UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
FACULDADE DE MEDICINA
PROGRAMA DE PÓS-GRADUAÇÃO EM EPIDEMIOLOGIA

TESE DE DOUTORADO

GRAU DE PROCESSAMENTO DE ALIMENTOS E PRESSÃO ARTERIAL EM ADULTOS E ADOLESCENTES DE PORTO ALEGRE

SINARA LAURINI ROSSATO

Orientador: Prof. Dr. SANDRA COSTA FUCHS

Porto Alegre

2013

CIP - Catalogação na Publicação

Laurini Rossato, Sinara
GRAU DE PROCESSAMENTO DE ALIMENTOS E PRESSÃO ARTERIAL EM ADULTOS E ADOLESCENTES DE PORTO ALEGRE / Sinara Laurini Rossato. -- 2013.
133 f.

Orientadora: Sandra Costa Fuchs.

Tese (Doutorado) -- Universidade Federal do Rio Grande do Sul, Faculdade de Medicina, Programa de Pós-Graduação em Epidemiologia, Porto Alegre, BR-RS, 2013.

1. Grau de processamento de alimentos. 2. Pressão arterial. 3. Adultos. 4. Adolescentes. 5. Ingestão de Nutrientes. I. Costa Fuchs, Sandra, orient. II. Título.

Elaborada pelo Sistema de Geração Automática de Ficha Catalográfica da UFRGS com os dados fornecidos pelo(a) autor(a).

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A apresentação desta tese é exigência do Programa de Pós-graduação em Epidemiologia, Universidade Federal do Rio Grande do Sul, para obtenção do título de Doutor.

Porto Alegre, Brasil

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AGRADECIMENTOS

A FAMÍLIA:

Agradeço em primeiro lugar ao meu Pai, Aldo Rossato, que acreditou desde o início.
A minha Mãe, Sirley Rossato, que à sua maneira, teve contribuição essencial e carinhosa, principalmente na fase final.
Aos meus irmão, Evandro e Gustavo Rossato, e suas famílias, Maristela e Igor, e Virgínia e Helena, compeenderam e apoiaram a minha escolha.
E principalmente, à Minha filha, companheira e compreensiva, que com muito carinho esteve ao meu lado à cada minuto.

A MINHA ORIENTADORA:

A Prof Sandra Fuchs, que teve contribuição crucial para o desenvolvimento dessa tese. Oportunizando o aprendizado e desenvolvimento profissional. Serei sempre grata pelas oportunidade, empenho incansável e por compartilhar da sua sabedoria.

AOS MENTORES

Tive a oportunidade de conhecer e trabalhar com pesquisadores que admiro profundamente pelo legado científico e profissional, são eles: Profa Leila Beltrami Moreira e Prof Flávio Fuchs, com quem compartilhei espaço ao longo do processo de doutoramento.
Também agradeço o aceite do Prof. Dr. Walter Willett, e a recepção do Prof. Dr. Eric Rimm e Prof. Dr. Darish Mozzafarium, por quem fui atenciosamente recebida na Harvard School of Public Health durante o período sanduíche.

AOS AMIGOS E COLEGAS

Agradeço de coração o apoio de colega e amigos, que paticiparam direta ou indiretamente nesta etapa.

“Quanta é a verdade que um espírito suporta, quanta é a verdade que ele ousa?
Essa foi, pra mim, e cada vez mais, a tábua para medir valores.
Engano (- a crença no ideal -) não é cegueira, engano e covardia…
Toda a conquista, todo o passo adiante no conhecimento é consequência da coragem, da dureza em relação a si mesmo, de decência consigo mesmo… Eu não refuto ideiais, eu apenas visto luvas diante deles…”

(Friedrich Nitzche – Ece Homo, pg 17)

Dedicatória

Com carinho
Aos meus pais
Aldo Rossato
Sirley Maria Laurini Rossato

Aos meus irmãos e suas famílias
Evandro, Maristela e Igor,
Gustavo, Virgínia e Helena,

Com amor, a minha filha
Isadora Rossato Sartori, que esteve carinhosamente presente em todos os momentos.

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ABREVIATURAS E SIGLAS

24hDR – 24 hour Dietary Recall
95%CI – 95% Confidence Interval
AGEs – Advanced Glycoxidation End Products
AIC - Akaike's Information Criterion
ALEs – Advanced Lipoxidation end Products
BP – Blood Pressure
BMI – Body Mass Index
Cr - Creatinina
DASH – Dietay Approach to Stop Hypertension
DRI – Dietary Refference Intake
FBA – Folhas de Balanço Alimentar
FFQ – Food Frequency Questionnaire
GLM – Generalized Linear Model
IMC – Indice de Massa Corporal
IC95% - Intervalo de confianca de 95%
JNC – Joint National Commitee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure
K/Na – Razão potassio / sódio
LDL-c – Low Density Lipoprotein colesterol.
Na – Sódio
Na/K – Razão sódio / potássio
NHANES – National Health Examination Survey
OMS – Organização Mundial de Saúde
PA – Pressão aterial
PAD – Pressão arterial diastólica
PAS – Pressão arteerial sistólica
POF – Pesquisa de Orçamento Familiar
RA24h – Recordatórios de 24 horas
SOFT – Estudo da síndrome de obesidade e fatores de risco cardiovasculares
TACO – Tabela Brasileira de composição quimica de alimentos
QFA – Questionário de Frequência Alimentar
USDA – National Nutrient Database for Standard Reference
WHO – World Health Organization

SUMÁRIO

RESUMO

Objetivo: Este estudo avaliou a relação entre o grau de processamento de alimentos e o teor de nutrientes da dieta e também com a pressão arterial em adolescentes e adultos de Porto Alegre.

Métodos: A hipóteses foi testada atravéz de em um estudo transversal, com amostra probabilística, onde foram recrutados 599 adolescentes e 1685 adultos, participantes do estudo SOFT (Estudo da síndrome de obesidade e fatores de risco cardiovasculares). Em uma sub amostra de adolescentes e adultos, recrutada com a finalidade de validar o questionário de frequência de consumo alimentar (QFA), a dieta foi avaliada por meio de dois recordatórios de 24 horas (RA24h) consecutivos. Informações dos RA24h foram utilizadas para desmembrar receitas e estimar a ingestão de ingredientes culinários. Alimentos foram agregados em três grupos: não processados, moderadamente processados e ultra-processados analisados em gramas por dia em tercis de ingestão (gramas por dia) e padrões alimentares baseados em diferentes combinações dos três grupos alimentares foram comparados a reomendações de ingestão de nutrientes para a dieta DASH (*Dietary approach to stop Hypertension*). Adolescentes e adultos do estudo SOFT foram avaliados com o mesmo QFA, com 135 itens. Peso e altura foram obtidos com equipamentos calibrados, de forma padronizada, por assistentes de pesquisa certificados. Medidas de pressão arterial foram realizadas durante a entrevista, utilizando monitor oscilométrico e a média de quatro aferições foi empregada na análise. Informações sobre sexo, idade, escolaridade, atividade física, tabagismo, consumo de bebidas alcoólicas foram obtidas com questionario padronizado. Todos os participantes assinaram o termo de consentimento livre e esclarecido. Análise estatística foi baseada em modelos lineares generalizados.

Resultados: Este estudo mostrou que a ingestão de alimentos moderadamente processados é maior entre os homens e indivíduos adultos de ambos os sexos e a ingestão de alimentos ultra-processados reduz com a idade. Quanto maior o grau de processamento, maior o teor de energia e carboidratos da dieta. O consumo de alimentos não processados associa-se com elevado teor de proteínas, fibras, cálcio e magnésio. Alimentos moderadamente processados resultaram em maior teor de gordura e sódio. Enquanto o elevado teor de potássio é nítidamente explicado pelo

consumo de não processados, o contrário ocorre com o sódio. A ingestão de proteínas, fibras, cálcio, magnésio e potássio foi diretamente relacionada com aumento do consumo de alimentos não processados. A ingestão de alimentos moderadamente processados foi inversamente relacionada com o teor de cálcio, e houve uma tendência a uma relação direta com sódio, enquanto a ingestão de alimentos ultra-processados foram associados negativamente com fibra e de potássio. O teor de fibras, magnésio e potássio da dieta foi maior quando o padrão alimentar foi composto por alta ingestao de alimentos não processados e baixa de moderadamente e ultra-processados. Quando houve alta ingestão de alimentos ultra-processados combinada com baixa ingestão de não processados, a meta para ingestão de sódio e energia foi ultrassada. Entre adolescentes, ao analisar o consumo dos alimentos classificados de acordo com o grau de processamento em gramas por dia, houve um efeito inverso entre o consumo de ultra-processados e a pressão arterial sistólica. Ao combinar os três grupos alimentares, a pressão arterial sistólica foi 4.6 mmHg (P=0.01) maior entre adolescentes com baixa ingestão (tercil 1) dos três grupos alimentares em comparação aqueles que tiveram uma dieta com baixa ingestão de não processados (tercil 1), intermediária de moderadamente processados (tercil 2) e alta em ultra-processados (tercil 3).

Entre os adultos, não houve associação entre a pressão arterial sistólica e diastólica de acordo com aumento, em tercis, no consumo de alimentos não processsados, moderadamente e ultra-processados e houve um significativo efeito de interação entre o grau de processamento e indice de massa corporal. Ao testar combinações de grupos alimentares observou-se que a pressão arterial sistólica foi 7,7 mmHg menor para indivíduos com ingestão baixa ingestão dos tres grupos alimentares (tercil 1) em comparação aqueles cujo dieta teve baixa ingestão de não processados (tercil 1) e alta de moderadamente e ultra-processados (tercil 3).

Conclusões: Conclui-se portanto, que o grau de processamento de alimentos influencia o teor de energia, fibras e micronutrientes da dieta. Em adolescentes o consumo de alimentos ultra-processados foi inverso a pressão arterial. Entre adultos houve interação entre o índice de massa corporal e o grau de processamento de alimentos. Entre adolescentes e adultos a combinação dos grupos alimentares associa-se significativamente com a variação da pressão arterial. Para ambos, a maior participação dos alimentos moderadamente e ultra-processados em detrimento de não

processados na ingestão alimentar total, associa-se com elevação da pressão arterial sistólica e diastólica. Salienta-se que este é o primeiro estudo avaliando o efeito do grau de processamento dos alimentos sobre a pressão arterial e que o delineamento do estudo implica potenciais limitações.

Palavras chave: Processamento de alimentos, pressão arterial, alimentos processados, pressão arterial, hipertensão arterial.

SUMMARY

Objective: This study evaluated the relationship between the degree of food processing and the nutrient content of the diet and tested the relationship between the degree of processing and blood pressure in adolescents and adults of Porto Alegre.

Methods: The hypothesis was tested in a transversal study, with a probabilistic sample, where 599 adolescents and 1685 adults were recruited, participants of the SOFT study (A study on the obesity syndrome and cardiovascular risk factors). In a sub-sample of adolescents and adults, recruited with the intention to validate the questionnaire on frequency of food consumption (FFQ), diet was evaluated via two consecutive 24-hour dietary recalls (24h-DR). Information from the 24h-DR was used to break down recipes and estimate the intake of culinary ingredients. Foods were aggregated in three groups: unprocessed, moderately processed and ultra-processed, which were analyzed in grams per day in tertiles (grams per day) and food patterns based on the combination of the three food groups were compared to the DASH diet eating plan recommendation (Dietary Approach to Stop Hypertension). Adolescents and adults of the SOFT study were evaluated with the same FFQ, with 136 items. Weight and height were obtained with calibrated equipment, in standardized form, by certified research assistants. Blood pressure measurements were realized during the interview, utilizing an oscillometric monitor and a mean of four calibrations were used in the analysis. Information on sex, age, education level, physical activity, smoking habits, alcohol consumption was obtained with a standardized questionnaire. All of the participants signed the term of free and clear consent. Statistical analysis was based on generalized linear models.

Results: This study showed that the intake of moderately processed foods is greater among men and adult individuals of both sexes and the intake of ultra-processed foods reduces with age. The greater the degree of processing, the greater the energy and carbohydrate content of the diet. The consumption of unprocessed foods is associated with an elevated content of proteins, fibers, calcium and magnesium. Moderately processed foods results in higher fat and sodium content. While the elevated potassium content is clearly explained by the consumption of unprocessed foods, the contrary occurs with sodium. The intake of proteins, fibers, calcium, magnesium and potassium was directly related with the increase in consumption of unprocessed foods. The intake

of moderately processed foods was inversely related with the calcium content, and there was a tendency to associate directly with sodium content; whereas, the intake of ultra-processed foods was negatively related with fiber and potassium. The dietary fiber, magnesium, and potassium contents were clearly improved when the food pattern was composed of a higher intake of unprocessed foods and a lower intake of moderately and ultra-processed. It was unlikely to achieve the target recommendation of sodium and energy when there was a higher intake of ultra-processed combined with a lower intake of unprocessed food products.

Among adolescents, in analyzing the consumption of foods classified by processing degree in grams per day, there was an inverse relationship between consumption of ultra-processed foods and systolic blood pressure. In combining the three food groups, the systolic blood pressure was 4.6 mmHg (P=0.01) higher among adolescents with lower intake of the three foods groups in comparison to those who have a diet with lower intake of unprocessed foods (1st tertile), intermediate intake of moderately processed (2nd tertile) and higher intake of ultra-processed foods (3rd tertile) The diastolic blood pressure was not different according to food groups combination.

Among adults, there was no association between the systolic and diastolic blood pressures according to increase, in tertiles, in consumption of unprocessed, moderately processed and ultra-processed foods, and there was a significant effect of interaction between the processing degree and body mass index. In testing combinations of food groups, we observed that the systolic blood pressure was 7.7 mmHg lower for individuals with lower intake of all the three food groups (1st tertile) in comparison to those who diet had lower intake of unprocessed (1st tertile), and higher intake of moderately and ultra-processed (3rd tertile). In comparing the systolic blood pressure of those who had lower intake of the three food groups and who consumed lower amounts of unprocessed and ultra-processed food products and higher amounts of moderately, the SBP was equally higher (130,2 and 130.1 mmHg).

Conclusions: We conclude, therefore, that the degree of food processing influences the energy, fiber and micronutrient content of the diet. In adolescents, the consumption of ultra-processed foods was inverse to blood pressure. Among adults, there was an interaction between body mass index and the degree of food processing. Among

adolescents and adults, the combination of food groups is significantly associated with blood pressure variations. For both, a greater consumption of moderately and ultra-processed foods in detriment of unprocessed foods in total food intake, is associated with reduced systolic blood pressure levels. We highlight that this is the first study evaluating the effect of the degree of food processing on blood pressure and the design of this study implies potential limitations.

Key words: Food processing, blood pressure, processed foods, blood pressure, arterial hypertension.

APRESENTAÇÃO

Este trabalho consiste na tese de doutorado intitulada "GRAU DE PROCESSAMENTO DE ALIMENTOS E PRESSÃO ARTERIAL", apresentada ao Programa de Pós-Graduação em Epidemiologia, da Universidade Federal do Rio Grande do Sul, em 15 de agosto de 2013. O trabalho é apresentado em três partes, na ordem que segue:

1. Introdução, Revisão da Literatura e Objetivos.
2. Artigo (s).
3. Conclusões e Considerações Finais.

Documentos de apoio estão apresentados em anexos.

INTRODUÇÃO

O efeito do grau de processamento de alimentos sobre o teor de nutrientes da dieta e seu potencial efeito sobre o desenvolvimento de doenças não transmissíveis apresenta uma abordagem relativamente recente, proposta por um brasileiro, Professor Carlos Augusto Monteiro. A avaliação do efeito de transformações físico-químicas dos alimentos da dieta sobre desfechos em saúde vai além da composição da dieta *per se*, amplamente documentada na literatura, e situa a questão no pós-transição nutricional.

O trabalho de Monteiro e colaboradores, inovador e abrangente, foi operacionalizado em dados secundários, coletados para amostra da população brasileira. Portanto, uma proposta de contribuição deveria agregar algum componente novo, que permitisse aumentar a qualidade da informação, visto que dificilmente poderia expandir sua abrangência. Nessa tese, utilizaram-se dados de recordatório alimentar de 24 horas, coletados para adultos e adolescentes de Porto Alegre, para detalhar o consumo, obtendo-se a descrição das receitas, que foram posteriormente desmembradas para estimarem-se macro e micronutrientes. Com isso, foi possível obterem-se dados sobre micronutrientes de uma base quantitativa detalhada, a partir da qual houve estimação. A resultante inclui proposta de modificação na classificação de alguns alimentos, justificada no texto.

Assim, essa tese aborda o consumo de alimentos classificados de acordo com o grau de processamento, sob dois aspectos complementares. Primeiramente, avaliou-se o impacto do grau de processamento sobre o teor de nutrientes da dieta. Nesse artigo, os dados foram obtidos em sub amostra do estudo SOFT – estudo da síndrome de obesidade e fatores de risco cardiovasculares – através de recordatórios alimentares de 24 horas, implementando-se as modificações propostas na classificação de Monteiro e colaboradores. A seguir, baseando-se na hipótese conceitual, testou-se a associação entre grau de processamento e pressão arterial em adolescentes e adultos de Porto Alegre. Para isto, foram utilizados dados do estudo SOFT, oriundos de estudo de base populacional, representativo da população adulta e de adolescentes de Porto Alegre. Os resultados foram apresentados em dois artigos, uma vez que as análises utilizaram abordagens diferentes, mas os métodos foram idênticos, assim como o questionário de frequência de consumo alimentar. O conjunto totaliza três artigos que compõem essa tese.

