margin of error, allowing better micronutrient intake estimations in Latin American urban areas. 4) The PHDI scores proportionally and accounts for intermediate intakes of the EAT-Lancet dietary pattern more precisely than other reference diet-based indices (31). 5) The methodology used to assess the association between adherence to the dietary pattern and the risk of nutrient inadequacy is robust. It has been previously used by several authors (55–58). On the other hand, limitations include the following: 1) The study only included urban areas in 8 Latin American countries, excluding rural areas and other countries in the region, so the data cannot be generalized to all of Latin America. 2) These results should be interpreted within the context of the study design (cross-sectional analysis), and it can assess associations but cannot determine causality. 3) The disaggregation of the ultra-processed foods to include their content of added sugar, vegetable oils, and animal (saturated) fat in the PHDI calculation might be

subject to bias. Therefore, this process underwent review by four trained nutritionists to minimize errors.

5. Conclusion

The low adherence to the EAT-Lancet dietary pattern observed is due to the general dietary pattern of Latin America being significantly different from the one proposed by EAT-Lancet. Adaptations are required to enable the population of Latin America to achieve greater adherence to this dietary pattern, which is considered healthy and sustainable. These adaptations should include the consumption of foods that are part of the region's food culture and provide nutrients of interest for public health, such as fortified staple foods. Modifications to the pattern for the Latin American region should consider the possibility of increasing the recommendation for the consumption of foods that are sources of cobalamin, calcium, and vitamin D, which were found to be at risk in those with higher adherence to the reference pattern.

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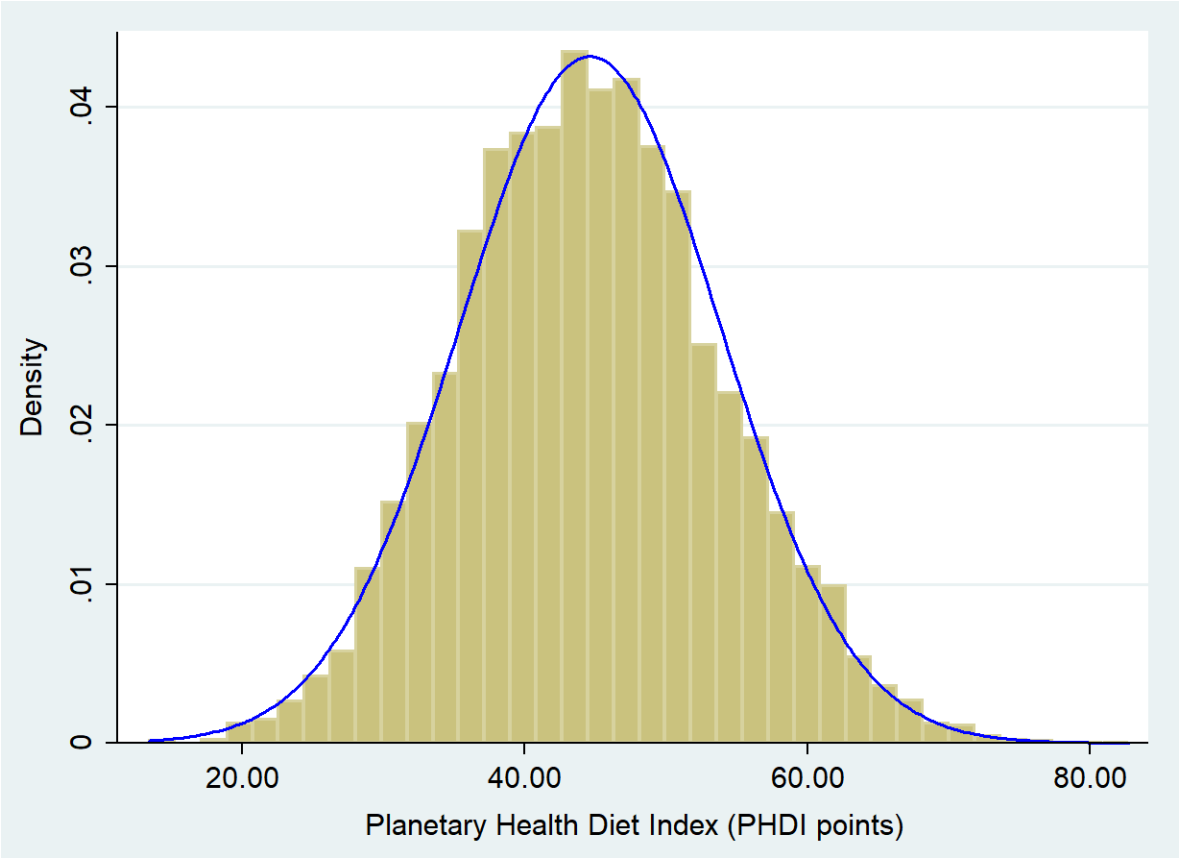
Supplementary materials

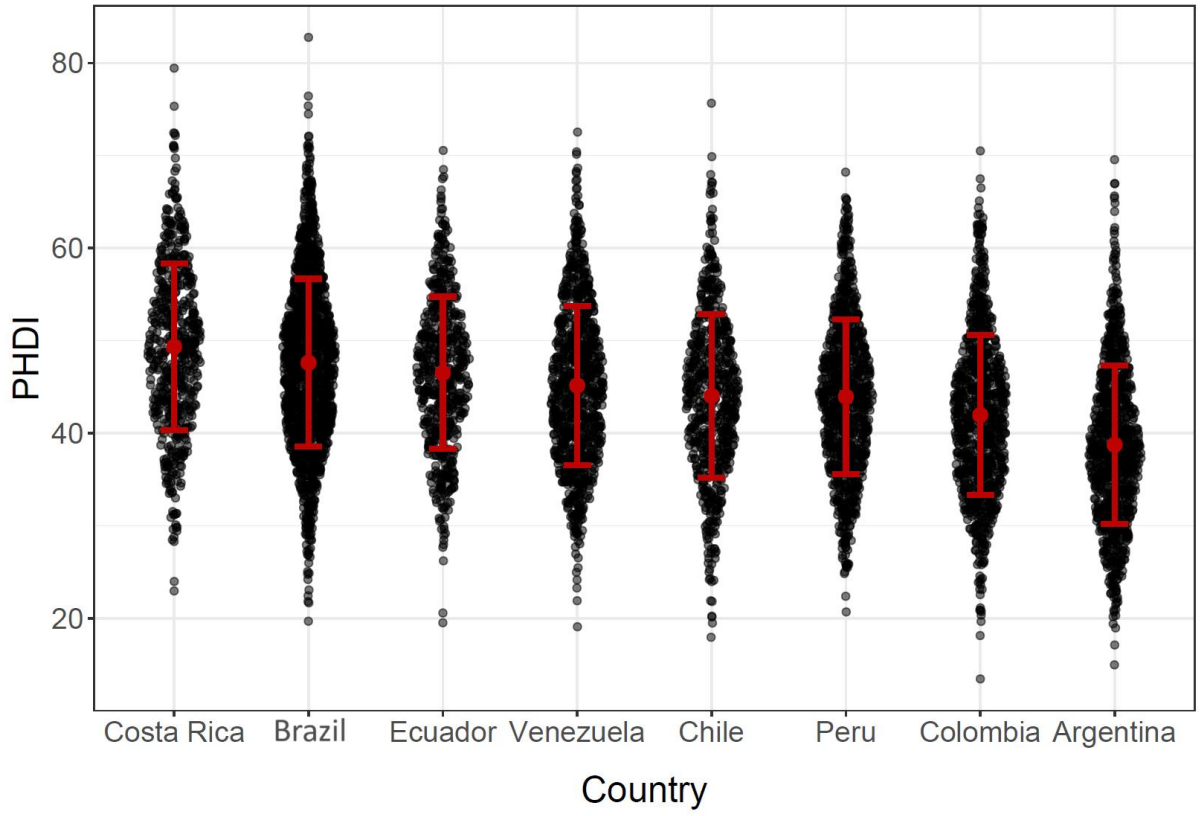
Adherence to the EAT-Lancet Diet and its Association with Micronutrient Inadequacy in the Urban Population of Eight Latin American Countries: Results from the Latin American Study of Nutrition and Health

Figure S1. Distribution of the Planetary Health Diet Index (PHDI) among participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6835).



PHDI: Planetary Health Diet Index.

Figure S2. Planetary Health Diet Index (PHDI) by country[1]. Latin American Study of Nutrition and Health (ELANS, 2016) (n=6835).



[1]Jittered-density plot showing mean and standard deviation of the PHDI for each country.

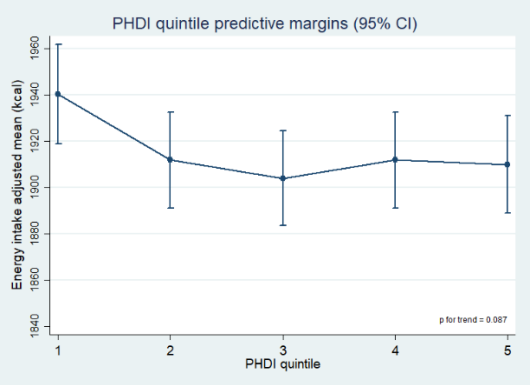
Table S1. Descriptive analysis of the Planetary Health Diet Index (PHDI) components by country. Latin American Study of Nutrition and Health (ELANS, 2016) (n=6835).