REVISÃO DE LITERATURA

1 - HIPERTENSÃO ARTERIAL SISTÊMICA (HAS)

As doenças cardiovasculares são a principal causa de morte mundial. (EZZATI et al., 2002). Em 2005, doenças cardiovasculares resultaram em 30% do total de mortes no mundo, equivalente a combinação de óbitos por doenças infecciosas, deficiências nutricionais e maternas e perinatais combinadas (WHO, 2009). Hipertensão arterial sistêmica (WRITING GROUP MEMBERS et al., 2010) constitui seu fator de risco mais importante (ENDRES M et al., 2011), assim como para doença renal crônica e doença vascular periférica (WRITING GROUP MEMBERS, 2010). Em 2001, 7,6 milhões de mortes e 92 milhões de *Daly* (*Disability-adjusted life years*) registradas no mundo foram atribuídos à pressão arterial elevada (LAWES et al., 2008). Hipertensão arterial é caracterizada pelo aumento sustentado da pressão arterial sistólica (PAS) ou diastólica (PAD) , causando lesões em órgãos alvo e aumentando o risco de eventos (CHOBANIAN et al., 2003). Embora o diagnóstico de hipertensão seja estabelecido a partir de 140 mmHg de PAS ou 90 mmHg de PAD, o risco de eventos é aumentado a partir de 115/75 mmHg, (LEWINGTON et al., 2002) sendo consideradas normais pressão sistólica inferior a 120 e diastólica menor do que 80 mmHg (CHOBANIAN et al., 2003). Em crianças e adolescentes, a elevação da pressão arterial está fortemente associada a estilo de vida, particularmente quando a dieta e constituída por excessiva ingestão de gorduras saturadas, colesterol e sal, inadequada ingestão de potássio e reduzida atividade física, frequentemente acompanhada de longos períodos diários assistindo à televisão, além de consumo de bebidas alcoólicas e tabagismo. Diferentemente da população adulta, para a qual há valores fixos caracterizando a anormalidade da pressão arterial, em adolescentes esses valores baseiam-se em percentis de acordo com a altura e sexo, definidos a partir de dados antropométricos do *Centers for Disease Control and Prevention e do National Center for Health Statistics* (NIH, 2004).

A hipertensão arterial afeta aproximadamente 25% da população adulta mundial e estima-se que, em 2025, sua prevalência alcançará 60% (KEARNEY et al., 2005). Em alguns países desenvolvidos, como a Polônia, a prevalência de hipertensão já ultrapassou essa estimativa (KEARNEY et al., 2004). Na América do Norte, um a cada três indivíduos tem hipertensão (WRITING GROUP MEMBERS, 2010) e, na Europa, 44% da população adulta (WOLF-MAIER et al., 2003). Nos Estados Unidos, em 2005 e 2006, 37% dos adultos maiores de 18 anos eram pré-hipertensos e 29% eram hipertensos, não havendo diferenças significativas entre homens e mulheres (OSTCHEGA et al., 2008). A elevação com a idade, no mesmo período, caracterizou que a prevalência passou de 7%, entre indivíduos com 18 a 39 anos, para 67%, entre aqueles com mais de 60 anos. (OSTCHEGA et al., 2008).

No Brasil, estimativas obtidas através de meta-análises indicam que a prevalência de hipertensão na população adulta seja 28.7% (IC95% 26.2-31.4%) (PICON et al., 2012), sendo que a análise por década mostrou que houve uma redução progressiva, passando de 36,1%, em 1980, para 32,9%, em 1990, e 28,7%, em 2000 (PICON et al., 2012). Em indivíduos idosos, a prevalência de hipertensão arterial estimada para a década de 2000 foi 68,9% (95%IC 64,1% -73,3%) (PICON et al., 2013). Níveis de PAS entre 120-139 mmHg e PAD entre 80-89 mmHg caracterizam pré-hipertensão e estão fortemente associados a risco de eventos cardiovasculares. Pré-hipertensão é uma etapa intermediária em direção à elevação sustentada dos níveis pressóricos e, em Porto Alegre, cerca de 80 de cada 100 indivíduos, com 40 a 49 anos, torna-se hipertenso em 10 anos (MOREIRA et al., 2008).

Entre os indivíduos hipertensos, 22% não conheciam o diagnóstico e 68% faziam uso de tratamento farmacológico para reduzir a pressão arterial. Entre esses, somente 64% apresentavam controle dos níveis pressóricos. No Brasil, a estimativa de prevalência de hipertensão varia de acordo com o critério de ponto de corte adotado. Segundo critério da OMS – Organização Mundial de Saúde [PA ≥ 160 / 95] (WHO TRS, 2011), de 1980 até 1990 a prevalência de hipertensão arterial sistêmica reduziu de 23,6% para 19,6%. Considerando como ponto de corte os critérios do JNC [PA ≥ 140 / 90] (1) a prevalência de hipertensão reduziu de 36,1% em 1980, para 32,9% em 1990 e 28,7% em 2000 (PICON et al., 2012).

A redução nos níveis pressóricos tem impacto sobre morbidade e mortalidade, o que foi demonstrado no INTERSALT, um dos primeiros grandes estudos multicêntricos mundiais sobre hipertensão arterial e fatores associados. O estudo incluiu 52 populações de 32 países, e demonstrou que a redução média de 5 mmHg na pressão sistólica pode reduzir a mortalidade por doença coronariana em 9% e 14% por infarto do miocárdio (STAMLER J et al., 1989). Reduções significativas nos níveis pressóricos têm sido alcançadas com tratamento medicamentoso e mudanças de estilo de vida. Intervenções indiretas, incluindo redução do teor de sódio em alimentos processados vem sendo implementada em diferentes países do mundo. A implementação de uma legislação voltada à redução do sódio e rotulagem correta de alimentos processados estão entre as medidas mais custo efetivas atualmente. (MURRAY et al., 2003). A eficácia e a efetividade de intervenções não farmacológicas têm sido bastante investigada no tratamento e prevenção da hipertensão (DASH, DASH SODIO e PREMIER) (RIEGEL et al., 2012; FUCHS et al., 2012).

1.1 HIPERTENSÃO ARTERIAL E DIETA

Além de intervenções públicas para redução do teor de sódio nos alimentos, está estabelecida a efetividade da recomendação de dieta com baixo teor de sal sobre a pressão arterial. A adesão a redução da quantidade de sal utilizada na preparação de refeições cozinhadas, do sal adicionado a salada e o aconselhamento para abster-se de alimentos ricos em sódio resultou em redução de 5,1 mmHg (IC95% 1,7-8,6) para a pressão sistólica e 2,1 mmHg (IC95% 0,2-3,9) para a diastólica (P = 0,02) (RIEGEL et al., 2012).

Contudo, além do efeito hipertensor do sódio há outros nutrientes, que exercem efeito hipotensor, como potássio e cálcio, e o padrão alimentar de um modo geral.

SÓDIO E OUTROS NUTRIENTES

Os principais micronutrientes envolvidos na prevenção e controle de hipertensão arterial são sódio, potássio, magnésio e cálcio, isoladamente ou em conjunto. O efeito hipotensor da dieta DASH (*Dietary Approach to Stop Hypertension*), por exemplo, é atribuído ao padrão alimentar como um todo. De acordo com a descrição do plano alimentar DASH, os autores citam que a ingestão simultânea de minerais e vitaminas resulta em efeito aditivo e a interação entre os nutrientes potencializa o efeito (SACKS et al., 1995).

O sódio é o principal nutriente relacionado a elevação da pressão arterial. Estima-se que a ingestão de 50 a 100 mmol de sódio por dia seja necessária, mas não suficiente, para o desenvolvimento de hipertensão (ADROGUÉ et al., 2007). Contudo, as evidências têm demonstrado que o consumo de sódio vai além desses valores. Nos Estados Unidos, dados do NHANES (*National Health Examination Survey),* de 2005-2006, mostraram que o consumo médio de sódio foi de 3.466 mg/dia (WRITING GROUP MEMBERS, 2010), contrapondo-se as recomendações de 2.300 mg/dia para indivíduos saudáveis, e de de 1500 mg/d para aqueles com doença renal crônica, diabetes mellitus e hipertensão. (U.S. DEPARTMENT OF AGRICULTURE, 2010). A ingestão de sódio na maioria dos países excede a recomendação da Organização Mundial de Saúde (OMS) e Organização para a Alimentação e Agricultura (*World Health Organization and Food and Agriculture Organization,* WHO/FAO), de 2003 [<85 mmol/dia] (WHO/FAO, 2003) em mais de 100 mmol/dia e, em mais de 200 mmol/dia, em países asiáticos.

A origem do sal consumido é outro aspecto que merece destaque, uma vez que adição de sal à mesa é sistematicamente desencorajada, bem como sua utilização durante o preparo. Contudo, o sal também é abundantemente encontrado em alimentos prontos para o consumo, como alimentos processados. Na Europa e América do Norte, a ingestão de alimentos ultra-processados contribui mais para o conteúdo diário de sódio da dieta do que o sal de cozinha (~75%). A ingestão de cereais e alimentos assados no Reino Unido e Estados Unidos, contribui significativamente para o conteúdo diário de sódio e, na China e Japão, o sal adicionado e molho de soja são os alimentos que mais elevam a ingestão diária de sódio (BROWN et al., 2009). A contribuição de sal adicionado à mesa ou em receitas e preparações caseiras foi superior a 75% na China e 29% nos Estados Unidos. No Japão, o molho de soja contribuiu com 20% e o sal adicionado com 9,5%; no Reino Unido, grãos e cereais contribuíram com 34,6% e sal adicionado com apenas 5% do conteúdo diário de sódio (ANDERSON et al., 2010).

No Brasil, a ingestão media de sódio é duas vezes maior do que a recomendação da WHO/FAO. Entre indivíduos de todos os níveis de renda, a maior parte do sódio deriva do sal adicionado ou de condimentos a base de sal (76,2%). A contribuição dos alimentos processados contendo sal adicionado para a ingestão total de sódio é diretamente proporcional à renda familiar, contribuindo com o conteúdo total de sódio da dieta em 9,7%, nos domicílios de baixa renda, e 25%, naqueles de alta renda (SARNO et al., 2009).

A relevância do consumo de sódio na dieta associa-se a seus efeitos sobre a morbimortalidade cardiovascular. No estudo INTERSALT observou-se o aumento de 50 mmol na ingestão de sódio por dia, associava-se a elevação de 5 mm Hg na pressão sistólica e 3 mm Hg na diastólica, em adultos com 25 a 55 anos de idade (INTERSALT COOPERATIVE RESEARCH GROUP, 1988). A evidência mais atual foi apresentada em uma revisão sistemática com meta-análise, incluindo trinta e quatro ensaios clínicos randomizados, com 3.230 participantes. A redução de 100 mmol de sódio urinário em 24 horas, equivalente a ingestão de seis gramas de sal por dia, associou-se à redução de 5,8 mmHg (2,5 a 9,2, P = 0,001) na pressão arterial sistólica, após controle para idade, etnia e status da pressão. Uma redução modesta na ingestão de sal por pelo menos quatro semanas causou redução, tanto em indivíduos hipertensos quanto normotensos. (HE et al., 2013) Por outro lado, uma meta-análise de 12 coortes demonstrou que o aumento na ingestão em 5 gramas/dia de sal foi associado com elevação de 23% no risco de acidente vascular cerebral e de 17% no risco de doença cardiovascular (STRAZZULLO et al., 2009).

As funções e concentrações celulares de Ca, Mg, K e Na estão inter-relacionados. O sódio afeta a pressão elevando a retenção de água que aumenta o volume sanguíneo e, consequentemente, a pressão no sistema vascular e débito cardíaco, e isso aumenta a atividade do sistema renina-angiotensina, que é um dos principais mecanismos de controle da pressão (HE et al., 2009). O aumento de fluidos resultante do excesso de sódio, sobrecarrega o sistema renal e desencadeia o processo de natriurese pressórica. Tratamentos que auxiliem o sistema renal a eliminar o excesso de sódio reduzem níveis pressóricos (SACKS & CAMPOS, 2010). Potássio e sódio interagem para manter a quantidade correta de fluido (equilíbrio osmótico) no interior das células. Aumentando a ingestão de potássio, aumenta a excreção de sódio e, portanto, a pressão é reduzida. O aumento dos níveis de cálcio na dieta aumenta a excreção de sódio e também afeta a função dos hormônios ativados por cálcio, mecanismos potenciais pelos quais o cálcio pode reduzir a pressão. Magnésio pode diminuir a pressão tanto diretamente, pelo relaxamento dos vasos sanguíneos, quanto, indiretamente, através de mecanismos de troca iônica que alteram a concentração de íons celulares.

Akita e colaboradores avaliaram o efeito da dieta DASH sobre a natriurese pressórica, no ensaio clínico desenvolvido para testar o efeito da dieta DASH-sódio. No estudo, foram testados três níveis de ingestão de sódio: baixo (50 mmol/d), intermediário (100 mmol/d) e alto (150 mmol/d). Observou-se que a curva normal de natriurese foi reestabelecida quando a ingestão de sódio situa-se entre intermediária e baixa. O que sugere que o benefício da dieta DASH sobre a curva de natriurese se deva a seu efeito diurético e não somente a restrição de sódio (AKITA et al., 2003). Pacientes idosos apresentam redução natural da eficiência da função renal. Assim, este grupo tem benefício adicional com a dieta DASH, uma vez que essa reduz expressivamente a carga renal (SACKS & CAMPOS, 2010).

O potássio é um nutriente essencial para a manutenção do volume de fluidos orgânicos, balanço ácido e de eletrólitos, e função celular normal (WHO 2012). A maior parte do potássio ingerido é eliminado através da urina, mas também através do suor, principalmente em condições de estímulo, como calor e atividade física intensa (SAWKA et al., 2007). Estudo recente demonstrou que, em 21 países da América do Norte, Europa, Ásia e Oceania, a ingestão média de potássio variou de 1,7gramas/dia (China) a 3,7 gramas/dia (Finlândia, Holanda e Polônia). As principais fontes de potássio são frutas e vegetais (WHO 2003) e laticínios (MCGILL et al., 2008). De acordo com a Organização Mundial de Saúde, recomenda-se que a ingestão de potássio seja pelo menos 90 mmol/dia (3.510 mg/dia) para adultos e sugere um aumento na recomendação para crianças, ajustada para o requerimento energético, podendo alcançar os valores recomendados para adultos (WHO 2012).

Em meta-análise, baseada em três ensaios clínicos controlados e um estudo de coorte, observou-se que entre crianças, não houve alteração significativa da pressão arterial diante do aumento na ingestão de potássio. Em adultos, o aumento da ingestão de potássio reduziu em 3,49 mmHg (IC95% 1,82 – 5,15) a pressão arterial sistólica em hipertensos, mas não em adultos sem hipertensão. Quando a ingestão de potássio situou-se entre 90-120 mmol/dia, houve redução de 7,16 mmHg (IC95% 1,91 – 12,41) na pressão sistólica e não houve efeito significativo sobre a função renal. Entretanto, o grau de evidência pode ser considerado moderado devido a heterogeneidade entre os estudos (ABURTO et al., 2013).

Além do efeito isolado da ingestão de sódio e potássio sobre a pressão arterial, seu efeito combinado também tem sido evidenciado.

A ingestão de sódio e relação Na/K foram diretamente associados com pressão sistólica em indivíduos hipertensos e razão de Na/K na população idosa (GEZMEN-KARADAG et al., 2012). Hábitos alimentares modernos são caracterizados por alta ingestão de sódio, simultaneamente a redução no teor de potássio. O efeito da interação entre sódio e potássio sobre a pressão arterial foi consistentemente evidenciado por estudos atuais e clássicos (ADROGUÉ, 2007). Além disso, os resultados dos estudos *Trials of Hypertension Prevention (TOHP)*, o primeiro (TOHP-I) com 18, e o segundo (TOHP-II) com 36 meses de acompanhamento, demonstrou tendência de aumento do risco para doença cardiovascular relacionada à razão sódio potássio, contrariamente ao efeito dos dois nutrientes isolados (COOK et al., 2009).

Abordagens atuais têm recomendado fortemente mudanças de estilo de vida, com ênfase na dieta e redução do consumo de sódio, mesmo quando o tratamento farmacológico esteja sendo administrado (EARL., 2012). Em ensaio clinico randomizado, a restrição de sal ingerido associada à atividade física adicional ao tratamento farmacológico, reduziu a pressão arterial sistólica em 7 mmHg, em três meses de intervenção (ARROLL & BEAGLEHOLE 1995).

AFERIÇÃO DA INGESTÃO DE SODIO DA DIETA

Restrição de sal na dieta é amplamente recomendada, mas a avaliação precisa da ingestão de sal é dificultada pelos métodos disponíveis. Os mais confiáveis apresentam operacionalização complexa, enquanto os métodos mais simples são menos confiáveis. O grupo de trabalho para a redução de sal na dieta, da Sociedade Japonesa de Hipertensão (KAWANO et al., 2007) recomendou avaliação do consumo de sal dos pacientes, para práticas assistenciais, utilizando um dos seguintes métodos:

1) Aferição do sódio (Na) na excreção urinária, em amostra de 24 h, ou através de análise dos conteúdos da dieta por nutricionista. Ambos são confiáveis, mas difíceis de executar

2) Estimação da excreção de Na a partir da razão Na/creatinina (Cr) em amostra casual de urina. É menos confiável, mas é prático e factível em consultórios médicos.

3) Estimação utilizando um sensor de sal eletrônico equipado com uma fórmula de cálculo. Esse método também é menos confiável, mas é simples o suficiente para que os próprios pacientes possam usá-lo.

Contudo, ainda que esses métodos sejam factíveis na prática, há potenciais limitações (WHELTON 2012). A avaliação da ingestão de sódio na dieta é propensa a vieses pela sub informação do consumo de alimentos, além de mudanças na composição e fabricação de alimentos e grande variabilidade intra-indivíduo. Isto torna necessária a medida da ingestão média de sódio, obtida a partir de coleta de dados por sete a 10 dias para determinar a ingestão de cada indivíduo (LIU et al., 1984). O padrão-ouro para a medida da ingestão de sódio é a estimativa de coleta de urina de 24 horas, de preferência com base em uma média de várias amostras (JI et al., 2011). Instruções sobre cuidados e controle de qualidade são essenciais para garantir a precisão das coletas de urina de 24 horas. Mesmo assim, a sub captação e, em menor medida, a excessiva coleta de urina, podem resultar em subestimação sistemática ou superaferição da excreção de sódio. A coleta de urina durante a noite e em amostras casuais são mais fáceis para os participantes do estudo e para a equipe de pesquisa. No entanto, mesmo essas medidas são um substituto fraco para coletas de urina de 24 horas. (JI et al., 2011)

Um recordatório de 24 horas, ou variantes, como diários de dois ou três dias, podem ser utilizados para medir sódio na dieta, mas apresentam limitações. (LEIBA et al., 2005). A análise de recordatórios depende das bases de dados com a descrição da composição alimentar, que muitas vezes não incluem nomes de marcas ou o conteúdo de sódio específico proveniente de alimentos industrializados que mais contribuem para o consumo diário. Essa abordagem não inclui a quantificação da adição de sódio na cozinha e à mesa, em suplementos, ou outras fontes não usuais. Subnotificação da ingestão de alimentos e bebidas e de porções também resulta em estimativa falsamente baixa, e aqueles que apresentam esse comportamento já podem estar em maior risco de eventos adversos. Finalmente, as estimativas de ingestão de sódio em recordatórios de 24 horas são imprecisas por mudanças na composição dos alimentos comerciais que não estejam descritas nas bases de dados de nutrientes utilizados para estimar o teor de sódio.

Além de viés de aferição, variáveis de confusão são igualmente problemáticas em epidemiologia nutricional. Mesmo quando as análises podem levar em conta a presença de fatores de confusão, o potencial para confusão residual pode ser substancial. Além disso, a colinearidade é outro aspecto ser verificado, pois muitas variáveis nutricionais são inter-relacionadas (WILLETT, 1998). O conteúdo dietético de sódio está fortemente relacionado com o consumo de energia, potássio, cálcio, magnésio e outros nutrientes. A colinearidade torna difícil identificar a causalidade das relações e pode resultar em estimativas instáveis ou viés, resultando em relações paradoxais quando esses fatores são simultaneamente incluídos na análise multivariada (ELMSTAHL & GULLBERG, 1997).

Um terceiro aspecto é a causalidade reversa, principalmente em pacientes doentes, tais como aqueles com insuficiência cardíaca, doença cardíaca coronária, doença renal crônica, ou diabetes mellitus. A inclusão de tais pacientes tende a resultar em maior número de eventos, observados durante o seguimento, aumentando o poder estatístico. No entanto, os pacientes doentes são suscetíveis de terem reduzido o consumo de sódio, quer porque tenham sido aconselhados a fazê-lo ou porque não tem apetite. Em ambos os casos, menor consumo de sódio é provável que seja o resultado, em vez de ser a causa da doença (causalidade reversa). A situação é ainda agravada pelo uso frequente de diuréticos e outros medicamentos que podem distorcer as estimativas de ingestão de sódio, especialmente durante a noite e em coletas casuais de urina (WHELTON et al., 2012). O sódio é apenas um dos componentes da dieta e sua redução é consistente com a obtenção de dados quantitativos, incluindo redução na ingestão de calorias e aumento do consumo de potássio.

DIETA DASH - DIETARY APPROACH TO STOP HYPERTENSION

O consumo de dietas balanceadas, com diferentes componentes adicionados ou restringidos foram amplamente documentados ao longo do tempo. Optou-se por discutir o papel da dieta DASH porque talvez seja a que maior impacto causou sobre as práticas alimentares e consolidou efeito da deta sobre a pressão arterial.

A dieta DASH foi criada para ser usada no ensaio clínico randomizado que deu origem ao nome, no qual foi prescrita para incrementar a ingestão de verduras, frutas, grãos integrais, laticínios dietéticos e regulares e carnes com baixo teor de gordura (principalmente peixe e frango), desenvolvida pelo *National Heart, Lung, and Blood Institute*, nos Estados Unidos (KANANJA et al., 1999). A dieta DASH foi comparada com outras duas dietas, conforme descritas na **Figura 1.**

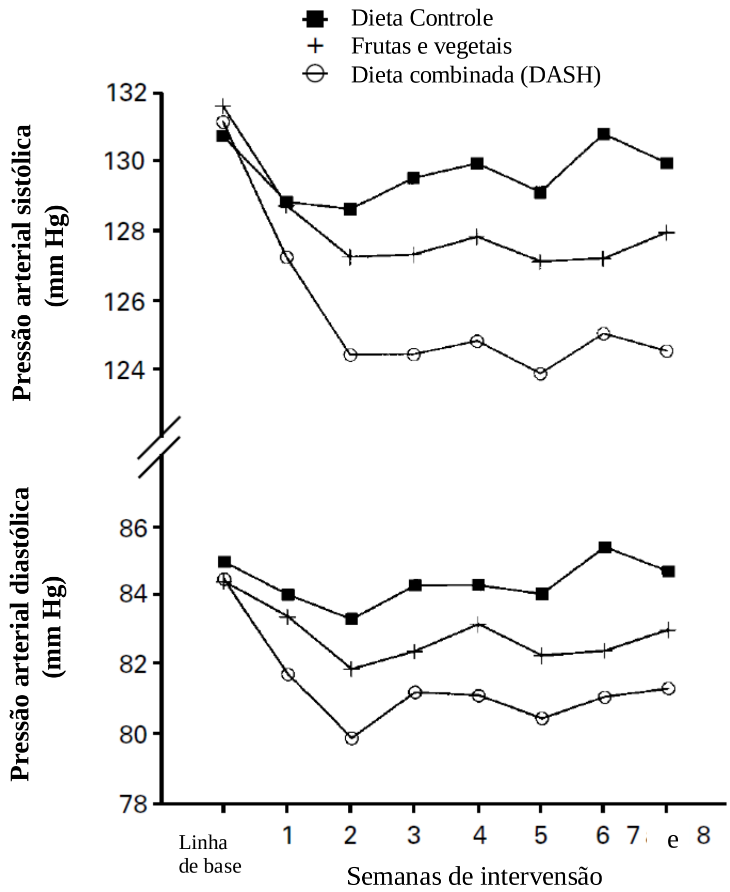
Figura 1. Cardápios experimentais para testar a dieta DASH em uma dieta com 2100 kcal

Refeição	**Dieta Controle**	**Frutas e vegetais**	**DASH (combinada)**
Café da manhã	Suco de maçã Cereais açucarados Pão branco torrado Manteiga Geleia Leite integral	Suco de laranja Bolinho de aveia Uva passa Damasco seco Manteiga	Suco de laranja Barra de cereal de granola Yogurte sem gordura Leite desnatado (1% gordura) Banana
Almoço	Sanduiche de presunto/ frango com pão branco, alface, picles, mostarda e maionese Coquetel de frutas	Sanduiche de presunto e queijo suíço com pão integral Banana	Sanduiche de peito de peru defumado com pão integral, alface e maionese Laranja
Jantar	Peixe temperado Arroz com cebolinha Cenouras Manteiga Pão francês	Peixe temperado Arroz com cebolinha Feijão de lima Manteiga Pão massinha Melão	Peixe temperado Arroz com cebolinha Margarina Pão massinha Melão Leite desnatado (1% gordura)
Lanche	Biscoitos Cobertura de baunilha Salada de frutas	Amendoim	Amendoim Damasco seco Salada de frutas

Fonte: KANANJA et al., 1999.

Durante três semanas os participantes receberam orientações para seguir a dieta controle, uma dieta americana típica. A seguir, foram randomizados para um de três grupos, de acordo com a dieta, sendo orientados a seguir por 8 semanas. Os padrões de dieta foram desenvolvidos para atender a três objetivos principais: reduzir a pressão arterial com base em uma dieta vegetariana, contendo uma quantidade de alimentos de origem animal suficiente para torná-la palatável para indivíduos não vegetarianos; alcançar um perfil de nutrientes de acordo com evidências clinicas e epidemiológicas para redução da pressão arterial; e incluir alimentos comuns, sem suplementação vitamínica além daquela acrescida industrialmente aos alimentos. Considerando-se uma dieta de 2100 kcal, o teor de carboidratos da dieta combinada foi um pouco mais alto, 58% da energia total *vs*. 52% na dieta de frutas e verduras e 50% na dieta controle; o teor de potássio e fibras foi quase 3 vezes maior nas duas dietas em relação a dieta controle; o teor de colesterol reduziu de 246 mg/d na dieta controle para 188 e 141 mg/d nas dietas de frutas e vegetais e combinada, respectivamente; e o teor de cálcio da dieta combinada em relação a controle e de frutas e vegetais foi 38% maior. (KANANJA et al., 1999). As dietas ricas em frutas e vegetais e combinada tiveram efeito redutor de níveis pressóricos. O grupo que recebeu a dieta DASH apresentou uma redução 5,5 e 3,0 mmHg na pressão arterial sistólica e diastólica, respectivamente, maior do que a do grupo controle. A redução da pressão arterial no grupo que recebeu a dieta de frutas e vegetais e no grupo dieta DASH foi substancial depois de duas semanas, sustentando a redução nas seis semanas seguintes (**Figura 2**) (APPEL et al., 1997).

Figura 2. Pressão sistólica e diastólica médias na linha de base e ao longo de 8 semanas de intervenção.



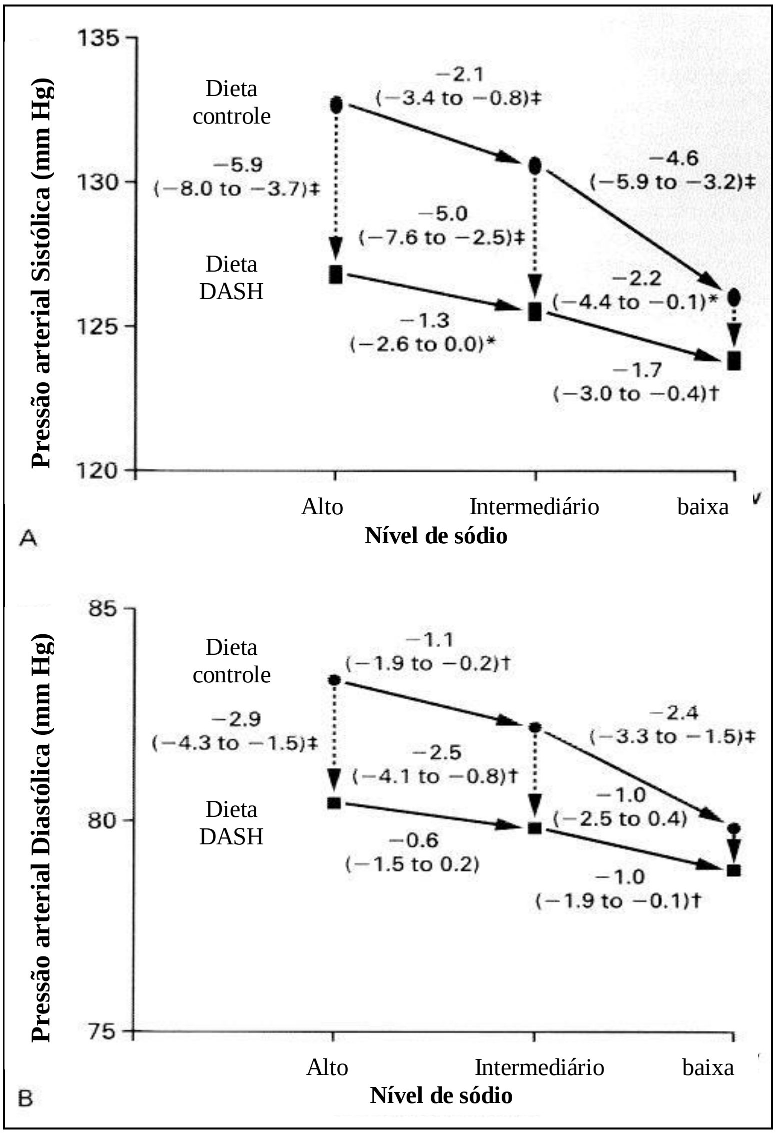
Fonte: APPEL et al., 1997.

A intervenção dietética baseada no plano alimentar DASH é capaz de atingir reduções de até 11% na pressão arterial sistólica e 10% na diastólica de indivíduos com hipertensão de estágio 1 (APPEL et al., 2006). Os melhores resultados com a dieta DASH foram alcançados com ingestão de gorduras totais (27%), saturadas (6%), monoinsaturadas (13%), poliinsaturadas (8%), carboidratos (55%), proteínas (18%), potássio (4700 mg), magnésio (500 mg), cálcio (1240 mg), fibras (31g), colesterol (150 mg) e sódio (3000 mg, na dieta DASH padrão e 1500mg na DASH-sódio), considerando uma dieta de 2000 kcal (Sacks et al., 1995).

Aplicações a partir da dieta DASH têm sido disseminadas mundialmente (NGUYEN., 2012; MILLER., 2013; MA et al., 2013; LIMA et al., 2013; SHIRANI et al., 2013; ASEMI et al., 2013; SALEHI-ABARGOUEI A et al., 2013) e, de certa forma, geraram a hipótese testada no estudo PREMIER. (WRITING GROUP OF THE PREMIER COLLABORATIVE RESEARCH GROUP, 2003).

O ensaio clínico randomizado subsequente acrescentou à restrição na ingestão de sódio aos resultados da intervenção dietética, sendo ainda mais expressivos. (SACKS et al., 2001). No estudo da dieta DASH-sódio, os participantes foram randomizados para um de três grupos, de acordo com o teor de sódio da dieta, classificado como alto (>150 mmol/dia), intermediário (100 mmol/dia) ou baixo (50 mmol/dia). O consumo de sal foi limitado a 6 g/dia (1 colher de chá ou menos), quantidade inferior a recomendada por especialistas. Comparando-se a combinação da dieta controle à dieta DASH com baixa ingestão de sódio, esta última reduziu a pressão sistólica em 7,1 mmHg entre os normotensos e em 11,5 mmHg entre os que tinham hipertensão no estágio 1 (**Figura 3**) (SACKS et al., 2001).

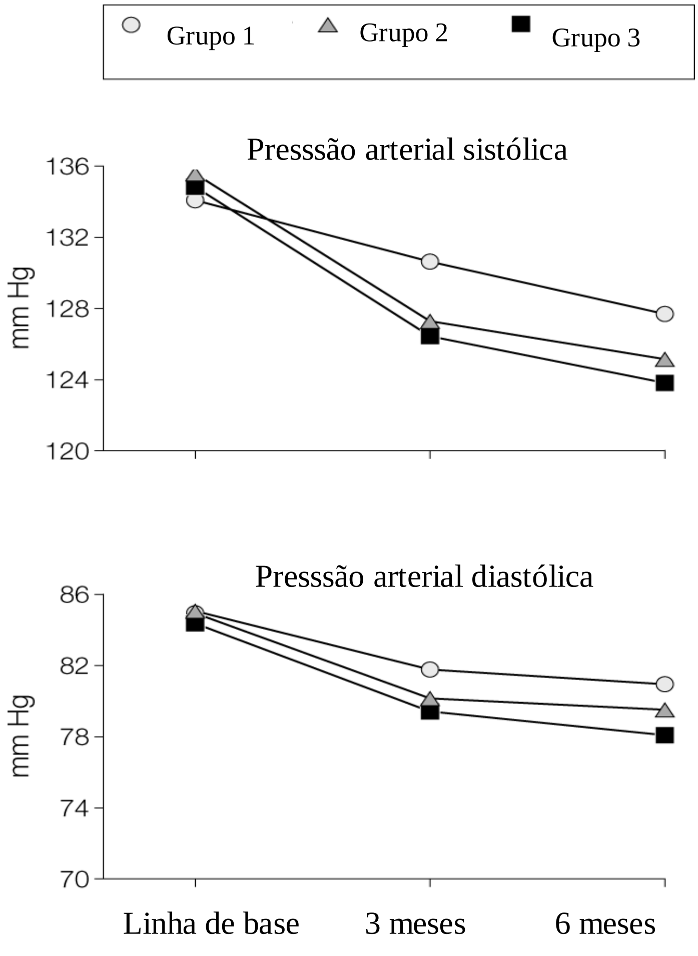
Figura 3 Efeito da dieta DASH e DASH-sódio sobre a redução da pressão arterial.



Fonte: Sacks et al., 2001.

O estudo PREMIER foi um ensaio clínico randomizado desenhado, com dois grupos intervenção e um controle, para testar o efeito da dieta DASH acompanhada por outros componentes de estilo de vida versus os componentes de estilo de vida sobre a pressão arterial ao longo de 18 messes de intervenção. Pacientes classificados como pré-hipertnesos e hipertensos estágio 1, sem uso de anti-hipertensivos foram randomizados em 3 grupos: 1) intervenção baseada somente em aconselhamento padronizado 2) Mudança de estilo de vida com foco em perda de peso, redução do consumo de sódio, aumento da atividade física, ingestão limitada de álcool e 3) intervenção com as recomendações do grupo 2 mais dieta DASH. A prevalência de hipertensão reduziu de 38% para 26%, no grupo 1, para 17% no grupo 2 e para 12% no grupo 3. O aumento mais expressivo na ingestão de frutas e vegetais (+3 porções por dia) e de laticínios de baixo teor de gordura (+0,5 porções por dia) foi observado entre indivíduos do grupo 3. Os grupos submetidos as intervenções 2 e 3 foram aqueles que tiveram maior mudança na pressão arterial sistólica e diastólica com tendência a estabilidade após o terceiro mês (**Figura 4**).

Figura 4 Pressão arterial sistólica e diastólica média ao longo do tempo em ensaio clinico randomizado



Fonte: (WRITING GROUP OF THE PREMIER COLLABORATIVE RESEARCH GROUP, 2003).

Diferentemente do estudo DASH e DASH-sódio, a alimentação não foi fornecida aos participantes e os resultados do estudo Premier não reproduziram a mesma adesão observada nos estudos originais. Embora tenha havido aumento no consumo de vegetais e frutas, a redução das pressões não foi diferente entre os grupos dois e três. Ou seja, a mudança de estilo de vida proporciona redução equivalente com ou sem dieta DASH. Observou-se aumento no consumo de carboidratos nos grupos 2 e 3 em relação a linha de base, tanto quando comparado as recomendações da plano alimentar DASH, quanto a DRI (*Dietary Reference Intake*). Após seis meses de tratamento, 32,2% dos pacientes do grupo 3 alcançaram ingestão de carboidratos acima da recomendação da DRI e 23,1% aos 18 meses, ao passo que na linha de base, apenas 6,6% dos participantes tinham ingestão acima da recomendação (LIN et al., 2007). Ao avaliar a associação entre o índice e carga glicêmica com fatores de risco cardiovascular, observou-se que aos seis meses, não houve mudanças no índice ou carga glicêmica. No entanto, aos 18 meses, houve associação direta entre o índice glicêmico e colesterol total com interação significativa com idade. A alteração na carga glicêmica foi diretamente associada com o colesterol total e inversamente associada com LDL-c com efeito de interação com idade para ambos (LIN et al., 2012).