PHDI Components	Argentina (n=896)		Brazil (n=1471)		Chile (n=629)		Colombia (n=901)		Costa Rica (n=570)		Ecuador (n=582)		Peru (n=890)		Venezuela (n=896)		p-value[3]
	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	
Adequacy components																	
Nuts and peanuts	0.21^{ab}	0.85	0.27^{c}	0.87	0.22^{b}	0.76	0.35^{abc}	1.27	0.38^{c}	1.32	0.48^{c}	1.45	0.58^{d}	1.23	0.08^{a}	0.39	<0.001
Legumes	0.78^{a}	0.80	3.71^{b}	2.09	1.52^{c}	1.83	2.31^{e}	2.39	4.76^{f}	2.84	2.28^{g}	1.91	1.78^{d}	1.73	1.74^{c}	2.12	<0.001
Fruits	6.14^{a}	3.12	7.16^{b}	3.05	7.91^{c}	2.76	7.73^{c}	2.86	6.47^{d}	3.05	7.55^{b}	2.80	7.42^{b}	2.86	7.28^{b}	2.97	<0.001
Vegetables	5.15^{a}	2.38	4.62^{b}	2.50	6.69^{c}	2.52	5.29^{a}	2.66	6.99^{c}	2.05	7.52^{e}	2.20	6.39^{d}	2.30	5.66^{f}	2.51	<0.001
Whole cereals	0.37^{ab}	0.76	0.21^{a}	0.55	0.22^{a}	0.62	0.33^{a}	0.69	0.30^{a}	0.69	0.37^{ab}	0.77	0.57^{c}	0.75	0.35^{b}	0.64	<0.001
Optimum components																	
Eggs	1.08^{a}	2.41	3.07^{b}	3.60	2.63^{c}	3.49	1.56^{e}	3.00	2.35^{cd}	3.47	2.47^{c}	3.39	2.03^{d}	3.21	2.73^{c}	3.53	<0.001
Fish and seafood	3.37^{a}	1.76	3.54^{a}	1.97	3.73^{b}	1.87	3.51^{a}	1.96	4.34^{c}	2.59	4.15^{bc}	2.58	3.79^{b}	2.16	3.47^{a}	1.82	<0.001
Tubers and potatoes	3.55^{a}	3.55	4.24^{b}	3.60	2.89^{c}	3.52	1.70^{d}	2.99	3.79^{a}	3.59	1.60^{d}	2.89	1.55^{d}	2.99	3.83^{a}	3.73	<0.001
Dairy	4.38^{a}	3.37	5.08^{b}	3.06	4.68^{ac}	3.11	4.97^{bc}	3.15	5.32^{b}	2.78	5.18^{b}	3.10	5.64^{d}	2.68	3.89^{e}	3.35	<0.001
Vegetable oils	6.08^{a}	1.90	7.00^{b}	1.64	6.05^{a}	1.59	5.99^{a}	1.60	6.67^{d}	1.46	6.95^{b}	1.52	5.73^{c}	1.45	6.50^{d}	1.83	<0.001
Ratio components																	
DGV / Total ratio[1]	0.66^{a}	1.09	0.56^{a}	0.92	0.39^{bc}	0.71	0.34^{b}	0.58	0.25^{d}	0.50	0.69^{a}	0.87	0.58^{a}	0.73	0.26^{c}	0.44	<0.001
ReV / Total ratio[2]	3.73^{a}	0.88	3.49^{b}	1.15	3.61^{ab}	0.99	3.79^{d}	1.08	3.66^{ac}	1.05	3.81^{cd}	0.91	3.83^{d}	0.95	4.05^{e}	0.79	<0.001
Moderation components																	
Red meat	0.01^{ab}	0.19	0.00^{a}	0.10	0.00^{ab}	0.05	0.01^{ab}	0.22	0.03^{ab}	0.31	0.02^{b}	0.20	0.05^{c}	0.38	0.00^{ab}	0.08	<0.001
Chicken and substitutes	2.58^{a}	2.59	2.15^{b}	2.47	2.74^{a}	2.66	2.48^{a}	2.57	2.51^{a}	2.53	1.54^{d}	2.25	1.05^{c}	1.92	1.94^{e}	2.49	<0.001
Animal fats	0.52^{a}	1.67	2.17^{b}	2.86	0.47^{a}	1.51	1.39^{d}	2.41	1.37^{d}	2.39	1.82^{b}	2.60	2.86^{c}	3.06	3.21^{f}	2.90	<0.001
Added sugars	0.14^{ad}	0.80	0.34^{b}	1.26	0.29^{bc}	1.19	0.21^{cd}	0.94	0.14^{acd}	0.82	0.10^{a}	0.58	0.08^{a}	0.57	0.14^{a}	0.91	<0.001
Total score	38.74^{a}	8.56	47.61^{b}	9.07	44.03^{c}	8.84	41.95^{d}	8.63	49.33^{e}	9.03	46.52^{f}	8.24	43.93^{c}	8.37	45.14^{g}	8.60	<0.001

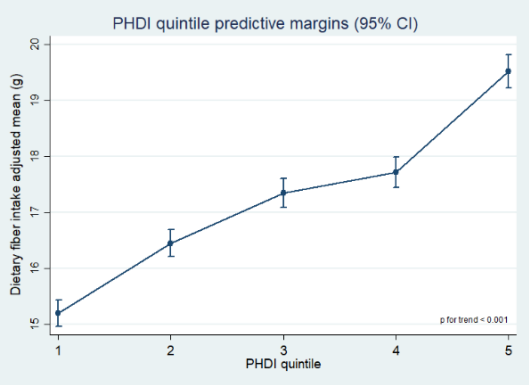
[1]DGV/total ratio: dark green vegetables/total ratio multiplied by 100. [2]ReV/total ratio: red and orange vegetables/total ratio multiplied by 100. [3]*p*-value corresponds to the Kruskal-Wallis test comparing among groups (*p*-values <0.05 denote statistically significant differences). Labeled mean values in the total score row without a common letter differ ($p<0.05$). x̄: mean. SD: standard deviation.

Figure S3. PHDI quintile predictive margins for the adjusted mean of energy and 5 usual nutrient intakes[1] among participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6835).

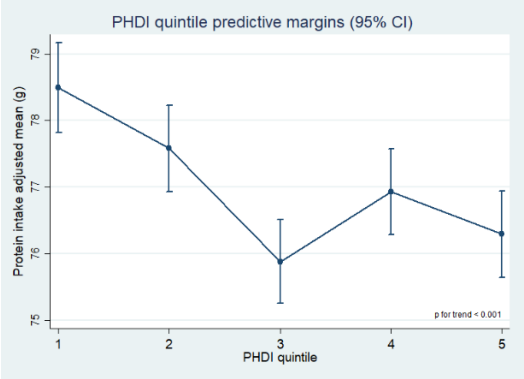
Energy



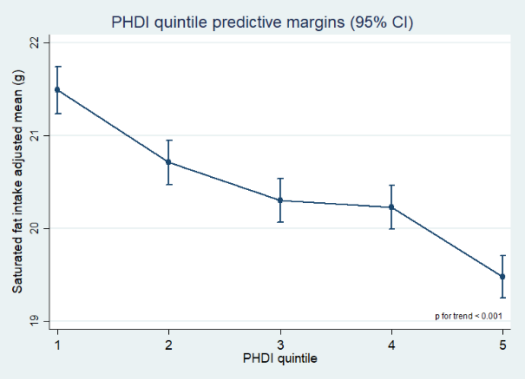
Dietary fiber



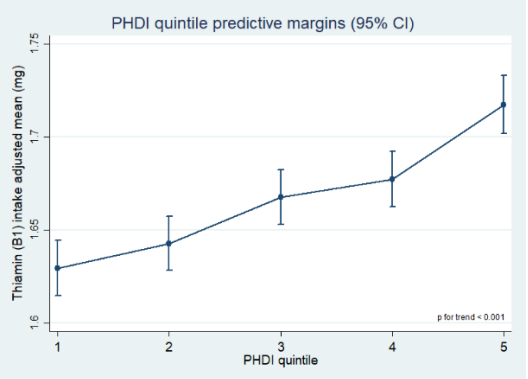
Protein



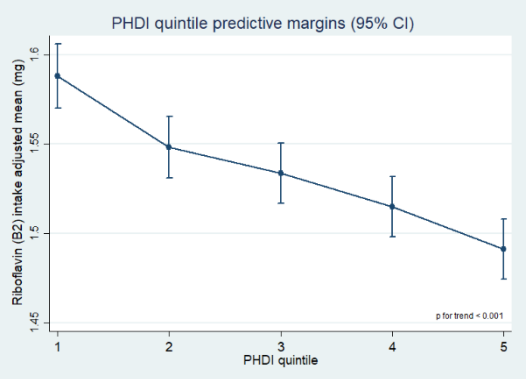
Saturated fat



Thiamin (B1)



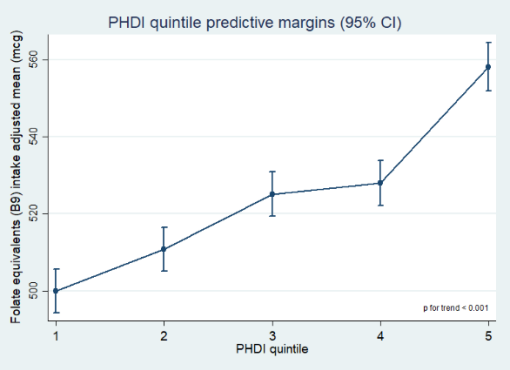
Riboflavin (B2)



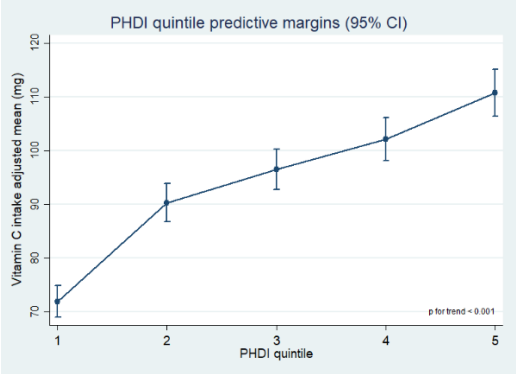
[1]Generalized linear regression model adjusted for sex, age, socioeconomic status, and country. Usual nutrient intakes were energy-adjusted by the nutrient residual model. PHDI quintiles: min–max score / 1st: 13.4–36.7; 2nd: 36.8–42.0; 3rd: 42.1–46.8; 4th: 46.9–52.3; 5th: 52.4–82.8.