Embora no estudo Premier o padrão DASH tenha sido associado a alto índice e carga glicêmica aos 18 meses, o padrão DASH incluía alimentos constituídos por carboidratos que também eram fontes de fibras, folato, potássio e outros nutrientes recomendados para prevenção ou tratamento da hipertensão arterial. O ensaio clinico através do qual testou-se o efeito da dieta DASH, também se descreveu o teor de nutrientes de cada grupo alimentar (**Tabela 1**). A contribuição do consumo de grãos refinados, grãos integrais, frutas e sucos de frutas, vegetais e doces para o teor de carboidratos mudou de 48,6%, 0,1%, 15,8%, 4,7% e 25,5% na dieta controle para 8,8%, 31,1%, 30,1%, 9,4% e 4% na dieta DASH, respectivamente. Em relação ao teor de magnésio e folato, a contribuição dos mesmos alimentos para a ingestão de magnésio foi de -32, +43%, +29,2%, +10,64%, +1.4% e -6.79% na dieta DASH em comparação a dieta controle e de folato foi de -50,7%, +23,9%, +22,1%, +5,7%, -4,0%. A ingestão média de folato entre os participantes que receberam a dieta DASH foi de 333.5 µg/d, 180,1 µg/d a menos do que na dieta controle (LIN et al., 2003).

Consumo alimentar similar ao padrão DASH também foi investigado em meta-analise, com o objetivo de sumarizar efeitos longitudinais do padrão de dieta DASH sobre risco cardiovascular. A manutenção do padrão alimentar similar ao DASH reduziu o risco para doença cardiovascular em 20%, doença arterial coronariana em 21% e acidente vascular cerebral em 19% (SALEHI-ABARGOUEI et al., 2013).

Outros estudo avaliaram o consumo de micro e macronutrientes. Em adolescentes, a alta ingestão de carboidratos, associada com índice e carga glicêmica, influenciou negativamente os níveis pressóricos, principalmente entre meninas (GOPINATH et al., 2012). A ingestão de fibras e magnésio em homens previne a hipertensão arterial. Aqueles que ingerem <12 g/d de fibra, tem um risco relativo 1,57 maior de desenvolver hipertensão do que aqueles que ingerem >24 g/d (ASCHIERIO et al., 1992). Também em homens, a ingestão de grãos integrais é inversamente associada com a incidência de hiepertensão arterial, representando uma proteção de 20% (FLINT et al., 2009). Em estudo longitudinal, observou-se que a ingestão de folato tem importante papel na incidência de hipertensão em mulheres. Comparando a ingestão de 1000 µg/d de folato com ingestão < 200 µg/d (incluída suplementação), mulheres jovens com alta ingestão tiveram uma proteção de 46% e as idosas de 18%. A redução de risco absoluto entre mulheres jovens foi de 8 casos por 1000 pessoas/ano e entre as idosas foi de 6 casos (FORMAN et al., 2005).

Ainda que os resultados da dieta DASH estejam consagrados em diferentes contextos, há contra-pontos técnicos. Em resposta ao estudo de caso apresentado por Sacks e Campos (2010) (SACKS E CAMPOS, 2010) argumenta-se que a redução de sal da dieta requer alimentos fonte de iodo, a fim de evitar a deficiência do mineral e, o alto teor de proteína é contraindicado a pacientes com nefropatia ou disfunção renal grave (ZENG et al., 2010). Nori e colegas atribuem o efeito da dieta DASH a seu alto teor de potássio, mais do que a redução de sódio e alertam para o efeito prejudicial da hipersensibilidade ao sódio, desenvolvida quando a ingestão do mineral é excessiva por longo período (NORI et al., 2010). Também, há o risco de potencial suspensão do tratamento medicamentoso, sendo a dieta criticada sob o argumento de que para médicos muito ocupados a ênfase sobre o uso de medicamentos é mais prática (OLIVERIA & SANTANA, 2010). A falta de recomendações sobre o consumo de bebidas doces, devido a seu efeito deletério, tanto para a pressão arterial quanto o diabetes melitus tipo 2, foi considerada falha neste estudo (OH et al., 2010). Em resposta, os autores sugerem o aumento no conteúdo de iodo no sal e alertam adequações da dieta para especificidades no tratamento de pacientes com doença renal grave. Também relatam que o efeito da hipersensibilidade ao sódio é insuficinte para ter valor clínico, discordam da preferência pelo tratamento medicamentoso enfatizando que a total adesão a dieta permitiu a paciente do estudo de caso abandonar o tratamento farmacológico e concordam e reforçam a sugestão de controle de consumo de bebeidas açucaradas (SACKS E CAMPOS, 2010)

Tabela 1 Número de porções / dia da dieta controle e dieta DASH e alimentos classificados em cada grupo.

Grupo alimentar	**Dieta Controle**	**Dieta DASH**	**Exemplos de alimentos**
Laticínios regulares	0,4	0,7	Leite integral, yogurt integral, creme de queijo integral e queijo regular
Laticínios baixa gordura	0,1	2,0	Leite desnatado, liete (1% de gordura), yougurte baixa gordura
Grãos refinados	9,1	3,6	Arroz branco, pão branco, biscoitos refinados, cereis refinados
Grãos integrais	0	4,1	Arroz integral, pão integral, biscoito integral, cereais integrais
Frutas e sucos de frutas	1,6	5,2	Sucos 100% de frutas frescas e congeladas, coquetel de frutas enlatado e outras frutas, frutas secas
Vegetais e sucos de vegetais	2,0	4,4	Vegetais fescos, enlatados e congelados, sucos de vegetais
Carne vermelha	1,5	0,5	Carne, carne moída, presunto
Frango	0,8	0,6	Frango e peru
Peixe	0,2	0,5	Atum e bacalhau
Gordura, óleo e temperos	5,8	2,5	Manteiga, óleo de canola, magarina, maionese, óleo de oliva, óleo de girasol
Nozes, sementes e leguminosas	0	0,6	Avela, creme de amendoin, amendoin, castanhas mistas
Doces	3,2	0,5	Açúcar, brownies, bolos, doces, bebidas doces
Condimentos e molhos	1,1	0,6	Molho de carne, molho de frango, mostarda, sal, molho de tomate, caldo de frango

[a] Alimentos e porções para 2100 kcal.
[b] Representa meia porção de nozes e semente e 0.1 porção de leguminosas
Fonte: LIN et al, 2003.

2 – ÍNDICE DE MASSA CORPORAL

O indicador mais frequentemente utilizado para detectar acúmulo de peso corporal foi denominado, inicialmente, índice de Quetelet, calculado pelo peso, em quilogramas, dividido pela altura, em metros ao quadrado. Ainda que não discrimine massa muscular de gordura corporal, o índice de massa corporal (IMC) permite a comparação do excesso de peso entre populações e na mesma população ao longo do tempo. Aferições padronizadas de peso e altura constituem os requisitos, que podem ser obtidos através de medidas diretas ou mesmo por informações dos participantes. Através do IMC podem ser avaliados os riscos de desenvolver hipertensão, diabetes mellitus e doença arterial coronariana. (LOPEZ-JIMENEZ et al., 2004; MARCADENTI et al., 2011; ORPANA et al., 2009).

Os pontos de corte para indicar anormalidade baseiam-se na padronização realizada pela OMS, que mais recentemente apresentou categorias intermediárias. A **Tabela 2** apresenta os pontos de corte principais e as variações que permitem discriminar a evolução dentro da mesma categoria do IMC.

Tabela 2 Classificação do índice de massa corporal segundo critérios da Organização Mundial da Saúde.

Classificação	Pontos de corte de IMC (kg/m²)	
	Principais	Adicionais
Magreza	<18,5	
Grave		<16,00
Moderada		16,00 - 16,99
Leve		17,00 - 18,49
Normal	18,5 - 24,9	18,50 - 22,99 23,00 - 24,99
Sobrepeso	25,0 - 29,9	
Pré-obesidade		25,00 - 27,49 27,50 - 29,99
Obesidade	≥ 30,0	
Obesidade classe I	30,0 - 34,9	30,00 - 32,49 32,50 - 34,99
Obesidade classe II	35,0 - 39,9	35,00 - 37,49 37,50 - 39,99
Obesidade classe III	≥40,0	

3 – GRAU DE PROCESSAMENTO DE ALIMENTOS

Mudanças nos hábitos alimentares da população têm sido evidenciadas e traduzidas no processo de transição da dieta, caracterizada pela mudança na produção, processamento, disponibilidade e consumo de alimentos (WHO, 2012).

Basicamente, o processamento de alimentos consiste na alteração de sua estrutura física, química ou biológica. Métodos físicos de processamento incluem quebra, deformação, perfuração, corte e alterações de cor, aparência ou sabor devido a exposição a luz, ar, ou calor. Alimentos são processados quimicamente por ação espontânea ou induzida, o que altera a cor, sabor e consistência do alimentos por provocar alterações enzimáticas ou não-enzimáticas. A alteração biológica se deve a ação de organismos vivos como fungos, leveduras ou bactérias, bastante utilizada domestica e industrialmente. Técnicas de processamento de alimentos têm como principal objetivo aumentar a vida de prateleira dos produtos e melhorar a palatabilidade. De acordo com Monteiro e colaboradores, o processamento de alimentos é definido como técnicas aplicadas aos alimentos e bebidas para transformar alimentos integrais em seus derivados (MONTEIRO et al., 2010). Baseado neste critério, foi proposta a classificação dos alimentos de acordo com o grau de processamento em não processados, moderadamente e ultra-processados. Os alimentos não processados são aqueles submetidos a processamentos físico realizado pelo produtor primário, em domicílio ou no varejo, como: higienização, porcionamento, remoção de porções não comestíveis, raspagem, descamação, compressão, engarrafamento, dessecação, congelamento, resfriamento, pasteurização, fermentação, redução do teor de gorduras, embalamento a vácuo e empacotamento. Os alimentos moderadamente processados, ou ingredientes culinários, são assim chamados por não serem comestíveis isoladamente e por demandar associação com outros alimentos, seja domésticos, em restaurantes, ou industrialmente. São substâncias extraídas dos alimentos não processados, purificadas para gerar ingredientes culinários e produtos para indústria alimentícia. Esses alimentos sofrem processamento físico e químico como pressão, moagem, refinamento, hidrogenação, hidrolise, uso de enzimas e aditivos. O processamento físicos a que os alimentos moderadamente processados são submetidos difere dos não processados pela significativa alteração na constituição original do alimento. O terceiro grupo consiste de alimentos ultra-processados, derivados ou compostos por alimentos dos dois grupos anteriormente citados, comprados já prontos para o consumo. Neste grupo incluem-se alimentos submetidos a processo de salga, acréscimo de açúcar, fritura intensa, defumação, cura, conserva e utilização de conservantes e substancias sintéticas, adição de vitaminas, minerais ou sofisticados métodos de embalo (MONTEIRO et al., 2010).

Na tabela 3, descrevem-se os itens alimentares incluídos em cada grupo alimentar, de acordo com a proposta de Monteiro e destacando itens que propomos incluir em outro grupo alimentar.

Tabela 3 Grupos alimentares e itens alimentares, com proposta de adaptações.

Grupo Alimentar	Itens alimentares
Alimentos não processados	Frutas, vegetais, tubérculos e raízes, secas (não adoçados), resfriadas, embaladas a vácuo congeladas (polpas), cogumelos, oleaginosas, sementes, grãos em geral [1], feijões, carnes em geral[2], peixe e frutos do mar[2], alimentos fermentados sem adição de sabor e açúcares, ovos, café, chás, ervas de infusão e água.
Alimentos moderadamente processados	Óleos vegetais, margarina, manteiga, creme de leite, banha, açúcar, adoçante, sal[4], amidos, farináceos, massas frescas feitas apenas de farinha e água [3], ingredientes industriais não vendidos a consumidores como frutose, lactose, proteína de soja, xarope de milho, gomas, aditivos e conservantes.
Alimentos ultra-processados[5]	Pães, biscoitos, bolos e tortas, frutas e vegetais enlatados, em calda ou em conserva, doces, chocolates, cereais em barra, cereais matinais, queijos, frutas secas adoçadas, bebidas adoçadas com açúcar ou adoçantes, bebidas diet, light ou zero calorias, massas congeladas e pizza, carne pré-preparada[2], vegetais e receitas [5], carnes processadas como presunto, salsicha, linguiça, hambúrgueres empanados, carnes defumados, curados, massas instantâneas, vegetais salgados, picles, formulas infantis, leites modificados e alimentos infantis.

Fonte: MONTEIRO et al., 2010, com adaptações apontadas no texto.

[1] O arroz branco é submetido a moagem que elimina parte não comestível no modo que se apresenta e também uma porção do grão quando submetido ao refinamento. Quando refinado, acredita-se não se tratar mais de um alimento

não processado e que para ser consumido deve ser submetido a processamento térmico.

[2] Na dieta ocidental, carnes de qualquer tipo, peixe e frutos do mar são consumidos fritos, assados, grelhados ou cozidos, exceto alimentos servidos em restaurantes étnicos. Assim, por obter a informação a partir de RA24h ou QFA e por ter acesso a informação sobre o método de preparo, propomos a inclusão de carnes, peixes e frutos do mar (exceto sushi e sashimi, e alimentos consumidos cru com base no relato individual) no grupo de alimentos ultra-processados.

[3] A mistura de água com farinha resulta em um alimentos completamente diferente do original e passível de ser consumido sem adição de qualquer outro alimentos ou ingrediente. Assim, propomos classifica-la como ultra-processados.

[4] Acrescentamos ao grupo 2, o glutamato monossódico, comumente usado em restaurantes japoneses, por se tratar de um ingrediente, como o sal, por exemplo.

[5] Alimentos incluidos no grupo dos ultra-processados passíveis de serem desmembrados e produzidos em domicilio ou restaurantes *self-service* como tortas, bolos e outras preparações, propõe-se estimar ingredientes. Aqueles alimentos comprados prontos para o consumo no varejo e em redes de *fast foods*, como lasanhas, tortas e produtos de confeitaria, por exemplo, são considerados como tal e incluídos no grupo dos alimentos ultra-processados.

Algumas técnicas de processamento repercutem na constituição química do alimento que podem influenciar desfechos em saúde. Diferentes métodos de aquecimento reduzem o teor de vitaminas voláteis, como a vitamina C (BUTZ et al., 2002). O tempo de cozimento de tubérculos tende a aumentar o índice glicêmico de alimentos (BAHADO-SINGH et al., 2006). O processamento térmico também desencadeia a formação de substâncias, como produtos finais de glicação avançada (AGEs), um grupo de componentes complexo formado pela reação de Maillard, uma reação não enzimática que ocorre quando açúcares simples reagem com aminoácidos em proteínas, lipídios e DNA (LUEVANO-CONTRERAS., 2010). O processo de industrialização de alimentos também resulta na inclusão de aditivos potencialmente nocivos a saúde como o sal. Até a década de 70, o sal foi o principal método de conservação de alimentos. A invenção do *freezer* resultou no declínio de sua utilização. No entanto, o consumo de sal devido a sua utilização em produtos processados ainda é similar a observada na década de 70, de 9 -12 g/dia (HENDERSON et al., 1988). Alguns tipos de processamento podem tornar os alimentos mais saudáveis, como o caso de alimentos fortificados com vitaminas e minerais, ou redução de nutrientes insalubres (ex.: gorduras saturadas e *trans*). Estes produtos reformulados são frequentemente chamados alimentos *Premium*. Contudo, a substituição de substâncias naturais por sintéticas pode acarretar efeitos adversos. Há estudos demonstrando que alimentos ultra-processados podem causar dicção (CORSICA & PELCHAT, 2010), desencadear comportamento caracterizado pela superalimentação (*overeating*) (HE et al., 2008), e ainda doenças crônicas como obesidade, síndrome metabólica, doença cardiovascular e diabetes tipo dois em crianças (LUDWIG et al., 2001), adolescentes (TAVARES et al 2011) e adultos (MALIK et al., 2006; IFLAND et al., 2009; BROWN et al., 2008).

Atualmente, o padrão alimentar da população tem-se modificado, com aumento no consumo de alimentos consumidos fora de casa e de fácil manipulação (WHO, 2012). Cerca de 18% das calorias totais consumidas diariamente por adolescentes são consumidas em *fast-foods*, e 27% entre os adultos. Na população americana, aproximadamente 41% dos adolescentes e 36% dos adultos comem em *fast-foods* (POWEL et al, 2012). O potencial efeito deletério do consumo de alimentos com alto grau de processamento deriva da depleção de nutrientes e do processo de fabricação em si (MONTEIRO, 2009).

Paralelo ao processo de transição entre um padrão alimentar baseado em alimentos com menor grau de processamento para um padrão baseado no consumo de lanches rápidos (GRAAF, 2006), restaurantes do tipo *fast-foods* e *self services* (POWEL et al., 2012), observa-se o aumento da prevalência de doenças crônicas, como diabetes mellitus e hipertensão (POPKIN, 2001).

O efeito do alto consumo de alimentos ultra-processados sobre o desenvolvimento de obesidade (MALIK et al., 2006; BROWN et al., 2008), e síndrome metabólica (TAVARES et al., 2011) tem sido evidenciado. Entretanto, o efeito sobre os níveis pressóricos, tanto em indivíduos saudáveis quando hipertensos, ainda é desconhecido e o método de classificação de alimentos requer adaptação a diferentes métodos de avaliação da dieta.

4 – AVALIAÇÃO DA DIETA NA POPULAÇÃO

Entre os métodos utilizados para obtenção de dados de dieta citam-se: folhas de balanço alimentar (FBA), inventário alimentar, Pesquisas de Orçamento Familiar (POF), registro ou diário alimentar (apenas recordado ou com pesagem de alimentos), recordatório alimentar de 24 horas e questionário de frequência alimentar (QFA) (PEREIRA et al., 2007).