Figure S4. PHDI quintile predictive margins for the adjusted mean of 6 usual nutrient intakes[1] among participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6835).

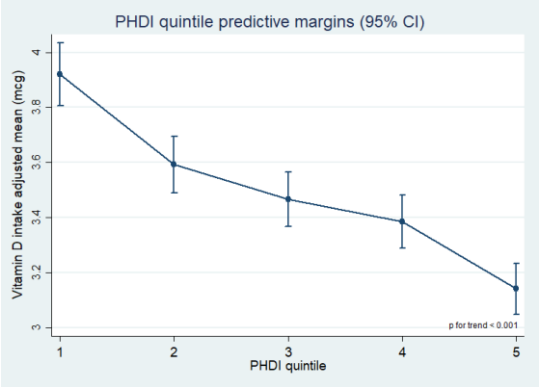
Folate equivalents (B9)



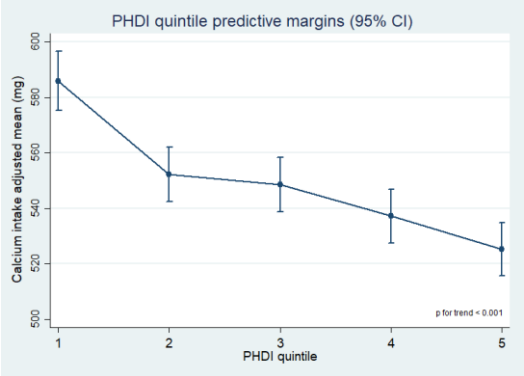
Vitamin C



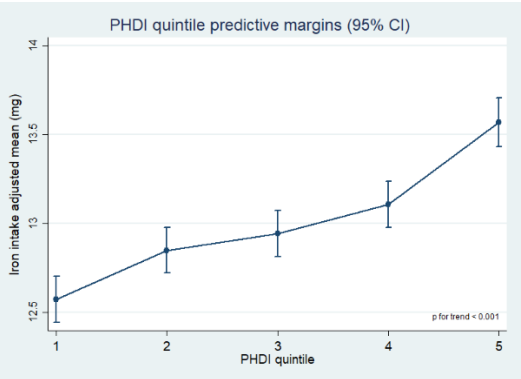
Vitamin D



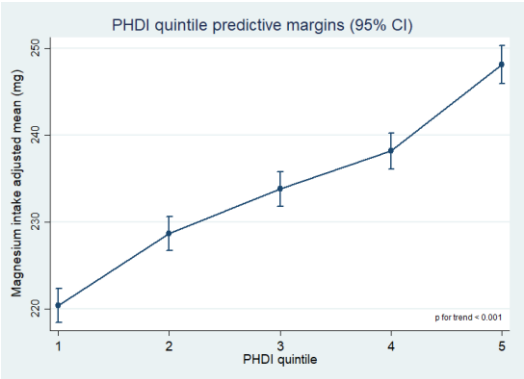
Calcium



Iron



Magnesium



[1]Generalized linear regression model adjusted for sex, age, socioeconomic status, and country. Usual nutrient intakes were energy-adjusted by the nutrient residual model. PHDI quintiles: min–max score / 1st: 13.4–36.7; 2nd: 36.8–42.0; 3rd: 42.1–46.8; 4th: 46.9–52.3; 5th: 52.4–82.8.

ARTÍCULO 2

Adherence to the EAT-Lancet Diet is not Associated with Weight Status in a Latin American Urban Multicentric Study

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Abstract

The high prevalence of overweight/obesity and the effects of climate change in Latin America underscores the potential benefits of adopting a healthy and sustainable diet to address the region's burden of diet-related non-communicable diseases. However, research on adherence to the EAT-Lancet dietary pattern in Latin America and its association with overweight/obesity is limited. This study explores the association between adherence to the EAT-Lancet dietary pattern and overweight/obesity in a cross-sectional, urban multicentric study involving 6683 participants aged 15-65. Adherence to the EAT-Lancet diet was assessed using the Planetary Health Diet Index (PHDI). The findings indicate that high adherence to the EAT-Lancet dietary pattern is not significantly associated with overweight/obesity (5th PHDI quintile vs. 1st PHDI quintile, PR: 1.057, CI: 0.993 – 1.125, *p*-trend=0.137) after adjusting for sex, age, total energy intake, country, socioeconomic status, and physical activity level. Similar findings were observed when using the EAT-Lancet Index (ELDI), the World Index for Sustainability and Health (WISH), and the Mexican Healthy and Sustainable Diet Index (HSDI) to assess adherence to the EAT-Lancet dietary pattern, after adjusting for the same variables. The persistently high levels of overweight/obesity across different levels of adherence to the EAT-Lancet pattern, combined with the study's design, do not seem to be the primary factors contributing to the lack of association between these variables. Instead, the notably low average adherence to the EAT-Lancet diet in the study sample appears to be the main factor contributing to the lack of observed association. However, further research is needed to verify this conclusion.

Keywords

EAT-Lancet diet, PHDI, Latin America, ELANS, sustainable diets, weight status, overweight, obesity

1. Introduction

Non-communicable diseases (NCDs) are the leading cause of morbidity and mortality globally, with high body mass index (BMI) and overweight/obesity being significant risk factors (1–3). Currently, the average consumption of healthy foods is substantially below recommended levels, while the intake of unhealthy foods continues to rise, contributing to the growing prevalence of overweight/obesity. This trend not only increases the burden of obesity and diet-related NCDs but also leads to environmental degradation (4).

In response, the EAT-Lancet Commission proposed a universal, healthy, and sustainable reference diet to reform global food systems, enhance environmental sustainability, and improve human health. The EAT-Lancet dietary pattern is primarily plant-based, which has been associated with a reduced risk of obesity and diet-related diseases compared to non-vegetarian diets (5,6). Based on epidemiological evidence, the proposed diet focuses on the predominant consumption of fruits, vegetables, legumes, whole grains, nuts and seeds, and unsaturated oils. It also recommends low to moderate consumption of dairy, fish and seafood, and poultry, and low to no consumption of red and processed meat, animal fats, and added sugars (4,7,8).

The EAT-Lancet Commission estimates that adopting this reference diet could potentially prevent 10.9 to 11.6 million (19.0–23.6%) deaths annually worldwide by reducing the incidence of diet-related NCDs, such as cardiovascular disease, stroke, and diabetes, while also decreasing environmental impacts (4). This raises the question of whether BMI differs between individuals who closely follow the EAT-Lancet diet and those who do not. This is particularly pertinent as various studies suggest that the beneficial effects of the EAT-Lancet diet on mortality and the risk of certain NCDs are largely mediated by BMI (9–11). Even though higher BMI and overweight/obesity are considered significant risk factors for diet-related NCDs (2), research on

the association between adherence to the EAT-Lancet dietary pattern and overweight/obesity is limited and presents mixed findings.

Results from the Brazilian Longitudinal Study of Adult Health (ELSA-Brazil 2010) (8), the Danish Diet, Cancer and Health Cohort study (12), the National Health and Nutrition Survey of Mexico (ENSANUT 2018-19) (13), and the Multiethnic Cohort Study in Hawaii and Los Angeles, USA (14) have indicated that adherence to the reference diet is associated with a lower prevalence or risk of overweight/obesity, elevated BMI, and waist circumference. In contrast, studies from the Finnish Institute of Health and Welfare (15), the Brazilian National Dietary Survey 2017-2018 (16), and the Canadian Community Health Survey (CCHS)-Nutrition (cycles 2004 and 2015) (17) found no significant association between adherence to the EAT-Lancet diet and overweight/obesity. Furthermore, despite a lower average total energy intake compared to the EAT-Lancet reference diet, obesity rates in India continue to rise (18). Additionally, a Swedish study even reported a slight increase in BMI among men who adhered more closely to the EAT-Lancet diet (10).

Given the high prevalence of diet related NCDs in Latina America (19), adopting a healthy and sustainable dietary pattern could significantly reduce the costs associated with the region's burden of these diseases and climate change effects (20). However, research on adherence to the EAT-Lancet dietary pattern in Latin America and its association with overweight/obesity is limited, with most studies conducted in populations from the Global North, such as Canada (17), the USA (14), and Europe (12,15). A more comprehensive understanding of this issue is essential for public health stakeholders to make informed decisions that could transform food systems and reduce the prevalence of overweight/obesity in Latin America. This study, using data from the Latin American Study of Nutrition and Health (ELANS), a multicentric study conducted in eight Latin American

countries, aimed to assess the association between adherence to the EAT-Lancet dietary pattern and the prevalence of overweight/obesity among the urban population in the region.

2. Methods and Materials

2.1. Sample and Setting

This cross-sectional study used baseline data from the ELANS, with its design and sampling methods detailed in previous publications (21–23). Conducted between September 2014 and August 2015, the ELANS surveyed a representative sample of urban households in eight Latin American countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, and Venezuela. The study included 9218 participants and aimed to assess their anthropometric measurements, dietary habits, and physical activity levels.