No Brasil, o uso de dados da POF é bastante utilizada e informativa sobre padrões de dieta da populaçõo. A Pesquisa de orçamento familiar (POF) é um inquérito domiciliar periódico baseado nos gastos com alimentos, a partir dos quais se estima a disponibilidade domiciliar de alimentos (e nutrientes) (MONTEIRO e al., 2000). O principal objetivo das POFs é estimar índices de preços, entretanto constituem importantes fontes de informação em epidemiologia nutricional a medida que empregam metodologia padronizada de coleta de dados, utilizam amostragem probabilística, são periódicas e incluem mensuração detalhada de características socioeconômicas (LEVY-COSTA et al., 2005). Na POF não é investigada a ingestão individual de alimentos, não é considerada a fração desperdiçada dos alimentos e não são registrados os alimentos doados ou consumidos fora do domicílio (MONTEIRO et al., 2000). Assim a mais recente POF (2008-2009) incluiu um módulo de ingestão alimentar individual, utilizando o registro alimentar na coleta de dados (YOKOO et al., 2008; SICHIERI et al., 2008). As POFs tem contribuído para o monitoramento da ingestão alimentar ao longo do tempo no Brasil, do processo de transição nutricional e sua associação com a prevalência de doenças crônicas (MONTEIRO et al., 2010; CLARO et al., 2010).

Além da POF, recordatório alimentar de 24 horas (RA24h) e o questionário de frequência alimentar (QFA) são amplamente utilizados no mundo todo. Em estudos de validação de QFA, ambos são aplicados simultaneamente, tendo o RA24h como método de referência (CADE et al., 2001).

O RA24h é um inquérito retrospectivo (COSTA et al., 2006) indicado para comparações de médias de ingestão de nutrientes (THOMPSON et al., 1994).

As vantagens do método incluem a não exigencia de relato ou pesagem dos alimentos consumidos, pelo entrevistado, e pode ser aplicado rapidamente, em cerca de 20 minutos. Isto aumenta a taxa de resposta e colaboração dos entrevistados, e evita viés de seleção amostral. Mesmo com maior índice de aceitação, atualmente vários estudos lançam mão de métodos alternativos para aumentar as taxas de resposta. Nesse sentido, entrevistas por telefone podem ser tão eficazes quanto as presenciais (CASEY et al., 1999; MONTEIRO et al., 2008). Por outro lado, o consumo alimentar pode ser influenciado pelo viés de memória e, devido à variação diária da ingestão individual, o relato de um único dia pode não representar a ingestão alimentar usual (HOFFMANN et al., 2002; THOMPSON & BYERS, 1994).

O relato da ingestão alimentar pode ser influenciado por associações entre dieta e conhecimento sobre saúde do entrevistado sobre. Há relatos de subestimação do consumo alimentar em indivíduos com sobrepeso ou obesidade (THOMPSON & BYERS, 1994; SCAGLIUSI & LANCHA JÚNIOR, 2003) e de sobre-estimativa de consumo alimentar, em o relato de mães de crianças desnutridas (OLINTO MTA et al., 1995). É possível captar o sub ou sobre relato avaliando o gasto energético com base em métodos como água duplamente marcada, calorimetria indireta ou através de equações de predição da taxa metabólica basal (SCAGLIUSI et al., 2009; COSTA et al., 2006) comparando a necessidade energética basal e o consumo energético relatado (WAHRLICH & ANJOS., 2001). Quando o sub ou sobre relato é identificado, sugere-se incluí-los na análise estatística como uma variável de ajuste (MACKERRAS & RUTISHAUSER 2005).

Vieses e erros aleatórios de natureza intra e entre indivíduos são inerentes ao método e estratégias de amostragem e estatísticas podem ser utilizadas para corrigir ou atenuar esses efeitos (DODD et al., 2006; WILLETT, 1998; PALANIAPPAN et al., 2003; BEATON et al., 1979; TOKUDOME et al., 2002; FOWKE et al., 2004).

Estudos observacionais com grandes amostras, sobre ingestão alimentar tem sido baseados em dieta de longo prazo, avaliada por QFA, devido a viabilidade operacional e de custo (CADE et al., 2002). Como um único registro alimentar ou RA24h não representa a ingestão usual dos indivíduos e, portanto, podem não ser apropriados para analisar a dieta pregressa, métodos alternativos foram criados com o intuito de atender a esta demanda (WILLETT, 1998). O QFA permite estimar a frequência com que itens ou grupos alimentares são consumidos durante um período de tempo específico, e consiste em dois componentes principais; a lista de alimentos e uma seção onde o indivíduo relata com que frequência consumiu cada item alimentar listado, em um determinado período de tempo – dias, semanas, meses ou até anos (WILLETT, 1998). A validação de um QFA para populações e objetivos específicos do estudo é critério fundamental para sua utilização (CADE et al., 2002).

OBJETIVOS

Objetivo Geral

Avaliar a associação entre o grau de processamento de alimentos consumidos e o teor de nutrientes da dieta, além do efeito do grau de processamento da dieta sobre a pressão arterial em adolescentes e adultos de Porto Alegre.

Objetivos Específicos

1 Avaliar a associação entre o grau de processamento dos alimentos e o teor de energia, macro e micronutrientes da dieta em uma sub-amostra de adolescentes e adultos de Porto Alegre avaliados com RA24h.

2 Avaliar a associação do grau de processamento dos alimentos e bebidas com níveis pressóricos em adolescentes de Porto Alegre, no sul do Brasil.

3 Avaliar a associação do grau de processamento dos alimentos e bebidas com níveis pressóricos em adultos de Porto Alegre, no sul do Brasil.

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ARTIGO 1

Classificação dos Alimentos de Acordo com o Grau de Processamento: Relação com o Teor de Nutrientes da Dieta

Classification of Foods According to Processing Grade: Relation with Dietary Nutrient Content

Short title: Food processing and nutrients

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Key words: Food processing grade, dietary nutrient content, nutritional behavior.

To be submitted to the British Journal of Nutrition

Resumo

Alimentos processados tem sido relacionados a depleção de vitaminas e minerais e elevação do teor de carboidratos refinados, gorduras e sódio da dieta. O objetivo deste esudo foi avaliar a diferença no teor de energia e nutrientes da dieta de acordo com o grau de processamento dos alimentos. Para a amostra, foram randomicamente recrutados 125 adultos e 111 adolescentes, e seus hábitos alimentares foram avaliados com dois recordatórios alimentares de 24 horas. Os itens alimentares foram agregados de acordo com o grau de processamento em: não processados, moderadamente e ultra-processados, e aseguir categorizados em tercis de consumo em gramas por dia. A ingestão de energia e principais nutrientes recomendados no plano alimentar DASH (*Dietary approach to stop hypertension*) como meio para atingir níveis pressóricos ideais foram estimados. As diferenças no teor de energia, proteínas, carboidratos, gordura total, fibra total, calcio, magnésio, potássio e sódio de acordo com o grau de processamento dos alimentos foi testado com modelo de regressão linear generalizado. O efeito de interação entre alimentos não processados, moderadamente e ultra-processados foi testado. Uma analise de comparação par-a-par entre os tercis de consumo de cada grupo alimentar foi realizada na intenção de combinar grupos e gerar padrões alimentares representativos da ingestão alimentar como um todo. A aproximação dos padrões alimentares da recomendação da dieta DASH foi demonstrada. A ingestão de alimentos não processados foi significativamente relacionada com maior teor de fibras, calcio, magnésio e potássio, enquanto a ingestão de ultr-processados foi inversamente relacionada com fibras totais e potássio. Houve uma tendencia apontando para uma diferença significativa no teor de sódio de acordo com a ingestão de alimentos moderadamente processados, os quais foram relaciodados a um menor teor de calcio. Um efeito de interação significativo entre alimentos não processados, moderadamente e ultra-processados foi evidenciada. O padrão alimentar de ingestão de alimentos não processados, moderadamente e ultra-processados nos tercis 1, 2 e 3, respectivamente, alcançaram a recomendação de energia, no entanto, foi acima da referencia para gordura total e sódio, e muito abaixo da recomendação para fibras totais, calcio, magnésio e potássio. A ingestão do tercil 3 de alimentos não processados combinado com tercil 2 ou 3 de moderadamente e ultra-processados foi mais provavel alcaçar a recomendação para ingestão de proteínas, fibras totais, cálcio, magnésio e potássio mas não para energia, gordura total e sódio.

Este estudo mostrou que o grau de processamento de alimentos afeta o perfil nutricional da dieta e a combinação de grupos alimentares classificados pelo grau de processamento pode impactar o teor de nutrientes referenciados pela dieta DASH, no entanto, os resultados sobre o teor de sódio devem ser considerados cuidadosamente.

Abstract

Processed food products have been related to the depletion of vitamins and minerals and elevation of the content of refined carbohydrates, fat, and sodium in the diet. We aimed to evaluate the differences in dietary energy and nutrient contents based on the intake of foods and their corresponding processing grades. For the sample, 125 adolescents and 111 adults were randomly recruited, and their eating patterns were evaluated with two 24-hour dietary recall. The food items were sorted into three groups – unprocessed, moderately processed, and ultra-processed foods – and then categorized in tertiles of intake (grams per day). Energy and the main nutrients advocated in the DASH diet eating plan for optimal blood pressure were estimated. Differences in energy, protein, carbohydrate, total fat, total fiber, calcium, magnesium, potassium, and sodium according to the varying processing grades of foods were tested with a generalized linear model. The interaction effect between unprocessed, moderately and ultra-processed foods was also tested. A pairwise comparison analysis of the food groups in tertiles of intake was performed in an attempt to combine food groups into food patterns representative of the whole food intake. The approximation of the food patterns to the nutrient recommendation of the DASH diet was demonstrated. The unprocessed food intake was significantly related to dietary fiber, calcium, magnesium and potassium contents, whereas the intake of ultra-processed foods was inversely related to fiber and potassium. There was a trend appointing to a significant difference in dietary sodium content according to the intake of moderately processed foods, which was associated with lower calcium content. A significant interaction among unprocessed, moderately, and ultra-processed foods was evidenced. The food pattern of intake of unprocessed, moderately, and ultra-processed foods in tertiles 1, 2, and 3, respectively, achieved the energy recommendation; however, it was above the reference for fat and sodium and very below the reference values for fiber, calcium, magnesium, and potassium. The tertile 3 intake of unprocessed foods combined with tertile 2 or 3 of moderately and ultra-processed foods were more likely to achieve the recommendation for protein, fiber, calcium, magnesium, and potassium but not for energy, total fat, and sodium. This study showed that the processing grade of foods affects the dietary nutrient profile and that the combination of food groups may impact the DASH diet nutrient references; however, the results regarding dietary sodium content must be warily considered.

Introduction

The nutritional transition has been associated with the increased prevalence of obesity-related chronic diseases (1, 2) and the simultaneous replacement of unprocessed foods by ultra-processed foods (3, 4). Food processing usually involves increasing or adding salt, oils, fats, sugar or sweeteners, flours or starches; depleting nutrients; and providing calories. As a result, the intake of highly processed products has been associated with overeating, overweight, and obesity. Sweetened drinks and soft drinks are potent obesogenic agents and may cause diabetes mellitus (4). Synthetic substances, such as glutamate monosodium, have also been associated with obesity (5). In addition, some of the mechanisms of food processing and preservation, which include cooking at a high temperature, soaking food with salt or sugar, or adding synthetic substances, are also responsible for a higher intake of sodium, an essential micronutrient for increasing blood pressure (6, 7).

Very recently, food processing has been set as a dietary determinant of nutrient density, and recommendations based on it have been described in dietary guidelines (8, 9). However, the classification of foods according to processing grade and its impact on nutrient content demand further discussion. Monteiro et al. (2010) proposed a new classification of foods and drinks, emphasizing the nature, extent, and purpose of the processing grade (10, 11). Although the effect of processed foods on dietary patterns has been shown, few studies take into account the food processing grade (12, 13). A study conducted in adolescents showed the association between a high intake of ultra-processed products and metabolic syndrome (12). The processing grade has also been associated with poor diet quality (13). However, the impact of the processing grade on the dietary nutrient content remains unclear. In this study, we investigated the relationship between food processing grades – unprocessed, moderately processed and ultra-processed – and the dietary nutrient content of energy, macronutrients, fiber, calcium, magnesium, potassium, and sodium in food intake. Because the nutrient intake recommended in the DASH diet eating plan is consistently effective in the prevention or treatment of hypertension, the DASH diet nutrient profile has been chosen as a reference parameter in this study.

Methods

Participants

A cross-sectional study was conducted in Porto Alegre, capital of the southernmost state in Brazil, to investigate the obesity syndrome and risk factors for cardiovascular disease (SOFT study). The study enrolled a subsample of adolescents (n=125, 11-19 years), adults (n=65, 20-59 years), and elderly individuals (n=46, 60 years or older) to assess 24-hour dietary recalls in order to validate a food frequency questionnaire (FFQ) (14). Details are provided elsewhere (15). The research protocol was approved by the Institution Review Board, which is accredited by the US Office of Human Research Protections.

Food intake evaluation

The food intake assessment was based on two sequential 24-hour dietary recalls, from which data on food items, preparation methods, ingredients of homemade concoctions and recipes, quantities, portion sizes, and brands of industrialized products were collected. Portion sizes and kitchen utensils were reported based on a photo album of 60 different food and household items. Quality control procedures included food survey supervision and repeated interviews with additional questioning, if needed. Quantity and portion size were converted to grams per day using the Nutrition Support Program (NUTWIN, Center for Health Informatics, USP, São Paulo, Brazil) (16). Homemade recipes were broken down in order to obtain information on intake of food items such as vegetable oils, sugar, sweeteners, salt, and salt-based spices. The weight (g) and volume (mL) of the ingredients were estimated based on their proportions (%) from the recipe, which were calculated by using the table for assessment of food consumption in portion sizes (17).

Recipes from ethnic or gourmet cuisine were converted using information from specialized gastronomy websites. One hundred seventy-two recipes and homemade concoctions were broken down, including fried, roasted, baked, cooked, and grilled foods. Purchased, ready-to-eat foods, such as frozen or processed foods, did not have their components broken down. The nutrient composition was analyzed based on the following food composition tables: TACO – *Brazilian Food Composition Table*, second edition (18) and USDA – *National Nutrient Database for Standard Reference*

– *Release 22 tables United States Department of Agriculture* (18). Sixty-nine percent of the 499 different food items were analyzed according to the TACO food composition table.

The overall list of food and food items was sorted into three groups: unprocessed or minimally processed foods, culinary ingredients or moderately processed foods, and ultra-processed food products (10). The latter group included foods submitted to salting, sugaring, baking, frying, curing, smoking, pickling, and canning, as well as those with cosmetic additives and preservatives, synthetic vitamins and minerals, and that are packaged with the aim of making them more durable, affordable, practical, attractive, and ready for consumption. Ultra-processed foods are processed to reduce microbial deterioration (long shelf life), making them easily portable, palatable and proper for habitual use. The consumption of the food groups (unprocessed, moderately, and ultra-processed food) was converted to grams per day and categorized into tertiles [Unprocessed foods (1st tertile: 26.35 - 433.40; 2nd: 433.95 - 767.55; 3rd: 768.10 - 2763,20); moderately processed (1st tertile: 19.00 - 177,30; 2nd: 177.40 – 347.65; 3rd: 348.00 – 3130.00); ultra-processed foods (1st tertile: <320.75; 2nd: 322.50 – 748.05; 3rd: 749.00 – 2416.9)]. The changes proposed in order to match the method used for dietary intake evaluation was described in **table 1**.

Statistical analysis

Nutrients were adjusted for energy intake by residual method (20). The differences in the average intake of the food groups, energy, and nutrients according to sex and age were tested with GEE (Generalized Estimated Equation). The content of energy and nutrients from each food group was graphically demonstrated. Differences in dietary energy and nutrient contents according to the increase in intake of unprocessed, moderately and ultra-processed food products, in tertiles (grams per day), were evaluated with GEE. The dietary energy and nutrient contents were estimated according to pairwise combinations of the unprocessed, moderately, and ultra-processed food products, thus representing food patterns. The analysis on adequacy of dietary energy and nutrient contents was graphically performed by using as a reference the nutrient recommendation of the DASH diet eating plan for a diet of 2100 kcal/day. [Energy = 2100 kcal/d; protein = 18%; total fat = 27%; carbohydrate = 55%; total fiber = 45 mg/d; calcium = 1200 mg/d; magnesium = 450 mg/d; potassium = 4500 mg/d; sodium = 2400 mg/d] (21). Food patterns were created by pairwise comparisons among the three food groups. All the analyses in the GEE model were performed with auto-regressive working correlation matrix level 1, Gamma distribution with identify link function. The goodness of fit was evaluated with the Akaike's Information Criterion (AIC) test and statistic diagnostic, assuming the lowest value as the best fit. The analyses were adjusted for sex and age.

The analyses were performed in the software Statistical Package for Social Sciences (SPSS®, version 18.0).

Results

Among the 125 adults selected, thirteen refused to participate, and one was excluded for being on a diet. Among 127 adolescents, two refused to participate. From the 236 individuals evaluated, 53 percent were adolescents, 20 percent were elderly, and 55 percent were women. **Table 2** shows the average intake of micro-, macronutrients, and energy by sex and age. Men had the higher intake of moderately processed food, total fat, and energy, while women had the greater intake of carbohydrate and magnesium. The total consumption of selected nutrients varied with age. A greater proportion of adolescents reported an intake of ultra-processed food, energy, and carbohydrate, whereas a higher proportion of adults reported eating moderately processed food. There was a linear association between age and intake of calcium, magnesium, and potassium.

Figure 1 shows the energy and nutrient contents of unprocessed, moderately, and ultra-processed food products. The higher the food processing grade, the higher the energy and carbohydrate contents of the food group. Unprocessed food had the highest dietary content of protein, fiber, calcium, magnesium and potassium, and the moderately processed food had the highest content of total fat and sodium. The lowest content of sodium was observed for unprocessed food.

Table 3 demonstrates the association of energy and nutrient contents with average dietary intake according to food processing grades. The energy content was directly associated with the reported average intake of unprocessed, moderately, and ultra-processed foods. The dietary protein content was linearly associated only with the average intake of unprocessed foods. The total fiber content was directly associated with the intake of unprocessed foods and inversely with ultra-processed foods. The dietary calcium content increased with the average intake of unprocessed foods but decreased with the moderately processed foods. The dietary magnesium and potassium contents were highest in the 3rd tertile (80% and 53%, respectively) of unprocessed food consumption. However, in the case of ultra-processed foods, the intake was inversely associated (11%). There was a significant interaction among intake of unprocessed, moderately, and ultra-processed foods, showing a strong dependence among unprocessed, moderately, and ultra-processed food products.

The energy, macro-, and micronutrients according to the pairwise analyses of the combined food groups (food patterns) are shown in **Figures 2, 3, and 4**. The nutrient recommendation of the DASH diet eating plan of 2100 kcal/day was used as a target. The energy content (**Figure 2**) of the diet was below the target (2100 kcal/d) for food patterns with tertile 1 of unprocessed food intake combined with all the tertiles of moderately and ultra-processed food products. The energy content was above the target when the food patterns were composed of tertile 3 of unprocessed foods, 2 or 3 of moderately processed food, and tertile 3 of ultra-processed food. The dietary protein content was above the recommendation only when the food pattern was composed of tertile 3 of unprocessed food, tertile 1 or 3 of the moderately processed, and tertile 3 of ultra-processed food products. The food patterns comprised of intake of tertile 3 of ultra-processed foods resulted in a dietary fat content above the target in the majority of comparisons. **Figure 3** describes the carbohydrate, total fiber, and calcium content of the diet according to food patterns. The food patterns composed of intake of tertile 1 or 2 of unprocessed foods combined with all the tertiles of moderately processed food and tertile 3 of ultra-processed foods were closer to the target. The intake of tertile 3 of unprocessed foods combined with tertiles 2 and 3 of moderately and ultra-processed foods, respectively, leads to a dietary carbohydrate content above the recommendation. The most adequate combination of food groups for appropriate dietary fiber content was observed when the food patterns were comprised of tertile 3 of unprocessed and moderately processed foods and tertile 1 of ultra-processed food products. The dietary calcium content was below the recommendation for all the food patterns; however, the higher the contribution of unprocessed food to the whole food pattern, the closer the dietary calcium content was to the target. The target dietary magnesium and potassium contents (**Figure 4**) were more likely to be achieved with the highest tertile of intake of unprocessed foods. Particularly, magnesium was above the target when the intake of moderately and ultra-processed foods was above tertile 2. When the intake of tertiles 1, 2, and 3 of unprocessed foods was combined with the intake of tertile 1 for both the moderately processed and ultra-processed foods, the dietary sodium content was adequate. A higher contribution of moderately and ultra-processed foods to the whole food pattern corresponds to a higher dietary sodium content.

Discussion

This study showed that the intake of processed foods varies differently according to sex and age and that the food processing grade affects the daily dietary contents of macro- and micronutrients. Because diet should not be partially analyzed, we estimated different combinations of the three food groups and their likely impact on the nutrient profile. The nutrient recommendation for an eating plan of 2100 kcal/day based on the DASH diet was influenced differently by the different combinations of tertiles of intake of unprocessed, moderately, and ultra-processed foods. The dietary fiber, magnesium, and potassium contents were clearly improved when the food pattern was composed of a higher intake of unprocessed foods and a lower intake of moderately and ultra-processed. It was unlikely to achieve the target recommendation of sodium and energy when there was a higher intake of ultra-processed combined with a lower intake of unprocessed food products.

Differences in consumption of processed food according to sex and age have been shown. Byrd-Bredbenner and colleagues showed that the intake of unprocessed foods increases from childhood to adulthood and tends to decrease in adulthood with aging, contrarily with ultra-processed foods. Fruits and vegetables represented ten percent of the total energy intake, highly sweetened foods only nine percent, and salty snacks and miscellaneous only two to three percent of the diet of the youngest children, whereas grains represented 43 percent (22). Twenty-four percent of the children aged 2-11 and 35 percent of the adolescents ate fast food twice a day (23). Bowman and colleagues showed that older adults were four times less likely to consume fast foods. (25). Differences in intake of moderately processed foods according to sex could be anticipated because, in addition to the general differences in body size, this food group includes a large portion of usual daily food. When evaluating the habit to have meals out of home, Bowman and colleagues found significant differences in fast-food intake according to sex among adults (24). Seventy-six percent of the women studied by Fretts et al. had smaller density energy arising from the intake of processed meat (<6.5 g/1000 kcal), whereas 48.2 percent of the men had 18.2 g/1000kcal from processed meat (25). The modifier effects of sex and age on the intake of the food groups were evidenced, which suggest that the intake is affected differently by both variables (26).

The energy content according to the food processing grade might be similar because all of the groups include foods with wide energy density, independent of other nutrients. Yet, these results were contrary to those pointed out by Monteiro and colleagues, whose results showed a very high energy density of ultra-processed foods in comparison with the other two food groups (27). Differences in the findings of both studies might be attributed to changes in classification of some foods, such as meat and pasta, and to the evaluation method of food intake in the population.

The evaluation of dietary sodium content from food records might be a critical task. In INTERMAP and INTERSALT studies, processed foods were responsible for the higher dietary sodium content in several countries. For instance, processed breads, cereals, and grains contributed to 34% of total sodium content, and red meat, poultry, and eggs contributed to 20.4% in the United Kingdom. In the United States, salt contributed most to sodium content (29%), followed by bread, cereal, and grains (19.5%), and then by red meat, poultry, and eggs (12%) (29). Furthermore, in these cases, salt from recipes was not estimated and sodium intake was evaluated by urine sample, except in the case of the United States. In our study, as in the US data, we estimated the salt in recipes and added to salads, and all the salt consumed was accounted for in moderately processed foods, not including the salt from ready-to-eat, junk, and fast foods. Although the strategy used for salt estimation in our study was not validated and must be cautiously considered, it has been applied in other studies (29). The dietary sodium and potassium contents have a particular relationship with blood pressure, as argued by Adrogue & Madias, who pointed out the potassium-to-sodium ratio as a mechanism for the development of high blood pressure (30).

Because the processing grade of food is a recently proposed method with very few studies based on it, this study might add an advantage over the previous food classification (10) since it was carried out using two 24-hour dietary recalls, which collected detailed descriptions of foods and recipes. Therefore, for the first time, the food processing grade has been established for estimated homemade recipes, and with reasonable credit. This procedure included grilled (any kind of meat), roasted (any kind of meat), fried (potato, manioc, vegetables, fried dumplings), and cooked (rice, beans, soups; lasagnas and similar pastas; pizza made at home or prepared at traditional restaurants) recipes. For instance, grilled meats (beef, poultry, or fish) were broken down into three foods: meat, vegetable oil, and salt. Roasted or cooked meats were broken down into two food items: meat and salt. As a consequence, meat was analyzed in the unprocessed food group, and salt or vegetable oil was analyzed in the moderately processed food group. Fried foods such as French fries were broken down into three items: potato (analyzed as cooked and classified in unprocessed), vegetable oil, and salt. Cooked foods such as rice and beans were broken down into either rice (moderately processed) or beans (unprocessed), and both were analyzed as cooked foods. The oil and the salt were analyzed as moderately processed foods.

We independently estimated ingredients from fried, cooked, and roasted foods, whereas, in the previous classification, French fries, lasagna, and prepared meat were all assumed to be ultra-processed foods. We have broken down the recipes in order to estimate salt, seasonings, oils, creams, butters, margarines, starches, flours, and sugars, which were not usually consumed independently but as ingredients of cakes, baked goods, lasagnas, and of recipes with meat, pastas, and grains. Otherwise, the consumption of culinary ingredients (moderately processed foods) would be underreported.

Although our study was based on a small sample, it included a representative enrollment of individuals and may have acceptable external validity. However, limitations owing to the use of consecutive 24-hour dietary recalls and a non-validated estimation of salt must be considered, and alternative approaches to estimate ingredients in dietary surveys must be encouraged.

This study reveals a beneficial impact of unprocessed foods on the nutrient profile, leading to a higher content of minerals and fibers, while moderately processed and ultra-processed foods may lead to a depletion of calcium, fiber, and potassium and a higher dietary content of sodium. In addition, the combination of unprocessed, moderately, and ultra-processed foods might impact the nutrient profile differently for each nutrient.

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Table 1 Food groups and food items, with proposal for adaptations.

Food Group	Food items
Unprocessed foods	Fruits; vegetables; tubers and roots; dried (unsweetened), chilled, vacuum-packaged frozen (pulp); mushrooms; oleaginous; seeds; grains in general [1] ; beans; meats in general[2] ; fish and seafood[2] ; fermented foods without added flavor and sugar; eggs; coffee; teas; infusion herbs; and water.
Moderately processed foods	Vegetable oils; margarine; butter; cream; lard/cooking grease; sugar; sweetener; salt[4] ; starches; farinaceous; fresh pasta made with just flour and water[3]; industrial ingredients not sold to consumers such as fructose, lactose, soy protein, corn syrup, gums, additives, and preservatives.
Ultra-processed foods[5]	Breads; cookies; cakes and pies; canned fruits and vegetables, in syrup or preserved; candies; chocolates; cereal bars; morning cereals; cheeses; sweetened dried fruits; sweetened beverages with sugar or sweeteners; diet, light or zero-calorie beverages; frozen pasta and pizza; pre-prepared meat[2] ,vegetables, and recipes[5] ; processed meats such as ham, sausages, breaded burgers; smoked meats; cured meats; instant pasta/noodles; salted vegetables; pickles; baby formulas; modified milk; and baby foods.

Source: MONTEIRO et al., 2010, with adaptations noted in the text.

[1] White rice is submitted to milling, which eliminates more than just the non-edible part of the grain and becomes a refined food with a high glycemic index. This is why it is considered a moderately processed food.

[2] In the occidental diet, meat of any kind, fish, and seafood are consumed fried, baked, grilled, or cooked, except for food served in ethnic restaurants. That way, because information obtained from the 24-hour dietary recalls or FFQ informs preparation method, we propose the inclusion of meats, fish, and seafood (except sushi, sashimi, and other raw food consumed, based on individual accounts) in the ultra-processed food group.

[3] The mixture of water with flour results in a completely different food from the original and is passable for consumption without adding any other food or ingredient. That way, we propose to classify it as ultra-processed.

[4] We add to group 2, monosodium glutamate, commonly used in Japanese restaurants,

because it is an ingredient that is used in a manner similar to the way salt and industrialized seasonings are used.

[5] Foods included in the ultra-processed group that can be broken down and produced at home or in self-service restaurants, such as pies, cakes, and other preparations, suggest an estimation of ingredients. Those foods that are bought ready-made for consumption in the market or in fast food restaurants, such as lasagnas, pies and bakery products, French fries, and cheeseburgers, are considered as such and are included in the ultra-processed food group. Note: French fries and cheeseburgers prepared at home should be broken down.

Table 2 Overall dietary nutrient content according to sex and age [Mean (95% CI)].

	Sex		P value for sex effect	Age (years)			P value for age effect
	Women, n=129	Men, n=107		11-18, n=125	19-59, n=65	≥ 60, n=46	
Unprocessed food, g/d	677.6 (602.5 - 752.8)	703.5 (598.6 - 808.5)	0.7	637.2 (566.8 - 707.5)	722.9 (601.4 - 844.3)	711.8 (578.4 - 845.1)	0.4
Moderately processed, g/d	316.4 (278.7 - 354.2)	412.6 (342.7 - 482.5)	0.02	261.5 (231.1 - 291.9)	488.8 (402.2 - 575.5)	343.2 (267.3 - 419.1)	<0.001
Ultra-processed foods, g/d	534.6 (467.8 - 601.3)	531.8 (458.4 - 605.1)	1.0	856.4 (751.2 - 961.6)	443.5 (364.4 - 522.6)	299.5 (230.0 – 369.0)	<0.001
Energy, kcal/d	1679.7 (1564.3 - 1795.2)	1945.2 (1768.0 - 2122.4)	0.01	2109.2 (1959.8 - 2258.5)	1785.0 (1595.0 – 1975.0)	1543.2 (1337.6 - 1748.7)	<0.001
Protein, g/d	57.7 (55.3 - 60.1)	61.5 (58.1 - 64.8)	0.07	55.6 (53.3 - 57.8)	61.2 (57.5 - 64.8)	62.0 (57.5 - 66.5)	0.002
Carbohydrate, g/d	231.4 (225.4 - 237.4)	216.0 (209.0 – 223.0)	0.001	238.3 (232.2 - 244.4)	214.0 (206.2 - 221.9)	218.7 (209.1 - 228.3)	<0.001
Total fat, g/d	57.9 (55.8 – 60.0)	62.6 (59.5 - 65.6)	0.01	55.1 (53.2 - 57.1)	64.0 (60.7 - 67.4)	61.6 (57.6 - 65.6)	<0.001
Total fiber, g/d	17.5 (16.2 - 18.9)	16.4 (14.7 - 18.1)	0.3	16.7 (15.4 – 18.0)	16.6 (14.7 - 18.4)	17.6 (15.3 – 20.0)	0.8
Calcium, mg/d	828.5 (723.9 - 933.2)	737.6 (632.5 - 842.7)	0.2	644.8 (573.3 - 716.3)	772.4 (648.6 - 896.3)	932.0 (761.5 - 1102.4)	0.005
Magnesium, g/d	243.6 (229.9 - 257.3)	221.3 (205.8 - 236.8)	0.04	193.3 (183.2 - 203.3)	233.8 (216.0 - 251.5)	270.3 (246.8 - 293.8)	<0.001
Potassium, g/d	2081.6 (1968.9 - 2194.4)	2094.2 (1946.6 - 2241.8)	0.9	1783.6 (1691.1 – 1876.0)	2252.4 (2080.7 - 2424.2)	2227.8 (2028.8 - 2426.8)	<0.001
Sodium, mg/d	2983.0 (2815.6 - 3150.3)	2993.6 (2767.8 - 3219.5)	0.9	2944.1 (2777.8 - 3110.5)	3099.9 (2849.3 - 3350.5)	2920.8 (2625.4 - 3216.3)	0.5

The intake of nutrients was adjusted for total energy intake by residual method. Macro- and micronutrients were adjusted for energy by residual method.

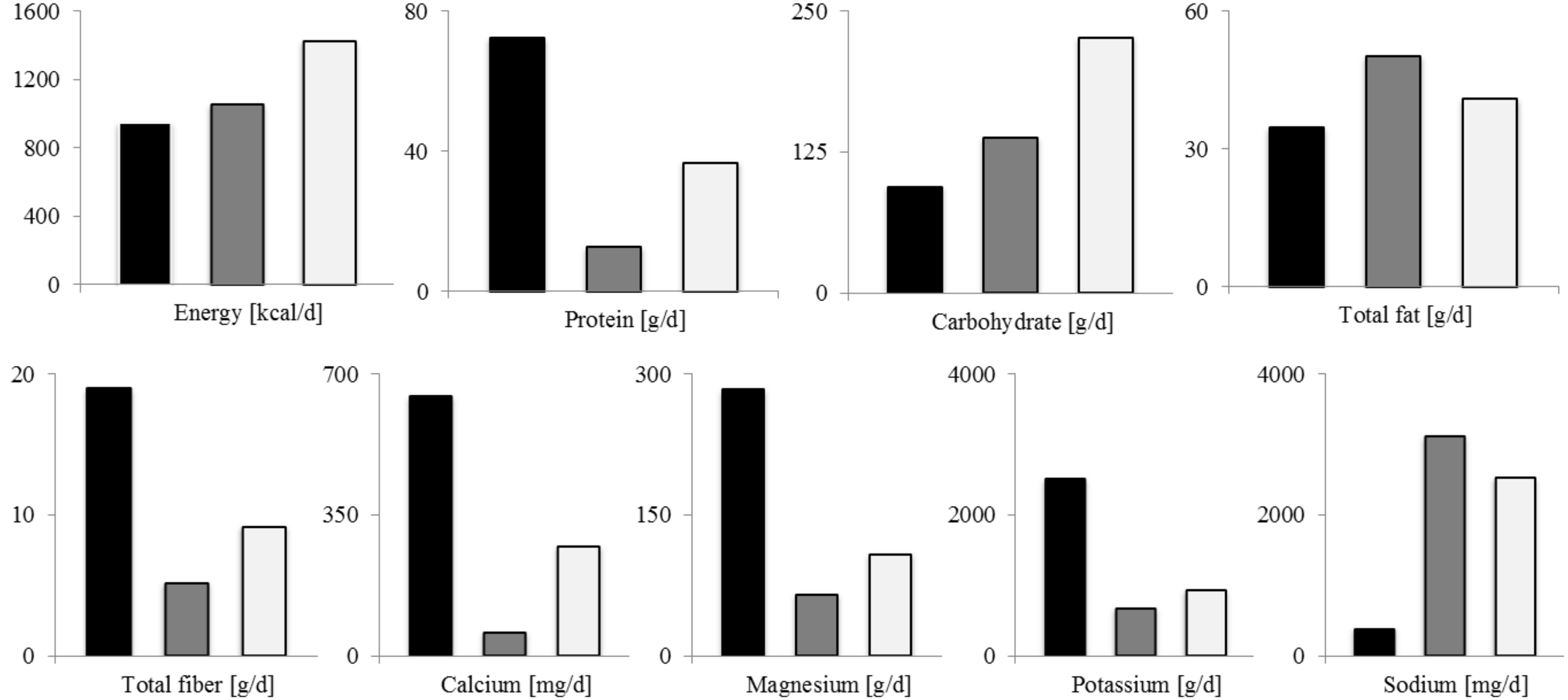

Figure 1 Dietary energy, macro- and micronutrient contents according to food processing grade. ■ Unprocessed; ■ Moderately; □ Ultra-processed foods.

Table 3 Energy and nutrient contents in tertiles of intake of the food groups classified according to food processing grade.