The study employed a complex, multistage random sampling method, stratified by region, sex, age, and socioeconomic status (23). Misreported energy intake (EI) was previously calculated for the ELANS study by Previdelli *et al.* (24), following the methodology used by McCrory *et al.* (25). After excluding participants with misreported EI and those without reported physical activity levels, the final valid sample for this study comprised 6683 participants. This group consisted of both men and women, encompassing adolescents aged 15-18 years and adults aged 19-65 years (24).

The ELANS protocol was approved by the Western Institutional Review Board (approval #20140605) and registered on ClinicalTrials.gov (registration #NCT02226627). Additionally, it received approval from the local ethics committees in each participating country. All participants provided informed consent or assent before participating in the survey. Furthermore, on June 21,

2023, the Scientific and Ethics Committee of the Costa Rican Institute for Research and Education in Nutrition and Health (INCIENSA) approved this study protocol (approval #IC-2023-02).

2.2. Data collection

2.2.1. Demographic and socioeconomic status variables

A questionnaire was used to collect data on sex and age (26). Socioeconomic status (SES) was assessed using a questionnaire tailored to each country, ensuring compliance with national legislative standards or established local formats. SES was categorized into low, middle, and high status according to the national indices of each country (21,26).

2.2.2. Anthropometric assessment

Height and weight were measured by trained nutritionists. Height was obtained to the nearest 0.1 cm using a stadiometer, and weight was measured to the nearest 0.1 kg, using a digital weight scale, following standardized protocols (27). Body mass index (BMI) values were calculated from measured height and weight values using the standard equation: weight (kg) / height $(m)^2$. For participants under 18 years old, BMI was classified using z-score cut-off criteria for age and sex as recommended by the World Health Organization (WHO) (28). For individuals aged 18 years and older, BMI was categorized as follows: underweight, BMI <18.5 kg/m²; normal weight, BMI 18.5-24.9 kg/m²; overweight, BMI 25.0-29.9 kg/m²; and obese, BMI ≥30.0 kg/m² (29).

2.2.3. Physical activity level assessment

The participant's physical activity level (PAL) was evaluated using a Spanish version of the long form "last 7 days" self-administered International Physical Activity Questionnaire (IPAQ) (21). This questionnaire measured walking, moderate, and vigorous physical activities in minutes per week. The collected data were then converted to Metabolic Equivalent minutes per week

(MET-min/week) using the methodology outlined by Ainsworth *et al.* (30). PAL was categorized as low, moderate, or high, based on the IPAQ guidelines (23,31).

2.2.4. Dietary assessment

The ELANS dietary assessment involved two household visits scheduled no more than eight days apart. During each visit, trained interviewers conducted a 24-hour dietary recall (24HR) to record all food and beverage consumption from the previous day, including both weekdays and weekends. The sample was proportionally distributed to ensure day-to-day intake variations were represented. Trained nutritionists supervised these recalls and converted the recorded measures into grams and milliliters (23).

Energy intake and diet composition values were calculated using the 2013 version of the Nutrition Data System for Research (NDS-R) software (32). All documented locally sourced and traditional foods were standardized using a USDA composition table to ensure nutritional equivalency and local food fortification (23,26). The Multiple Source Method (http://mss.dife.de/tps/en) (33,34) was used to estimate the usual intake of energy and the 16 components of the Planetary Health Diet Index for the study sample.

2.3. Adherence to the EAT-Lancet dietary pattern

2.3.1. Planetary Health Diet Index assessment

The Planetary Health Diet Index (PHDI) was used to evaluate adherence to the EAT-Lancet dietary pattern. This index encompasses all EAT-Lancet food groups and uses a gradual scoring system to assess components based on the amount consumed of each food group (7,35). Scores in the PHDI are calculated using a caloric intake ratio, which is determined by dividing the total calories from all foods within a PHDI component by the total calories from all foods consumed, excluding alcoholic beverages, as they are not part of the reference diet (4,7).

The PHDI consists of 16 components divided into four categories: adequacy (nuts, fruits, legumes, vegetables, whole grains), optimum (eggs, dairy, fish, potatoes, vegetable oils), ratio (dark green to total vegetables, red-orange to total vegetables), and moderation (red meat, poultry, animal fats, added sugars). Adequacy, optimum, and moderation are scored from 0 to 10 points, while ratio is scored from 0 to 5 points. Each score reflects the relative energy intake based on the EAT-Lancet dietary pattern and the PHDI index (7).

All foods consumed by the ELANS plausible sample were first disaggregated to their ingredient level. Then, the ingredients were classified into 16 PHDI components using the methodology by Cacau *et al.* for extracting PHDI components from food consumption data (7). Highly processed foods were meticulously disaggregated to estimate their content of added sugar, vegetable oils, and animal (saturated) fat using the USDA composition table, ensuring accurate categorization within the PHDI components and avoiding under or overestimation. This process was reviewed by four trained nutritionists.

The total PHDI score ranges from 0 to 150, with higher scores indicating greater adherence to the EAT-Lancet dietary pattern (7,36). Adherence can be estimated by dividing the PHDI score by the total possible points (16). For detailed information on PHDI development, scoring criteria, cutoff points, validity, and reliability, refer to the sources (7).

2.3.2. Alternative EAT-Lancet diet indices

This study utilized the PHDI to assess adherence to the EAT-Lancet dietary pattern. To validate the results, analyses were also conducted using other indices designed to evaluate adherence to the EAT-Lancet pattern: the EAT-Lancet Diet Index (ELDI) (10), the World Index for Sustainability and Health (WISH) (37), and the Mexican Healthy and Sustainable Diet Index (HSDI) (13). The methodologies for calculating each index differ slightly from that of the PHDI (7); however, these

indices are comparable as their main objective is to evaluate how well diets adhere to the EAT-Lancet dietary pattern.

The ELDI developed by Stubbendorff *et al.* (10), consists of 14 components grouped into two categories: those that should be prioritized (whole grains, vegetables, fruits, legumes, nuts, fish, and unsaturated oils) and those that should be restricted (potatoes, dairy, beef and lamb, pork, poultry, eggs, and added sugars). Each component is scored on a scale from 0 to 3 points, depending on how well one follows the recommended daily intake for each food group. For the emphasized components, a score of 0 represents the lowest adherence, while a score of 3 indicates the highest adherence. In contrast, the scoring for the limited components is reversed. As a result, the overall score can range from 0 to 42 points.

Similarly, the WISH developed by Trijsburg *et al.* (37), comprises 13 components: whole grains, vegetables, fruits, dairy products, red meat, fish, eggs, poultry, legumes, nuts, unsaturated oils, saturated oils, and added sugars. Each component is scored on a scale of 0 to 10 points, with 0 indicating no adherence and 10 representing full adherence to the EAT-Lancet recommendations in terms of daily gram intake. The total WISH index score can range from 0 to 130 points.

The Mexican HSDI developed by Shamah-Levy *et al.* (13), uses 13 food groups: whole grains, tubers and starchy vegetables, non-starchy vegetables, fruits, milk and dairy products, red meat, poultry, eggs, fish and seafood, legumes, soy and nuts, saturated fats, unsaturated oils, and added sugars. The proportional energy contribution of each food group is compared with its recommended intake. A binary system is then used to assign 1 point to a food group if the energy contribution recommendation is met, and 0 points if it is not. The total HSDI score can range from 0 to 13 points.

2.4. Statistical analyses

Continuous variables were presented as means ± standard deviations (SD) with 95% confidence intervals (CI), and categorical variables as frequencies (%). The Shapiro-Wilk test was used to assess the normal distribution of continuous variables. Multivariate linear regression models were employed to estimate total energy intake (TEI) and PHDI-adjusted means (95% CI) across strata of categorical variables. In separate models, both TEI and PHDI were used as response variables, adjusting for sex, age group, country, SES, PAL, and weight status. Multivariate model assumptions were assessed (38), and adjusted means for TEI and PHDI are presented as marginals within each multivariate model. Therefore, for each stratum of categorical variables, the effect of that same variable is not included in the adjusted mean.

Comparisons of adjusted TEI and PHDI scores among groups based on sex, age group, country, SES, PAL, and weight status were conducted using the Mann-Whitney or Kruskal-Wallis tests, followed by the Bonferroni procedure for multiple-comparison correction. Additionally, comparisons of participant frequencies by categorical variables among PHDI quintiles were conducted using the Chi-square test.

Multivariate Poisson regression models with robust variance were used to examine the association between relative adherence to the EAT-Lancet dietary pattern (PHDI quintiles) and the prevalence of overweight/obesity. This method was chosen over logistic regression to avoid overestimating the risk, which is common with logistic regression's odds ratio, especially in cross-sectional studies and events with high prevalence (≥10%) (39–43). As a complementary analysis and given that the other EAT-Lancet indices have different scoring magnitudes compared to the PHDI, the same modeling logic used with the PHDI quintiles was applied to each of the EAT-Lancet indices (PHDI, ELDI, WISH, and HDSI), this time treating each index as a continuous

variable within each model to enable comparison between indices with significantly different score magnitudes.

Poisson models were adjusted for sex, age, total energy intake, SES, PAL, and country. The association trend was evaluated using orthogonal polynomial contrast for linear trend among PHDI quintiles within each model. Non-multicollinearity within each model was assessed using the variance inflation factor, and over-dispersion was evaluated using negative binomial models.

All tests were two-tailed, with p-values < 0.05 considered statistically significant. Data analysis was performed using Stata software version 14.1 (2015, College Station, TX, USA) (44), IBM SPSS® (version 27, IBM Corp) (45), and Jamovi version 2.3.28 (46).

3. Results

3.1. General characteristics, energy intake, and Planetary Health Diet Index (PHDI) score of the study participants

The average age of the sample was 36.0 ± 14.1 y (data not shown). The majority of the study sample was 51.8% female, 83.0% aged 19-59 y, 52.0% with low SES, 58.9% with low physical activity level, and 60.0% of the participants were classified as overweight/obese (Table 1).