Nutrient	Food intake, g/day	T1	T2	T3	P value[1]	P value[2]
Energy, kcal/day	Unprocessed	1477.8 (1376.8 - 1578.8)	1697.8 (1595.3 - 1800.4)	2286.7 (2149.0 - 2424.3)	<0.001	<0.001
	Moderately processed	1561.8 (1462.0 - 1661.7)	1822.5 (1712.1 - 1932.9)	2078.0 (1952.7 - 2203.3)	<0.001	
	Ultra-processed	1408.2 (1316.3 - 1500.1)	1810.3 (1700.6 – 1920.0)	2243.9 (2081.3 - 2406.4)	<0.001	
Protein, g/d	Unprocessed	53.6 (50.6 - 56.5)	60.7 (57.6 - 63.8)	63.7 (60.4 - 66.9)	<0.001	<0.001
	Moderately processed	61.4 (58.1 - 64.6)	59.0 (55.9 – 62.0)	57.6 (54.7 - 60.5)	0.2	
	Ultra-processed	60.6 (57.4 - 63.8)	59.4 (56.5 - 62.4)	57.9 (54.4 - 61.3)	0.5	
Carbohydrate, g/d	Unprocessed	221.2 (212.9 - 229.4)	222.7 (215.2 - 230.2)	225.5 (218.0 - 232.9)	0.7	<0.001
	Moderately processed	219.4 (211.2 - 227.6)	221 (213.5 - 228.6)	228.9 (221.3 - 236.5)	0.2	
	Ultra-processed	221.6 (213.9 - 229.2)	225 (217.5 - 232.5)	222.8 (213.4 - 232.2)	0.8	
Total fat, g/d	Unprocessed	62.9 (59.9 – 66.0)	59.8 (57.0 - 62.6)	58.4 (55.7 - 61.1)	0.06	<0.001
	Moderately processed	59.7 (56.8 - 62.7)	62.0 (59.2 - 64.9)	59.4 (56.6 - 62.1)	0.3	
	Ultra-processed	60.7 (57.8 - 63.6)	59.9 (57.1 - 62.6)	60.6 (57.3 - 63.9)	1.0	
Total fiber, g/d	Unprocessed	13.4 (11.9 - 14.9)	17.0 (15.3 - 18.6)	18.8 (17.0 - 20.6)	<0.001	<0.001
	Moderately processed	16.3 (14.6 - 18.1)	15.4 (13.9 - 16.9)	17.4 (15.8 – 19.0)	0.2	
	Ultra-processed	18.2 (16.5 – 20.0)	16.4 (14.7 – 18.0)	14.5 (12.7 - 16.3)	0.02	
Calcium, mg/d	Unprocessed	497.9 (431.1 - 564.6)	837.4 (729.4 - 945.3)	968.5 (836.0 - 1101.1)	<0.001	<0.001
	Moderately processed	847.6 (740.5 - 954.6)	762.8 (670.5 - 855.1)	657.3 (577.3 - 737.3)	0.007	
	Ultra-processed	764.9 (673.5 - 856.3)	748.5 (662.5 - 834.5)	754.3 (658.0 - 850.6)	1.0	
Magnesium, mg/d	Unprocessed	518.1 (433.7 - 602.4)	817.0 (711.7 - 922.3)	932.6 (819.5 - 1045.7)	<0.001	<0.001
	Moderately processed	223.4 (209.1 - 237.7)	229.8 (216.3 - 243.2)	232.4 (218.7 - 246.2)	0.6	
	Ultra-processed	240.5 (225.5 - 255.6)	223.4 (210.3 - 236.5)	221.7 (206.5 - 236.9)	0.2	
Potassium, mg/d	Unprocessed	1629.5 (1529.9 - 1729.1)	1992.2 (1886.0 - 2098.4)	2507.2 (2376.8 - 2637.6)	<0.001	<0.001
	Moderately processed	1990.2 (1877.3 - 2103.1)	2008.6 (1902.3 - 2114.8)	2130.2 (2019.4 - 2240.9)	0.1	
	Ultra-processed	2179.8 (2063.3 - 2296.4)	2001.8 (1897.7 - 2105.8)	1947.3 (1826.2 - 2068.4)	0.02	
Sodium, mg/d	Unprocessed	3008.9 (2771.8 - 3246.1)	3045.4 (2821.7 - 3269.1)	2864.3 (2653.9 - 3074.6)	0.5	<0.001
	Moderately processed	2776.9 (2555.0 - 2998.7)	3005.2 (2782.6 - 3227.7)	3136.6 (2909.5 - 3363.7)	0.06	
	Ultra-processed	2957.3 (2733.6 – 3181.0)	2989.1 (2770.9 - 3207.2)	2972.2 (2711.1 - 3233.3)	1.0	

Macro- and micronutrients adjusted for total energy intake by residual method.

[1] P value for linear trend. [Unprocessed foods (1st tertile: 26.35 - 433.40; 2nd: 433.95 - 767.55; 3rd: 768.10 - 2763,20); moderately processed (1st tertile: 19.00 - 177,30; 2nd: 177.40 – 347.65; 3rd: 348.00 – 3130.00); ultraprocessed foods (1st tertile: <320.75; 2nd: 322.50 – 748.05; 3rd: 749.00 – 2416.9)]

[2] P value for interaction effect among unprocessed, moderately, and ultra-processed foods, in tertiles of intake.

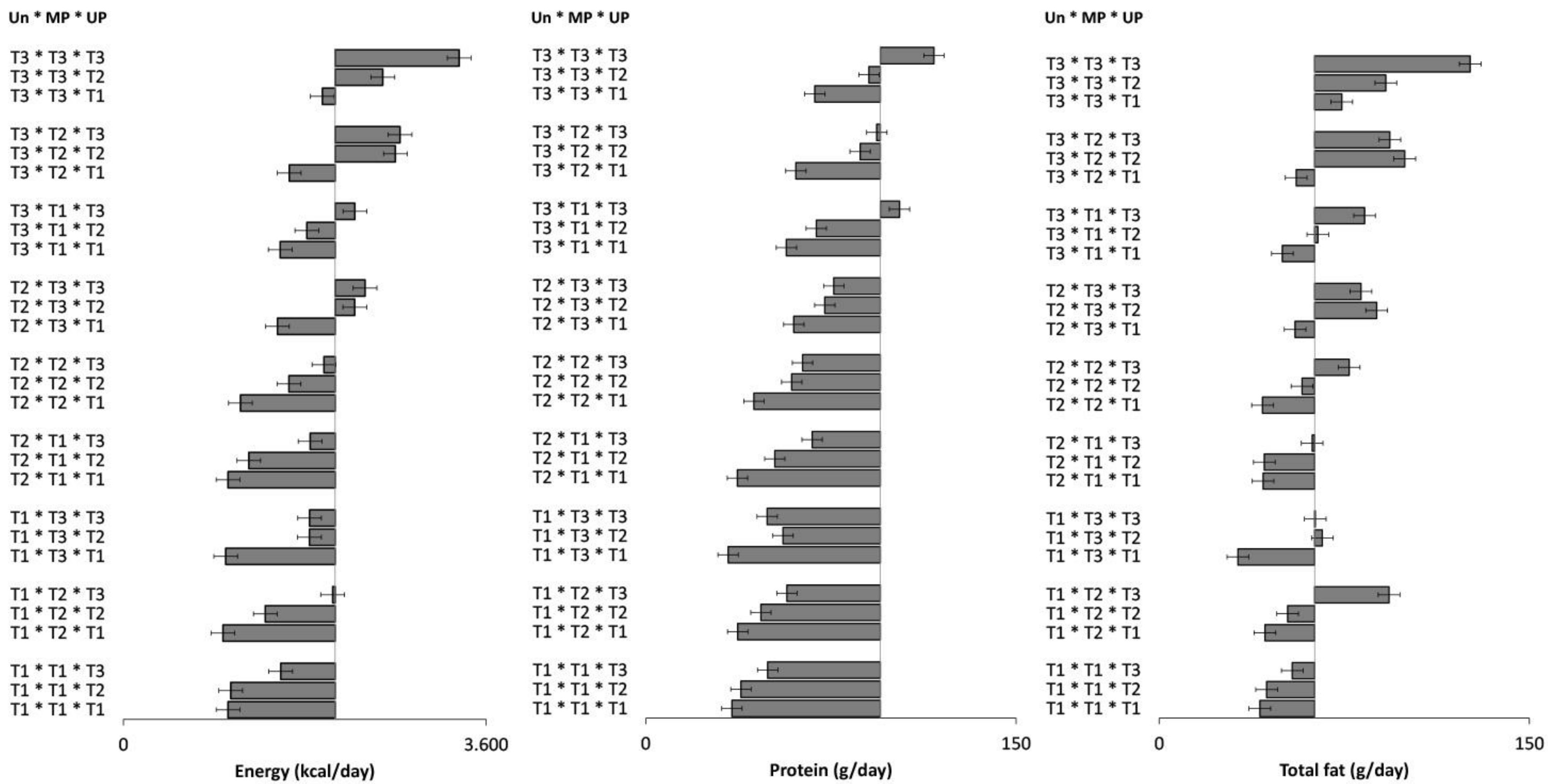

Figure 2 Dietary energy, protein, and total fat contents for food patterns (combinations of unprocessed, moderately, and ultra-processed food products in tertiles of intake in grams per day). DASH diet reference nutrient intake: Energy = 2100 kcal/d; protein = 18%; total fat = 27%. Legend: T = Tertile; Un = Unprocessed; MP = Moderately Processed; UP = Ultra-Processed food products.

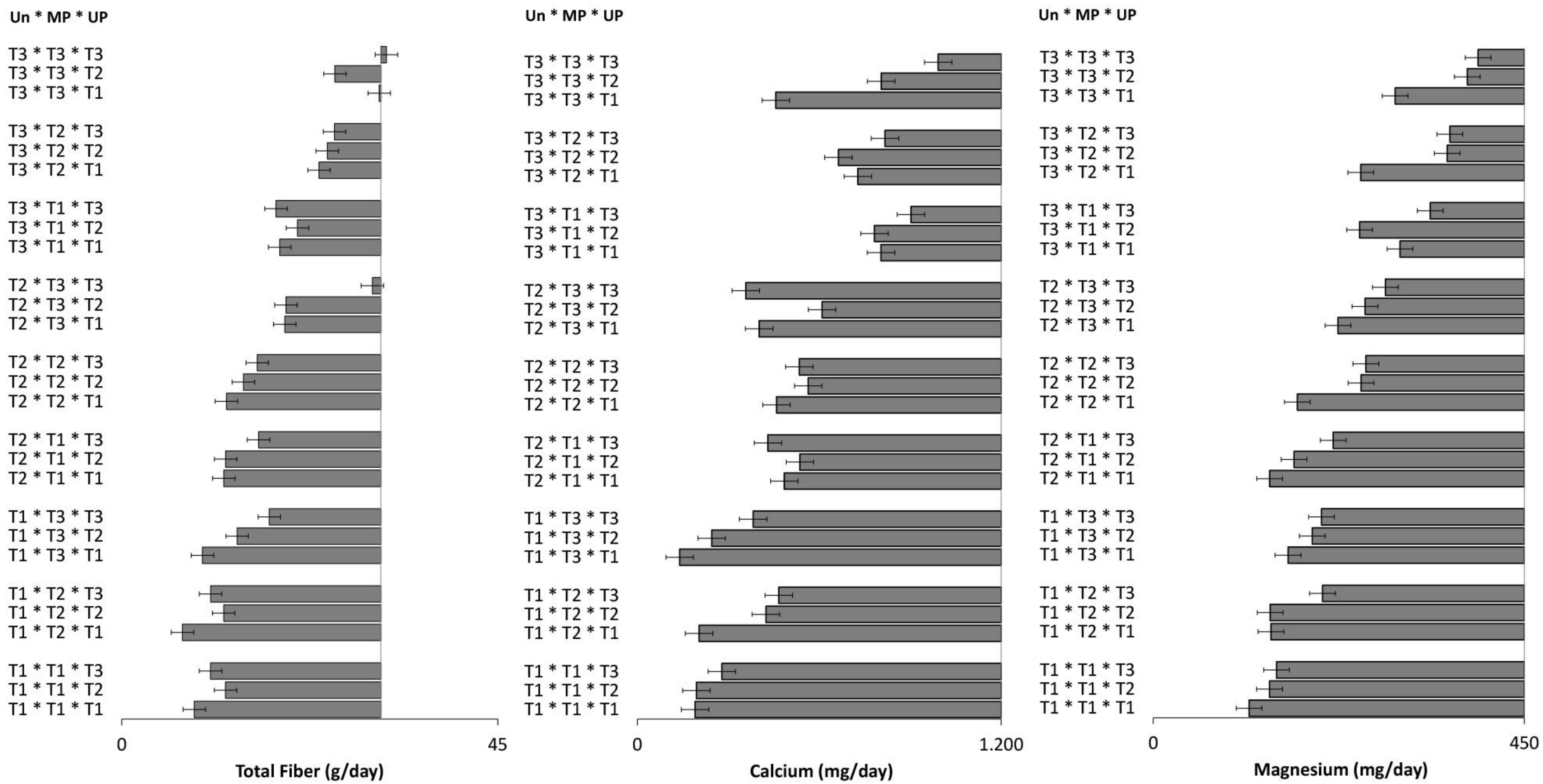

Figure 3 Carbohydrate, total fiber, and calcium contents of the diet for food patterns (combinations of unprocessed, moderately and ultra-processed food products, in tertiles of intake in grams per day). DASH diet reference nutrient intake: carbohydrate = 55%; total fiber = 45 mg/d; calcium = 1200 mg/d.

Legend: T = Tertile; Un = Unprocessed; MP = Moderately Processed; UP = Ultra-Processed food products.

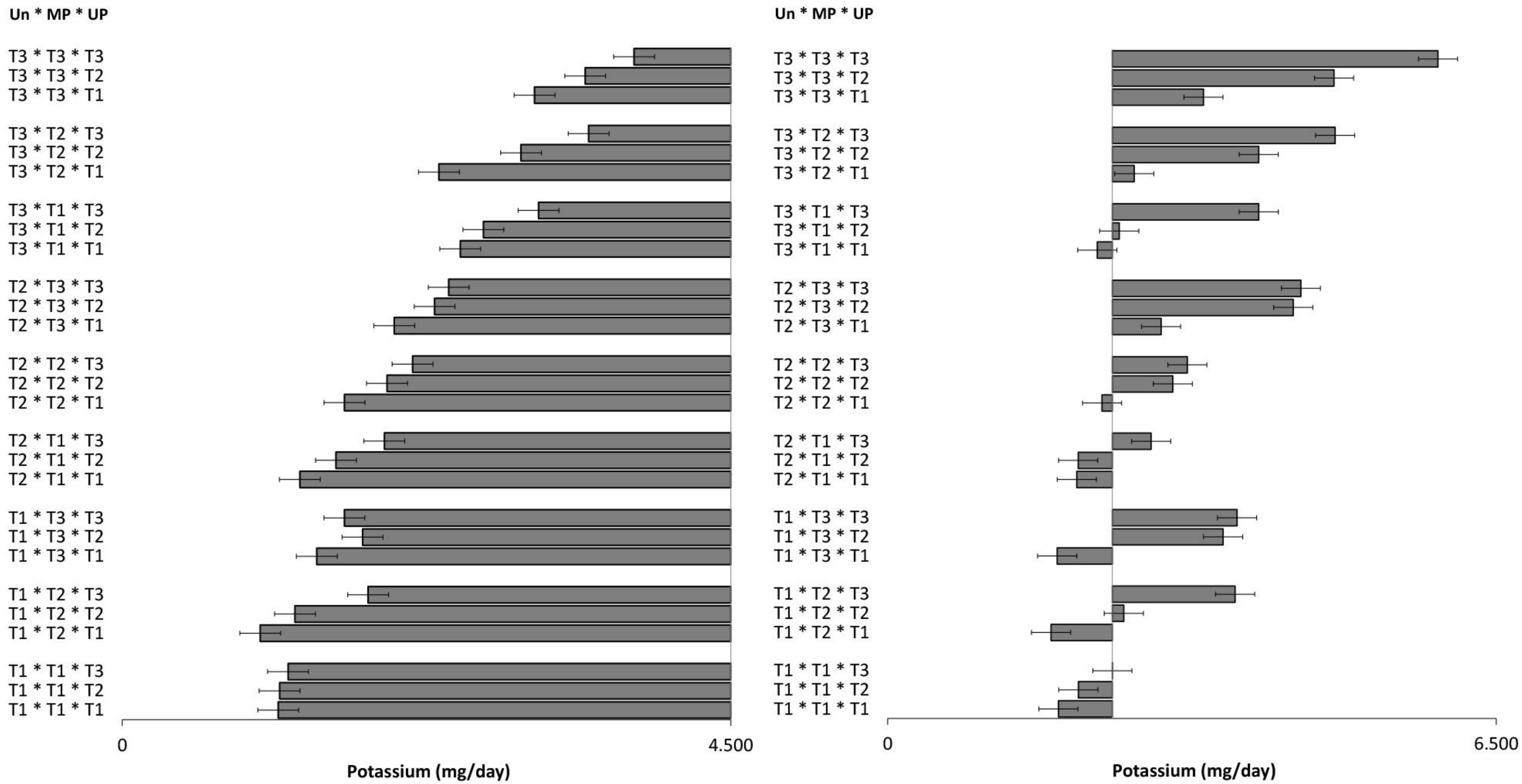

Figure 4 Magnesium, potassium, and sodium contents of the diet for food patterns (combinations of unprocessed, moderately and ultra-sed food products, in tertiles of intake in grams per day). DASH diet reference nutrient intake: magnesium = 450 mg/d; potassium = 4500 mg/d; sodium = 2400 mg/d.

Legend: T = Tertile; Un = Unprocessed; MP = Moderately Processed; UP = Ultra-Processed food products.

ARTIGO 2

Relação entre o grau de Processamento de Alimentos e Pressão Arterial em Adolescentes.

Relation between Food Processing Grade and Blood Pressure in Adolescents

Food Processing Grade and Blood Pressure in Adolescents

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To be submitted to the Archives of Pediatrics & adolescents Medicine

Background: The increased intake of ultra-processed foods along with the decreased intake of unprocessed and moderately processed foods have been associated with augmented body mass index and, potentially, blood pressure.

Objective: To estimate the relationship between food processing grade and blood pressure.

Design: Cross-sectional study.

Setting: Probabilistic sample of adolescents recruited in Porto Alegre, South Brazil, in 2006.

Participants: All adolescents who were home, aged 12 to 18 years.

Main outcomes and measures: Systolic and diastolic blood pressures, weight, and height were measured. Sex, age, years of schooling, smoking habits, and physical activity were informed by the adolescents. Diet was assessed through a validated food frequency questionnaire. The list of foods was sorted into: unprocessed, moderately processed, and ultra-processed foods. Analyses were performed with generalized linear models with sequential forward inclusion of main confounder, energy, and body mass index. The intakes of the food groups, in tertiles of consumption, were combined into food patterns.

Results: For males, blood pressure ranged among the tertiles of unprocessed food intake, while in females, systolic and diastolic blood pressures were inversely related to the tertiles of ultra-processed. There was a strong body mass index effect on the results. Multivariate analyses showed blood pressure to have a non-linear association with unprocessed foods and a linear trend with ultra-processed for males. Among females, the major effect attributed to body mass index was observed in tertile 1 of ultra-processed food intake for systolic and diastolic blood pressures. For individuals with food patterns consisting of a low intake of unprocessed foods, blood pressure changed significantly in the highest tertile of ultra-processed food intake. However, blood pressure was less affected by ultra-processed foods when the food pattern already consisted of a high intake of them.