After adjusting for categorical variables, the average total TEI and PHDI score of the sample were 1917 kcal/d (95% CI: 1908 – 1927) and 44.6 points (95% CI: 44.4 – 44.8) out of 150, respectively; comprising an average relative adherence to the EAT-Lancet dietary pattern in the urban population of the 8 Latin American countries of 29.7% (Table 1). The adjusted TEI was significantly higher in men, the adolescents group, participants with high SES and PAL; and slightly higher in those who had overweight/obesity. In contrast, adjusted TEI was lower in women, participants aged 60-65, individuals with low SES and PAL, and those who were not

overweight or obese ($p<0.001$). Regarding country, adjusted TEI ranged from 1804 kcal/d (95% CI: 1774 – 1835) in Chile to 1996 kcal/d (95% CI: 1971 – 2022) in Argentina, with significant differences among countries ($p<0.001$) (Table 1).

The adjusted PHDI score was significantly slightly higher in the 60-65 y age group, participants with high SES and PAL, and those who were overweight or obese. In contrast, the adjusted PHDI score was lower in adolescents, individuals with low SES and PAL, and those who were overweight/obese ($p<0.001$). There were significant differences in PHDI scores among countries ($p<0.001$) and ranged from 49.3 points (95% CI: 48.6 – 50.0) in Costa Rica to 38.7 points (95% CI: 38.2 – 39.3) in Argentina ($p<0.001$) (Table 1). There were no significant differences in the PHDI between men and women ($p=0.052$) (Table 1).

Table 1. Total energy intake and Planetary Health Diet Index (PHDI) among subgroups of participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6683).

Characteristic	Total	Total energy intake (kcal)			PHDI score		
	n (%)[1]	Mean[2]	95% CI	*p*-value[3]	Mean[2]	95% CI	*p*-value[3]
Overall	6683 (100)	1917	1908 – 1927	-	44.6	44.4 – 44.8	-
Sex							
Men	3223 (48.2)	2109	2096 – 2123	<0.001	44.6	44.3 – 44.9	0.052
Women	3460 (51.8)	1738	1725 – 1751		44.6	44.3 – 44.9	
Age group							
15 – 18 y	683 (10.2)	1986[a]	1956 – 2016	<0.001	43.6[a]	42.9 – 44.3	<0.001
19 – 59 y	5544 (83.0)	1922[b]	1912 – 1932		44.6[b]	44.4 – 44.9	
60 – 65 y	456 (6.8)	1755[c]	1719 – 1791		45.9[c]	45.1 – 46.7	
Country							
Argentina	885 (13.2)	1996[a]	1971 – 2022	<0.001	38.7[a]	38.2 – 39.3	<0.001
Brazil	1444 (21.6)	1857[b]	1837 – 1877		47.6[b]	47.1 – 48.0	
Chile	611 (9.1)	1804[c]	1774 – 1835		44.0[c]	43.3 – 44.7	
Colombia	879 (13.2)	1968[d]	1942 – 1994		42.0[d]	41.5 – 42.6	
Costa Rica	564 (8.4)	1853[e]	1821 – 1885		49.3[e]	48.6 – 50.0	
Ecuador	557 (8.3)	1992[f]	1958 – 2025		46.3[f]	45.6 – 47.0	
Peru	877 (13.1)	1989[a]	1963 – 2015		43.9[c]	43.3 – 44.4	
Venezuela	866 (13.0)	1885[e]	1858 – 1911		45.3[g]	44.7 – 45.9	
Socioeconomic status							
Low	3479 (52.0)	1911[a]	1861 – 1885	<0.001	44.4[a]	44.1 – 44.7	<0.001
Middle	2546 (38.1)	1924[b]	1916 – 1952		44.7[b]	44.3 – 45.0	
High	658 (9.9)	2094[c]	2067 – 2122		45.4[c]	45.7 – 46.0	
Physical activity level							
Low	4024 (60.2)	1873[a]	1861 – 1885	<0.001	44.4[a]	44.1 – 44.7	<0.001
Moderate	1832 (27.4)	1934[b]	1916 – 1952		44.7[a]	44.3 – 45.1	
High	827 (12.4)	2094[c]	2067 – 2122		45.4[b]	44.8 – 46.0	
Weight status[4]							
Non-overweight/obese	2664 (39.9)	1900	1885 – 1915	<0.001	44.3	44.0 – 44.7	<0.001
Overweight/obese	4019 (60.1)	1928	1916 – 1941		44.8	44.5 – 45.0	

[1]Values are frequencies (%). [2]Multivariate linear regression model used to obtain adjusted means (95% CI) across strata of categorical variables. Total energy intake and PHDI score were included as the response variables in separate models; adjusted for sex, age group, country, socioeconomic status, physical activity level, and weight status. [3]*p*-value corresponds to the Mann-Whitney or Kruskal-Wallis tests comparing groups. Labeled adjusted mean values within the same variable and without a common letter differ ($p<0.05$). [4]Weight status according to BMI categories.

3.2. Body mass index and Planetary Health Diet Index (PHDI) distribution

The average BMI did not differ among PHDI quintiles ($p=0.144$) (Table 2). However, the frequency of participants with overweight/obesity according to the PHDI quintile showed a trend

of higher accumulation in the 2nd to 5th PHDI quintiles (60.7% - 61.5%), compared to the 1st quintile (56.3%) (p=0.035). The opposite was true for the participants who did not have overweight/obesity. As expected, the adjusted PHDI score among PHDI quintiles followed a logically increasing trend (p<0.001).

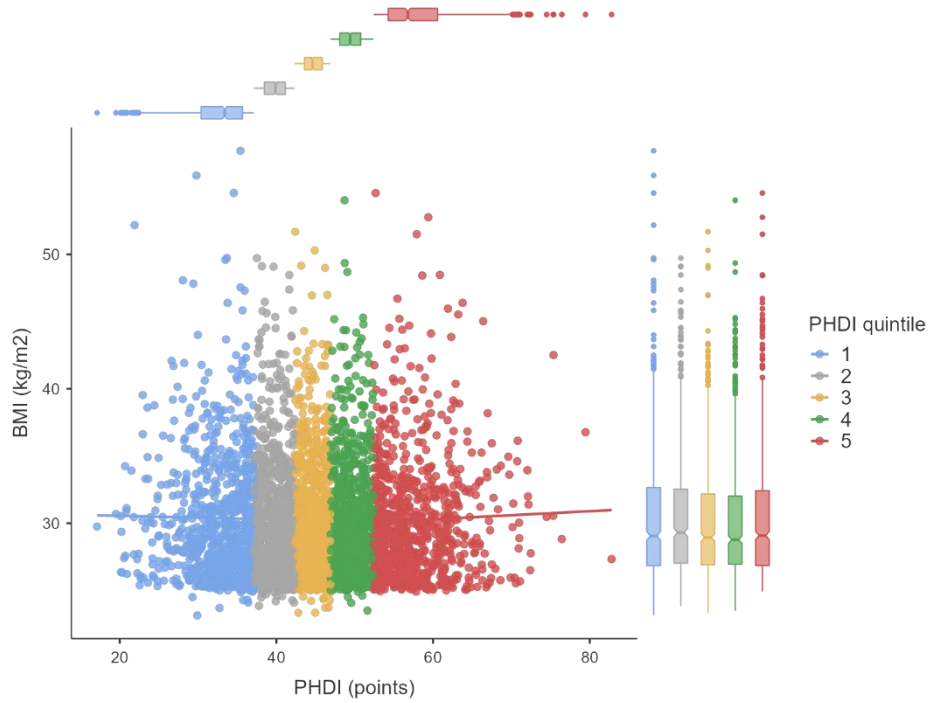
Table 2. Frequency of participants by weight status and adjusted Planetary Health Diet Index (PHDI) score according to PHDI quintile in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6683).

Characteristics[1]	**Total**	**PHDI quintile**[2]					***p*-value**[3]
		1st	**2nd**	**3rd**	**4th**	**5th**	
Overall, n (%)	6683 (100.0)	1337 (20.0)	1340 (20.0)	1334 (20.0)	1336 (20.0)	1336 (20.0)	-
Body mass index (kg/m²)	26.9 ± 5.5	27.4 ± 5.7	27.1 ± 5.5	26.9 ± 5.5	26.9 ± 5.3	27.0 ± 5.6	0.144
Weight status[4], n (%)							
Non-overweight/obese	2664 (39.9)	584 (43.7)[a]	526 (39.3)[b]	517 (38.8)[b]	523 (39.1)[b]	514 (38.5)[b]	0.035
Overweight/obese	4019 (60.1)	753 (56.3)[a]	814 (60.7)[b]	817 (61.2)[b]	813 (60.9)[b]	822 (61.5)[b]	
Adjusted PHDI (points)	44.6 ± 3.2	42.9 ± 3.2[a]	44.1 ± 3.2[b]	44.7 ± 3.0[c]	45.3 ± 2.8[d]	46.0 ± 2.7[e]	<0.001

[1]Values are frequencies (%) or adjusted means ± SD otherwise indicated. [2]PHDI quintiles: min–max score / 1st: 13.4–36.7; 2nd: 36.8–42.0; 3rd: 42.1–46.8; 4th: 46.9–52.3; 5th: 52.4–82.8. [3]*p*-value corresponds either to the Chi-square test comparing frequencies or adjusted means among PHDI quintiles. Labeled values in a row without a common letter differ (p<0.05). [4]Weight status according to BMI categories.

The distribution of both unadjusted variables, BMI by PHDI score, among participants with overweight/obesity, showed that the BMI values are widely distributed across all PHDI quintiles (Figure 1). This widespread distribution of BMI values limits the ability to establish a clear trend in the association between adherence to the EAT-Lancet dietary pattern (PHDI score) and overweight/obesity, evidenced in similar values for BMI medians among PHDI quintiles (right-side box plot, Figure 1).

Figure 1. Distribution of body mass index (BMI) by Planetary Health Diet Index (PHDI) score among participants with overweight/obesity in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=4019).



BMI: body mass index. PHDI: Planetary Health Diet Index. PHDI quintiles for participants with overweight/obesity: min–max score / 1st: 17.1–37.1; 2nd: 37.2–42.3; 3rd: 42.4–46.9; 4th: 47.0–52.4; 5th: 52.5–82.8. Graph created with Jamovi 2.3.28.

3.3. Models assessing the association between adherence to the Planetary Health Diet Index (PHDI) and overweight/obesity prevalence

Regarding overweight/obesity prevalence, the unadjusted model indicated a 9.2% significantly higher prevalence of overweight/obesity in individuals in the 5th PHDI quintile (with high adherence to the EAT-Lancet dietary pattern), compared to those in the 1st PHDI quintile (with low adherence) (*p*-trend=0.013). However, after adjusting for sex and age (Model A1), participants with high adherence to the EAT-Lancet dietary pattern (5th PHDI quintile) did not have a significantly higher prevalence of overweight/obesity compared to those with low adherence (1st PHDI quintile) (*p*-trend=0.110). Similarly, in the fully adjusted model (Model B1:

adjusted for sex, age, TEI, country, SES, and PAL); participants with high adherence to the EAT-Lancet dietary pattern (5th PHDI quintile) neither had a significantly higher prevalence of overweight/obesity compared to those with low adherence (1st PHDI quintile) (*p*-trend=0.137) (Table 3). Additional graphs illustrating the non-association between high adherence to the PHDI and overweight/obesity prevalence, after adjusting for different variables, are shown in the Supplementary materials (Figure S1).

Table 3. Association between high adherence to the Planetary Health Diet Index (PHDI) and overweight/obesity status among participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6683).

Models	PHDI quintile	Overweight/obesity			
		PR[1]	95% CI	*p*-value[2]	*p*-trend[3]
Unadjusted				0.046	0.013
	1st	ref	ref	-	
	2nd	1.079	1.012 – 1.150	0.020	
	3rd	1.087	1.020 – 1.159	0.010	
	4th	1.080	1.013 – 1.152	0.018	
	5th	1.092	1.025 – 1.164	0.006	
Model A1[4]				<0.001	0.110
	1st	ref	ref	-	
	2nd	1.051	0.989 – 1.116	0.110	
	3rd	1.049	0.988 – 1.114	0.118	
	4th	1.051	0.989 – 1.116	0.108	
	5th	1.059	0.994 – 1.121	0.075	
Model B1[5]				<0.001	0.137
	1st	ref	ref	-	
	2nd	1.050	0.989 – 1.116	0.111	
	3rd	1.046	0.985 – 1.112	0.142	
	4th	1.046	0.983 – 1.112	0.155	
	5th	1.057	0.993 – 1.125	0.083	

Bivariate and multivariate Poisson regression with robust variance analysis: [1]Prevalence ratio of overweight/obesity for the 5th PHDI quintile vs the 1st PHDI quintile (baseline). [2]*p*-value corresponds either to the global test of the model or to the Wald test for the 5th PHDI quintile as a category of the PHDI within each model. [3]*p*-value for trend corresponds to the linear trend among PHDI quintiles within each model. PHDI quintiles: min–max score / 1st: 13.4–36.7; 2nd: 36.8–42.0; 3rd: 42.1–46.8; 4th: 46.9–52.3; 5th: 52.4–82.8.

[4]Model A1: adjusted for sex and age. [5]Model B1: adjusted for sex, age, total energy intake, country, socioeconomic status, and physical activity level.

As a confirmation of the previously determined lack of association between the PHDI and overweight/obesity status, the other three indices used to assess adherence to the EAT-Lancet dietary pattern (ELI, WISH, and HSDI) also did not show an association between adherence to the reference pattern and the prevalence of overweight/obesity after adjusting for sex and age (Model A2), and for sex, age, total energy intake, country, socioeconomic status, and physical activity level (Model B2) (Table 4). Correlation analyses among indices used to assess adherence to the reference diet showed significantly positive correlations between the PHDI and each additional index (ELI: rs=0.62; WISH: rs=0.55; HSDI: rs=0.50; $p<0.001$) (data not shown).

Table 4. Association between adherence to different EAT-Lancet dietary indices and overweight/obesity status among participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6683).

Model	Index	Overweight/obesity			Global test
		PR[1]	95% CI	*p*-value[2]	*p*-value[3]
Unadjusted	PHDI	1.003	1.001 – 1.005	0.008	0.008
	ELDI	1.005	0.999 – 1.011	0.115	0.115
	WISH	1.000	0.999 – 1.002	0.731	0.731
	HSDI	1.009	0.994 – 1.025	0.246	0.246
Model A2[4]	PHDI	1.001	0.999 – 1.003	0.181	<0.001
	ELDI	0.999	0.993 – 1.005	0.741	<0.001
	WISH	0.999	0.998 – 1.007	0.283	<0.001
	HSDI	0.989	0.974 – 1.004	0.136	<0.001
Model B2[5]	PHDI	1.001	0.999 – 1.004	0.210	<0.001
	ELDI	1.000	0.994 – 1.006	0.909	<0.001
	WISH	1.000	0.998 – 1.001	0.808	<0.001
	HSDI	1.002	0.986 – 1.017	0.846	<0.001

Bivariate and multivariate Poisson regression with robust variance analysis: [1]Prevalence ratio of overweight/obesity for each EAT-Lancet index. [2]*p*-value corresponds Wald test for each index as a continuous variable with each model. [3]*p*-value corresponds to the global test of the model. PHDI: Planetary Health Diet Index; ELDI: EAT-Lancet Diet Index; WISH: World Index for Sustainability and Health; HSDI: Mexican Healthy and Sustainable Diet Index.

[4]Model A2: adjusted for sex and age. [5]Model B2: adjusted for sex, age, total energy intake, country, socioeconomic status, and physical activity level.

4. Discussion

This is the first study aimed to assess the association between adherence to the EAT-Lancet dietary pattern, as measured by the PHDI, and the prevalence of overweight/obesity among urban populations in eight Latin American countries. Our results showed that high adherence to the EAT-Lancet diet was not significantly associated to a lower prevalence of overweight/obesity. This finding contrasts with those observed in the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil 2008-2010) (8) and the Multiethnic Cohort Study in Hawaii and Los Angeles (14), which reported positive associations between adherence to the EAT-Lancet diet and a lower prevalence or risk of overweight/obesity. However, results from the Finnish Institute of Health and Welfare (15) and the Brazilian National Dietary Survey 2017-2018 (16) align with our findings. The lack of association was confirmed in this study by applying other indices (ELDI, WISH, and HSDI) designed to evaluate adherence to the EAT-Lancet diet to the same sample, confirming that the results were consistent regardless of the index used to assess adherence to the reference diet.

Another factor that could explain why high adherence to the EAT-Lancet diet did not correlate with overweight/obesity in our study is the high prevalence of overweight/obesity within the ELANS sample, which is uniformly distributed across all PHDI quintiles (Table 1, Figure 1). This uniformity makes it challenging to identify a higher prevalence of overweight/obesity among participants based on their adherence to the EAT-Lancet dietary pattern. However, the Multiethnic Cohort Study in Hawaii and Los Angeles found an association between adherence to the EAT-Lancet dietary pattern and overweight/obesity, despite a similar prevalence of overweight/obesity (58.7%) compared to our study (60.1%) (14). This suggests that obesity prevalence may not be a significant factor influencing the relationship between adherence to the EAT-Lancet diet and the prevalence or risk of overweight/obesity.

The level of adherence to the EAT-Lancet dietary pattern appears to be a critical factor in its association with overweight/obesity. Studies with different designs (cross-sectional or longitudinal), such as those conducted by Cacau *et al.* (7,8) and Klapp *et al.* (14), which reported higher average adherence to the EAT-Lancet dietary pattern (40.2% and 52.1%, respectively), found a significant negative association between adherence and overweight/obesity. Additionally, in the study conducted by Klapp *et al.* (14), the highest percentage of individuals with weight excess was concentrated in the lower adherence groups to the EAT-Lancet dietary pattern, rather than being evenly distributed across all adherence levels as observed in our study.

In our study, the average adherence to the EAT-Lancet dietary pattern was relatively low, at 29.7%, ranging from 25.8% in Argentina to 32.9% in Costa Rica. Similarly, other studies with different designs, such as those by Marchioni *et al.* (16) and Suikki *et al.* (15), which reported lower relative adherence (30.6% and 27.7%, respectively), also did not find an association between adherence to the dietary pattern and overweight/obesity. This suggests that, more important than the study design, the lower adherence to the EAT-Lancet dietary pattern, combined with the narrow range of variation in PHDI score values observed across the study sample, could explain the difficulty in distinguishing the higher prevalence of overweight/obesity among participants according to their degree of adherence to the dietary pattern, as previously suggested by Suikki *et al.* (15). This evidence is supported by two cross-sectional studies conducted in Brazil (8,16), both of which reported similar prevalence of overweight/obesity: 58.4% for ELSA-Brazil 2008-2010 (47) and 52.9% for the Brazilian National Dietary Survey 2017-2018 (16). An association between adherence to the EAT-Lancet dietary pattern and overweight/obesity was identified only in the study with relatively higher adherence to the EAT-Lancet dietary pattern (≥40%) (8); in contrast,

no association was found in the other study, where adherence was lower (30.6%) (16). Despite this evidence, further studies are required to validate our explanation for the results of this study.

This study has several strengths and limitations. The strengths include: 1) The use of the 24-hour dietary recall method for collecting food intake data, which is more accurate than the food frequency questionnaire used in similar studies. 2) The PHDI scores proportionally and more precisely account for intermediate intakes of the EAT-Lancet dietary pattern compared to other reference diet-based indices composed of binary food components (35). 3) The large plausible sample size, comprised only by plausible reporters of energy intake, provided precise mean values, identified outliers, and reduced the margin of error when assessing adherence to the reference pattern. 4) The methodology (multivariate Poisson regression models with robust variance) used to assess the association between adherence to the dietary pattern and the prevalence of overweight/obesity is robust, has been previously applied (12), and is preferred over logistic regression to avoid overestimating risk, particularly in cross-sectional studies and when dealing with events of high prevalence (39–43). However, there are limitations: 1) The study was limited to urban areas in eight Latin American countries, excluding rural regions and other nations in the area, so the findings cannot be generalized to the entire Latin American region. 2) These results should be interpreted in the context of the study design, which is a cross-sectional analysis and only assesses association but not causality. 3) The disaggregation of ultra-processed foods to include their content of added sugar, vegetable oils, and animal (saturated) fat in the PHDI calculation might be subject to bias. To minimize errors, this process was reviewed by four trained nutritionists. While the study has robust methodologies and provides valuable insights, the limitations should be considered when interpreting the results.

5. Conclusion

Our study did not identify a significant association between adherence to the EAT-Lancet dietary pattern and the prevalence of overweight/obesity in a Latin American multicentric study. The consistently high prevalence of overweight/obesity across all levels of adherence to the EAT-Lancet pattern and the study's design do not appear to be key factors in explaining this lack of association. Instead, the relatively low average adherence to the reference pattern within the study sample seems to be the primary reason for the absence of a significant association. However, future studies are needed to confirm this conclusion.

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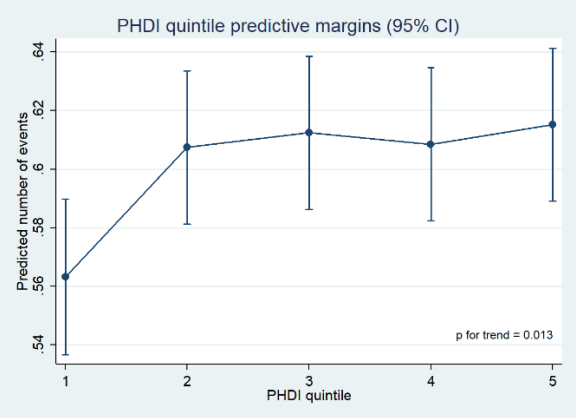
Supplementary materials

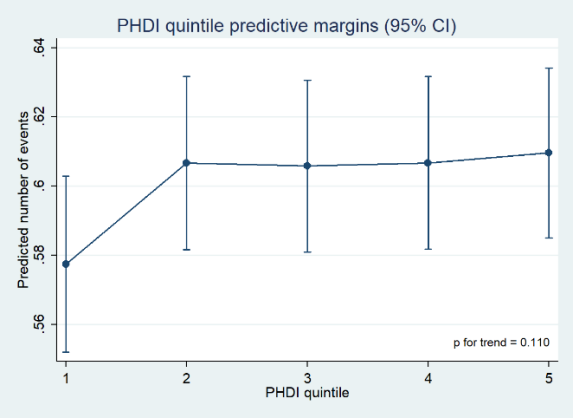
Adherence to the EAT-Lancet Diet is not Associated with Weight Status in a Latin American Urban Multicentric Study

Figure S1. PHDI quintile predictive margins for overweight/obesity[1] status among participants in the Latin American Study of Nutrition and Health (ELANS, 2016) (n=6683).

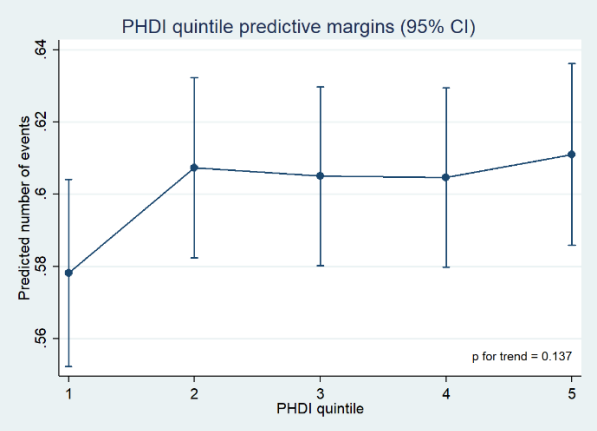
Unadjusted



Model 1



Model 2



[1]Bivariate and multivariate Poisson regression with robust variance analysis. Model 1: adjusted for sex and age. Model 2: adjusted for sex, age, total energy intake, country, socioeconomic status, and physical activity level. PHDI quintiles: min–max score / 1st: 13.4–36.7; 2nd: 36.8–42.0; 3rd: 42.1–46.8; 4th: 46.9–52.3; 5th: 52.4–82.8. Overweight/obesity according to participants' body mass index classification.

DISCUSIÓN GENERAL

Esta investigación en ocho países de América Latina proporciona conocimientos fundamentales sobre los desafíos e implicaciones de adherirse al patrón alimentario de EAT-Lancet dentro de poblaciones urbanas de la región. Estos hallazgos son relevantes ya que abordan tanto la insuficiencia de la ingesta de micronutrientes asociada a este patrón alimentario como su asociación con la prevalencia de sobrepeso y obesidad en la región.

Adherencia al patrón alimentario de EAT-Lancet: Desafíos e implicaciones

Los análisis revelaron de forma consistente una baja adherencia relativa al patrón alimentario de EAT-Lancet en el área urbana de la región latinoamericana. Esta observación coincide con estudios similares realizados a nivel global, incluyendo Brasil (1), México (2), Estados Unidos (3), Europa (4–8) y África (9). La baja adherencia consistente en diversas regiones sugiere que el patrón alimentario de EAT-Lancet puede no alinearse fácilmente con los hábitos dietéticos y las prácticas culturales de las poblaciones, particularmente en los países en desarrollo.

En América Latina, varios factores contribuyen a esta baja adherencia, incluyendo las limitaciones económicas que juegan un papel fundamental. El costo de adherirse al patrón alimentario de EAT-Lancet es prohibitivamente alto para muchas personas en estas poblaciones urbanas (10–13), donde las tasas de pobreza son significativas y están aumentando debido a la urbanización acelerada (14). Los estudios destacan que el costo de la dieta de EAT-Lancet excede los ingresos diarios de una gran parte de la población, haciéndola inaccesible para muchos (10–13). Esta barrera económica es particularmente pronunciada en las áreas urbanas, donde la inseguridad alimentaria y el acceso limitado a grupos diversos de alimentos son prevalentes (14), lo que limita aún más la capacidad de las personas para adherirse a este patrón alimentario.

Además, los hábitos dietéticos en América Latina divergen significativamente de las recomendaciones de EAT-Lancet. Incluso en países con una adherencia relativamente mayor, como

Costa Rica y Brasil, sigue existiendo una brecha sustancial entre las prácticas dietéticas reales y el modelo ideal de EAT-Lancet. Los estudios señalan que, aunque el consumo de alimentos beneficiosos para la salud como nueces, semillas, leguminosas, frutas y vegetales es generalmente bajo (15), existe un consumo excesivo de alimentos que la dieta EAT-Lancet recomienda limitar, como las carnes rojas (16), las grasas saturadas de origen animal y los azúcares añadidos (17). Esta discrepancia entre la dieta tradicional de la región y las directrices de EAT-Lancet subraya los desafíos de implementar un patrón alimentario global sin considerar las culturas alimentarias y preferencias locales (18,19).

Riesgos nutricionales asociados con una mayor adherencia al patrón alimentario

Un hallazgo fundamental de esta investigación es la asociación entre una mayor adherencia al patrón alimentario de EAT-Lancet y un mayor riesgo de ingestas inadecuadas de ciertos micronutrientes, como cobalamina, vitamina D y calcio. Estos nutrientes se encuentran predominantemente en alimentos de origen animal, que son limitados en el modelo dietético EAT-Lancet. Esto plantea preocupaciones sobre la adecuación nutricional de la dieta, particularmente en poblaciones con mayores necesidades nutricionales o acceso limitado a un suministro alimentario diverso.

La naturaleza restrictiva de la dieta EAT-Lancet, que enfatiza los alimentos de origen vegetal a expensas de los productos animales, podría llevar inadvertidamente a deficiencias nutricionales. Esto es particularmente preocupante en regiones como América Latina, donde la prevalencia de ingesta inadecuada de calcio y vitamina D ya es alta (20). Los estudios sugieren que, para que la dieta EAT-Lancet sea más aplicable y beneficiosa, podría requerir adaptaciones significativas, como la inclusión de alimentos fortificados o suplementos dietéticos para abordar estas posibles deficiencias. América Latina tiene una sólida historia de programas de fortificación de alimentos

destinados a erradicar las deficiencias nutricionales (21,22), y el tomar estos alimentos en cuenta dentro del patrón alimentario podría desempeñar un papel crucial para garantizar que la dieta cumpla con las necesidades nutricionales de la población.

Relación entre la adherencia al patrón alimentario y el sobrepeso/obesidad

El segundo enfoque de esta investigación fue evaluar la asociación entre la adherencia al patrón alimentario de EAT-Lancet y la prevalencia de sobrepeso y obesidad. Contrariamente a algunas investigaciones realizadas en Brasil (23), México (2), Estados Unidos (24) y Dinamarca (25), esta investigación no encontró una asociación significativa entre una alta adherencia a la dieta EAT-Lancet y menor prevalencia de sobrepeso/obesidad. Este hallazgo es particularmente notable dado las altas tasas de sobrepeso y obesidad observadas en las poblaciones estudiadas.

Se ofrecen varias explicaciones para esta falta de asociación. Una posibilidad es la alta prevalencia de sobrepeso y obesidad de manera uniforme en todos los niveles de adherencia dentro de la muestra de estudio, lo que podría haber dificultado evidenciar cualquier efecto protector potencial de la dieta. Además, la relativamente baja adherencia al patrón alimentario de EAT-Lancet observada en las poblaciones estudiadas podría ser insuficiente para producir un impacto medible en la prevalencia de exceso de peso (sobrepeso y obesidad). Otros estudios con niveles de adherencia más altos han reportado una asociación negativa entre la adherencia a la dieta EAT-Lancet y el exceso de peso (23,24), lo que sugiere que podría ser necesario un umbral de adherencia mayor para poder observar una asociación entre la adherencia al patrón alimentario de EAT-Lancet y la prevalencia de sobrepeso/obesidad (7).

Esto plantea preguntas importantes sobre la practicidad y efectividad del patrón alimentario de EAT-Lancet para reducir la obesidad en poblaciones con hábitos dietéticos arraigados y alta prevalencia de sobrepeso y obesidad. Los estudios sugieren que, aunque la dieta EAT-Lancet puede

tener un potencial teórico, su aplicación en el mundo real en contextos culturales y económicos diversos requiere una investigación adicional y, potencialmente, adaptaciones significativas.

Fortalezas, limitaciones y direcciones futuras

Esta investigación utilizó una metodología robusta, tanto para la recolección de datos como para el análisis de estos. El uso de dos recordatorios de 24 horas, la determinación del consumo usual de micronutrientes y componentes del IDSP y la desagregación de alimentos ultraprocesados para el cálculo del IDSP verificada por personal entrenado en análisis de consumo de alimentos brinda alta confiabilidad a los resultados obtenidos. Adicionalmente, el uso de modelos lineales generalizados y modelos de regresión de Poisson multivariante con varianza robusta (en lugar de modelos de regresión logística) les dan alta credibilidad a los hallazgos. El uso de los modelos de Poisson con varianza robusta evita la sobreestimación del riesgo característica de la razón de momios de la regresión logística, especialmente en estudios transversales y cuando se trata de eventos de alta prevalencia (≥10%) (26–30).

Por otro lado, los estudios derivados de esta investigación también presentan limitaciones. El enfoque solo en áreas urbanas excluye a las poblaciones rurales y el diseño transversal permite estudiar asociaciones pero limita la capacidad de establecer relaciones causales.

Este estudio subraya la necesidad de realizar más investigaciones en el futuro para validar hallazgos reportados en los manuscritos y sugiere la necesidad de explorar cómo el patrón alimentario de EAT-Lancet puede adaptarse efectivamente a los contextos locales. Esto incluye considerar la viabilidad económica, las preferencias culturales y las necesidades nutricionales para mejorar la adherencia y lograr los resultados de salud previstos.

Los hallazgos de estos estudios destacan los desafíos significativos de implementar el patrón alimentario de EAT-Lancet en América Latina. La baja adherencia relativa, los posibles riesgos

nutricionales y la falta de asociación con la reducción de la exceso de peso subrayan la necesidad de adaptaciones regionales importantes de la dieta latinoamericana. Estas adaptaciones deben ser culturalmente sensibles, económicamente viables y nutricionalmente adecuadas para apoyar tanto la salud como la sostenibilidad en la región. A medida que la conversación global sobre dietas sostenibles continúa, estos conocimientos provenientes de América Latina proporcionan lecciones valiosas sobre las complejidades de traducir las directrices dietéticas globales en prácticas locales.

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CONCLUSIÓN GENERAL

La investigación actual sobre la aplicabilidad del patrón alimentario de EAT-Lancet en el contexto latinoamericano ha destacado varias consideraciones críticas que deben abordarse para mejorar su efectividad y adherencia en la región. La baja adherencia observada al patrón alimentario de EAT-Lancet puede atribuirse en gran medida a la significativa divergencia entre las prácticas dietéticas tradicionales de las poblaciones latinoamericanas y el modelo global propuesto. Esta discrepancia subraya la necesidad de realizar adaptaciones culturales y nutricionales sustanciales al patrón EAT-Lancet para que sea más relevante y alcanzable para los latinoamericanos.

Un aspecto clave de estas adaptaciones implica la integración de alimentos que están profundamente arraigados en las tradiciones culinarias de la región y que contribuyen a la nutrición en salud pública. Por ejemplo, se debe enfatizar en los alimentos básicos fortificados, así como otros que sean fuente de nutrientes esenciales como la cobalamina, el calcio y la vitamina D, especialmente dado que estos nutrientes fueron identificados con ingesta inadecuada entre quienes tienen una alimentación que se adhiere más el patrón de EAT-Lancet. Al ajustar las recomendaciones dietéticas para incluir alimentos culturalmente significativos y nutricionalmente fundamentales, podría ser posible fomentar una mayor adherencia a una dieta que sea tanto sostenible como alineada con los objetivos de salud pública.

Paralelamente, la relación entre la adherencia al patrón alimentario de EAT-Lancet y la prevalencia de sobrepeso y obesidad en América Latina merece un análisis más profundo. Este estudio no encontró una asociación significativa entre estos factores, lo que sugiere que simplemente seguir las pautas de EAT-Lancet puede no ser suficiente para abordar la alta prevalencia de sobrepeso y obesidad observadas en la región. La prevalencia consistentemente elevada de estas condiciones en todos los niveles de adherencia indica que otros factores

(posiblemente incluyendo los hábitos dietéticos generales, los niveles de actividad física, las condiciones socioeconómicas y las predisposiciones genéticas) pueden jugar un papel más influyente en la determinación de los resultados de exceso de peso que la adherencia a este patrón alimentario en particular.

Además, la relativamente baja adherencia promedio al patrón de EAT-Lancet dentro de la muestra de estudio probablemente contribuyó a la ausencia de una asociación significativa. Este hallazgo sugiere que cualquier beneficio potencial de la dieta EAT-Lancet puede estar enmascarado o diluido en poblaciones donde la adherencia no es lo suficientemente elevada. Por lo tanto, futuras investigaciones deberían explorar estas dinámicas con mayor profundidad, incorporando potencialmente intervenciones diseñadas para aumentar la adherencia y examinando los resultados de salud subsecuentes.

En conclusión, aunque el patrón alimentario de EAT-Lancet ofrece un marco prometedor para una alimentación saludable y sostenible, su implementación exitosa en América Latina requiere una cuidadosa adaptación a las prácticas dietéticas locales y una comprensión más profunda de los múltiples factores que contribuyen a los desafíos de salud pública como el exceso de peso. Son esenciales más estudios para refinar estas recomendaciones dietéticas y evaluar su impacto a largo plazo en los resultados de salud dentro de las diversas poblaciones latinoamericanas.

RECOMENDACIONES GENERALES

Adaptación cultural y nutricional del patrón alimentario de EAT-Lancet

Es fundamental adaptar el patrón alimentario de EAT-Lancet para que sea más compatible con las tradiciones culinarias y las preferencias culturales de las poblaciones latinoamericanas. Esto podría incluir la integración de alimentos típicos de la región que sean fuentes importantes de nutrientes críticos como la cobalamina, el calcio y la vitamina D, los cuales se han identificado como deficientes en dietas que siguen este patrón.

Viabilidad económica y accesibilidad

Se recomienda llevar a cabo estudios adicionales que evalúen la viabilidad económica de adherirse al patrón EAT-Lancet en diferentes contextos socioeconómicos dentro de América Latina. Esto incluiría el análisis del costo de los alimentos propuestos y el desarrollo de estrategias para hacer que estos alimentos sean más accesibles para las poblaciones urbanas, especialmente en áreas con altas tasas de pobreza e inseguridad alimentaria.

Fortificación de alimentos y suplementación

Dada la identificación de posibles ingestas inadecuadas de micronutrientes asociados con una mayor adherencia al patrón alimentario de EAT-Lancet, se recomienda considerar la inclusión en el patrón de alimentos de consumo masivo fortificados como estrategia complementaria. Esta medida podría ayudar a garantizar que la dieta no solo sea sostenible, sino también nutricionalmente adecuada para la población.

Investigaciones futuras en relación con el sobrepeso y obesidad

Es necesario realizar investigaciones adicionales que exploren la relación entre la adherencia al patrón alimentario de EAT-Lancet y la prevalencia de sobrepeso y obesidad en América Latina. Dado que este estudio no encontró una asociación significativa, futuras investigaciones podrían

centrarse en identificar otros factores que influyen en el exceso de peso, como los hábitos dietéticos generales, los niveles de actividad física, y las condiciones socioeconómicas.

Promoción de la adherencia al patrón alimentario

Para maximizar los beneficios potenciales del patrón alimentario de EAT-Lancet, se recomienda valorar la necesidad de realizar intervenciones educativas y políticas públicas que fomenten una mayor adherencia a este modelo. Estas intervenciones deberán ser culturalmente sensibles y estar diseñadas para superar las barreras económicas y sociales que actualmente limitan la adopción de la dieta en la región.

Evaluación continua y ajustes del patrón alimentario

Dado que la aplicabilidad y los efectos del patrón alimentario de EAT-Lancet pueden variar significativamente en diferentes contextos, se recomienda una evaluación continua de su implementación en América Latina. Esto permitirá realizar los ajustes necesarios para garantizar que la dieta sea efectiva en mejorar los resultados de salud pública a largo plazo.