Conclusions: Our results showed an inverse relationship between food processing grade and blood pressure in adolescents. Because diet is not composed of just one food group, the results generated by food patterns might be most relevant. Food patterns with a high intake of unprocessed foods might attenuate the impact that changes in tertiles of intake of moderately and ultra-processed food products have on blood pressure, leading to more homogeneous blood pressure levels.

BACKGROUND

In children and adolescents, increased blood pressure is triggered by an unhealthy lifestyle and environment, characterized by high intakes of fat, cholesterol, and salt; lower potassium intake; reduced physical activity; excessive time watching TV or using digital media; alcohol consumption; and smoking[1]. A strong linear relationship between body mass index and systolic and diastolic blood pressures identified that a gain of 1.7 kg/m^2 in men and 1.25 kg/m^2 in women corresponded to 1 mmHg increase in systolic blood pressure[2]. In addition to genetic susceptibility, factors such as overweight, central deposition of fat, and metabolism of sodium are together in the development of obesity-hypertension syndrome, which accounts for the hyperactivity adrenergic and renin-angiotensin aldosterone system, leading to fluid retention[3,4].

In adolescents, hypertension has a strong impact on long-term development of chronic diseases[1] and could be averted with a diet based on vegetables and fruits, nuts, whole grains, and less refined carbohydrates[5]. The exceedingly high prevalence of obesity led to a general recommendation encouraging the intake of unprocessed foods and refraining from ultra-processed foods, such as processed meat, sodas, and refined items[5], in order to prevent high metabolic syndrome[6].

Lifestyle characteristics of adolescents, such as eating at fast food and self-service restaurants, have been associated with higher intakes of regular soda, energy, fat, saturated fat, sugar, sodium, and protein[7,8]. Although some processed foods[9] and added substances[10] have been shown to be risk factors for obesity[10], cardiovascular diseases[11, 12], and metabolic syndrome among adolescents[6], evidence regarding the effect of food processing grades on blood pressure is lacking. Therefore, the aim of this study was to evaluate the association between food processing grade and blood pressure.

METHODS

Subjects

Five hundred ninety-nine adolescents aged 12 to 18 years were enrolled in Porto Alegre, a capital city in southern Brazil, through a multistage probability sampling to participate in a population-based, cross-sectional study, the Syndrome of obesity and cardiovascular risk factors (SOFT). Details are described elsewhere[13]. Firstly, 106 census sectors were selected from a random sampling of 2,157 census sectors[14]. Then a simple random sampling of one block and street corner was performed, which was then followed by a systematic sampling of one house in each. All adolescents in the household were selected.

Certified research assistants conducted standardized interviews with the adolescents and their mothers or legal guardians, measured blood pressure, weight, and height, and collected dietary information using a validated food frequency questionnaire (FFQ)[15]. The adolescents and their mothers or legal guardians signed a consent form. The research protocol was approved by the Institution Review Board, which is accredited by the US Office of Human Research Protections.

Dietary assessment

The diet was evaluated using a semi-quantitative FFQ with a list of 136 food items consumed during the last 12 months. In order to estimate the intake of moderately processed foods, 59 recipes were broken down according to methods described elsewhere[16]. All the recipes prepared at home or in restaurants had their ingredients estimated. As a result, a set of 155 food items was categorized by processing grades according to the classification proposed by Monteiro et al. (2010)[17] and adapted by Rossato et al. (2013)[16]. Unprocessed foods included fruits, dried fruits, and natural fruit juices (not bottled or canned); whole grains (oat); milk and plain yogurt; vegetables; legumes; seeds; nuts; coffee; tea and mate (specific kind of tea from southern Brazil); and cooked potato and manioc (cassava). Moderately processed foods or culinary ingredients comprised of refined grains (white and brown rice), *requeijão* (a particular kind of soft, salty cream), cream, cheese, butter, margarine, mayonnaise, jelly, honey, salt, vegetable oil, vinegar, glutamate monosodium, and yeast. Refined, light, or whole bread; *pão de queijo* (Brazilian cheese bread), sweet bread, cookies, biscuits and crackers, cheese, soy milk, artificially flavored yogurt bottled or canned fruit juices, soda, pasta, gnocchi, tomato sauce, processed meat (ham, sausage, hot dog frank, hamburger), fried egg, fried potato, fried manioc (cassava); canned fish (tuna and sardine), candies, chocolates, and popcorn were classified as ultra-processed foods. Food groups were calculated as continuous variables, in grams per day, and categorized into tertiles of consumption: unprocessed (Tertile 1: ≤1557.71 grams/day; Tetile 2: 1557.72 – 2412.06 grams/day; Tertile 3: ≥2412.07 grams/day); moderately processed (Tertile 1: ≤126.04 grams/day; Tertile 2: 126.05 – 207.25 grams/day; Tertile 3: ≥207.26 grams/day); and ultra-processed foods (Tertile 1: ≤579.54 grams/day; Tertile 2: 579.55 – 1010.17 grams/day; Tertile 3: ≥1010.18 grams/day). Energy and nutrient intakes were assessed based on the TACO – Brazilian Food Composition Table[18] and USDA – National Nutrient Database for Standard Reference – Release 24 tables United States Department of Agriculture[19].

Assessment of non-dietary information

Four standardized blood pressure (mmHg) measurements were obtained during household interviews, using a validated automatic device (OMRON HEM – 705 CP, OMHOM, Matsuzaka, Mie, Japan)[20]. The average blood pressure was used in the analysis.

Weight (kg) was assessed with the subject wearing light clothes and no shoes, rounded to the nearest 100g scale (Plenna, model TINN 00088 Plenna S.A., Sao Paulo, Brazil). Height was measured with a Frankfort plane to the nearest 0.1cm. Body Mass Index [BMI = weight (kg)/(height (m))^2] was calculated and categorized as underweight and normal (BMI < 25 kg/m^2) and overweight and obese (BMI ≥25 kg/m^2)[21].

Information on sex, age, skin color, education level, smoking, and physical activity was gathered by a standardized questionnaire. Smoking habit information was obtained by asking the adolescent if he or she has already smoked 100 or more cigarettes during his or her lifetime. For categorization, we considered the current smoking habit by sorting current smokers, those who have smoked 100 or more cigarettes in a lifetime or continue to smoke, and non-smokers, those who have never smoked or have stopped. Education level was defined according to the number of successfully accomplished school years. Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ, short version), and overall activity was categorized into <150 or ≥150 min/week[22]. Adolescents were categorized according to age (12-14, 15-17, and 18-19 years), years at school (0-6 and ≥ 7 years at school), and smoking (yes or no).

Statistical analysis

Out of the 599 adolescents who responded to the questionnaire, outlier procedures identified 30 adolescents with an energy intake higher than 6000 kcal/day and were excluded from the analysis. Generalized linear regression model with normal distribution and robust estimator was performed to take into account the nonlinear relationship between predictors and dependent variables. The interaction effect between the three food groups was tested. The systolic and diastolic blood pressures were averaged for food patterns, which were generated by combining the tertiles of intake of unprocessed, moderately, and ultra-processed foods. The goodness of fit was evaluated with the Akaike's Information Criterion (AIC) test and diagnostic statistic. Systolic and diastolic blood pressure analyses were categorized into <25 kg/m^2 and ≥25 kg/m^2 [21]. Sex, age, years at school, smoking, physical activity, and energy intake were considered potential confounding factors. Analyses were carried out separately for males and females and adjusted for age, years at school, smoking, physical activity, and total energy intake. Body mass index was not included in the analysis as an adjustment variable because it is involved in the path of causation and is supposed to be a mediator, not a confounder[26]. We have considered significant P<0.05 for mean comparisons and interaction effects.

RESULTS

Bivariate analyses showed that males and smokers were more likely to consume higher amounts of unprocessed, moderately, and ultra-processed foods than females and non-smokers (**Table 1**). Older adolescents with a higher education level consumed a greater amount of moderately processed foods, while ultra-processed food intake was more prevalent among males, smokers, and physically active adolescents.

Table 2 shows that the systolic and diastolic blood pressures increased with age and education level. Systolic and diastolic blood pressures were on average higher among males who were older, more active, and had seven or more years of schooling. Body mass index increased with age, but it was not associated with education or smoking.

Table 3 shows the average systolic and diastolic blood pressures according to tertiles of unprocessed, moderately processed, and ultra-processed foods, after controlling for confounding factors. Among males, unprocessed food intake showed a non-linear association with systolic blood pressure, but there was no association with diastolic blood pressure. There was a trend for an inverse relation between ultra-processed food intake and systolic blood pressure (P=0.09). The multivariate models showed significant associations between unprocessed food grade and systolic blood pressure; therefore, an increase in unprocessed food intake accounted for higher systolic blood pressure. However, the analysis stratified for body mass index determined that the associations were mainly explained by body mass index in the second and third tertiles of unprocessed food. Diastolic blood pressure was not associated with food processing grades, yet there were associations with BMI.

Table 4 shows that for females, ultra-processed food was associated with systolic and diastolic blood pressures, and these associations did not change according to BMI. The intake of ultra-processed foods was significant and inversely related to systolic and diastolic blood pressures, regardless of age, education, smoking, physical activity, and energy intake.

The systolic and diastolic blood pressures according to food patterns for the overall sample are shown in **Figure 1**. The intake of tertile 3 of ultra-processed foods was related to lower systolic blood pressure when combined with tertile 1 or 2 of both unprocessed and moderately processed foods. A food pattern with tertile 3 of unprocessed foods, tertile 2 of moderately processed, and tertile 2 or 3 of ultra-processed food products was also related with lower systolic blood pressure. These findings showed in the overall sample that blood pressure levels might be better explained by the intake of moderately processed foods than by the other two food groups. In general, the diastolic blood pressure was lower when the intake of moderately processed foods was above tertile 2, except when the combination was tertile 2 of both unprocessed and ultra-processed foods and tertile 3 of moderately processed.

Figure 2 shows the systolic and diastolic blood pressures for males and females according to food patterns. For males, increases in intake of moderately and ultra-processed foods in tertiles were clearly related to lower systolic blood pressure levels. The closest to the optimal systolic and diastolic blood pressure levels for males was achieved for the food pattern with tertile 1 of unprocessed and moderately processed foods and tertile 3 of ultra-processed foods. An increase in tertiles of intake of unprocessed and ultra-processed food products was likely to change diastolic blood pressure. Among females (**Figure 3**), systolic blood pressure was significantly lower for food patterns with tertile 3 of ultra-processed foods, and a higher diastolic blood pressure level was observed for a pattern with tertile 3 of unprocessed foods and tertile 2 of moderately and ultra-processed foods. Diastolic blood pressure for females was lower with a food pattern of tertiles 2, 1, and 2 of unprocessed, moderately, and ultra-processed food products, respectively. Higher blood pressure levels were observed for a combination consisting of tertiles 1, 2, and 1 of unprocessed, moderately, and ultra-processed food products, respectively.

DISCUSSION

This study demonstrated that food processing grade is weakly related to blood pressure in the entire sample and inversely related to blood pressure among females, though this was attributed to the BMI effect. The food patterns composed mostly of ultra-processed foods were related with lower blood pressure mainly for males, and the effect of moderately processed food was negligible. The blood pressure levels were less impacted by food patterns composed mostly of unprocessed foods in spite of changes in tertiles of intake of moderately and ultra-processed foods.

Processed foods have been associated with an unhealthy effect on diet due to an unbalanced nutrient content[17]. The effect of ultra-processed foods on blood pressure might be partially attributed to their high content of sodium[23] and low contents of potassium and magnesium, resulting in a deleterious potassium-to-sodium ratio[24]. Additionally, ultra-processed foods such as sugar, sweetened beverages, chips, cookies, ice cream, cake-type desserts, muffins, pastries, doughnuts, crispy rice bars, candies, and French fries are major sources of “empty calories”. They are widely consumed by children and adolescents and are rich sources of sodium. On a typical day, children and adolescents consume 527 “empty calories” derived from these foods at schools[25].

The results of this study were against our conceptual hypothesis but are in line with theories regarding mediation, confounding, moderation, and suppression effect. The effect of BMI on the association between processed food and blood pressure was interpreted as presenting a suppression effect since the association vanished with the analysis by BMI[26]. In addition, the overall inverse relationship between ultra-processed foods and systolic blood pressure is also likely to have been confounded by temporality since the intake of fast food reduces with age[27], while blood pressure augments[28].

We must consider some methodological particularities of this study. The classification method for food processing grade was proposed with basis on family purchases[17] and first adapted for 24-hour dietary recalls[16], and now for FFQ. The estimation of ingredients from recipes was crucial because without it, the intake of moderately processed foods could be subdued. A high intake of unprocessed foods has been related with higher dietary contents of fiber, potassium, magnesium, and calcium. For moderately processed foods, high intake has been associated with calcium depletion and increased sodium content. Ultra-processed foods have been related with depletion of fiber, potassium, and magnesium[16] and increases in energy, sodium, fat, and refined carbohydrate density[25]. Nevertheless, individuals who have a natural diet usually have a lower potassium-to-sodium ratio, which may negatively impact blood pressure levels[25] , compared to those who have a diet based on processed foods. Thus, the findings regarding the relation between processed food and BMI were confirmed, while they were not for blood pressure. The direction of the relationship between ultra-processed foods and blood pressure was contrary, and this may be due to the timing needed for the development of abnormalities. Also, the effect of ultra-processed foods on hypertension may not be direct but mediated by BMI.

This study is likely to be restricted by methodological issues. The methods of estimation of salt used in this study were based on a recent study that proposed a reclassification for 24-hour dietary recall analyses[16] with a reasonable confidence level; however, they were not validated until now. In addition, blood pressure was measured on a single random occasion during the day; therefore, we cannot dismiss the measurement bias[29]. Cross-sectional studies are likely to be affected by reverse causality; however, it still allows for proposing hypotheses, especially regarding undisclosed issues.

Finally, this study shows no independent relationship between the food processing grade and blood pressure other than those that BMI and confounding factors may explain in adolescents. The strong inverse relationship between food processing grade and blood pressure is more likely to be led a suppressor effect of BMI in adolescents. Prospective studies should be enlightening because the study design make possible to avoid potential inverse. Because the classification method of foods according to food processing grade is a recent proposal, more studies are advocated. Nonetheless, the mediator effect of BMI between the processing grade of food and blood pressure is strongly advocated in prospective studies.

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Table 1 Intake of food groups classified by processing grade according to characteristics of adolescents. (N=569).

	N (%)	Unprocessed	Moderately processed	Ultra-processed
		Mean (95%CI)	Mean (95%CI)	Mean (95%CI)
Sex				
Males	277 (49%)	2425.7 (2272.2 - 2579.2)	196.3 (184 - 208.7)	1061.4 (977.2 - 1145.6)
Females	292 (51%)	2047.8 (1898.3 - 2197.3)	172.4 (160.4 - 184.4)	844.2 (762.2 - 926.1)
P value		0.001	0.007	<0.001
Age				
12-14	200 (35%)	2104.7 (1922.6 - 2286.8)	170.6 (156.1 - 185.1)	940.5 (840.4 - 1040.7)
15-17	229 (40%)	2298.6 (2128.4 - 2468.8)	181.1 (167.6 - 194.7)	943.8 (850.1 - 1037.4)
18-19	140 (25%)	2303.9 (2086.3 - 2521.5)	208 (190.7 - 225.4)	973.3 (853.6 - 1093.1)
P value		0.2	0.004	0.9
Years at school				
0-6	423 (74%)	2238.7 (2113.2 - 2364.2)	176.6 (166.7 - 186.6)	972.3 (903.5 - 1041.1)
≥7	146 (26%)	2211.7 (1998 - 2425.3)	205.5 (188.5 - 222.5)	885.1 (768 - 1002.3)
P value		0.8	0.004	0.2
Smoking				
Yes	59 (10%)	2644.9 (2310.7 - 2979.1)	228.4 (201.8 - 255.1)	1142.4 (958.7 - 1326.2)
No	510 (90%)	2184 (2070.3 - 2297.6)	178.9 (169.8 - 188)	927.6 (865.1 - 990.1)
P value		0.01	0.001	0.03
Physical activity (min/week)				
<150	107 (19%)	2181.3 (1931.7 - 2430.8)	196.3 (176.4 - 216.3)	827.3 (690.7 - 963.8)
≥150	462 (81%)	2243.5 (2123.4 - 2363.5)	181.2 (171.6 - 190.8)	978.3 (912.6 - 1044)
P value		0.7	0.2	0.05

Unadjusted analyses.

Table 2 Systolic and diastolic blood pressures and body mass index according to characteristics of adolescents (N=569).

	Blood Pressure (mmHg)		Body mass index(kg/m^2)
	Systolic	Diastolic	
	Mean (95%CI)	Mean (95%CI)	Mean (CI 95%)
Sex			
Males	115.8 (114.3 - 117.4)	68.0 (66.9 - 69.2)	21.7 (21.2 - 22.2)
Females	105.0 (103.5 - 106.4)	65.1 (64.0 - 66.3)	21.5 (21.0 – 22.0)
P value	<0.001	<0.001	0.5
Age			
12-14	106.0 (104.1 - 107.9)	65.3 (64.0 - 66.7)	20.6 (20.0 - 21.1)
15-17	111.7 (109.9 - 113.4)	66.7 (65.4 - 67.9)	21.9 (21.4 - 22.4)
18-19	113.9 (111.6 - 116.2)	68.1 (66.5 - 69.8)	22.7 (22.0 - 23.3)
P value	<0.001	0.03	<0.001
Years at school			
0-6	108.9 (107.5 - 110.2)	66.0 (65.1 – 67.0)	21.5 (21.1 - 21.9)
≥7	114.2 (112.0 - 116.5)	68.0 (66.4 - 69.6)	22.0 (21.3 - 22.6)
P value	<0.001	0.04	0.2
Smoking			
Yes	112.1 (108.5 - 115.7)	67.5 (65.0 - 70.1)	22.0 (20.9 – 23.0)
No	110.0 (108.8 - 111.2)	66.4 (65.6 - 67.3)	21.6 (21.2 - 21.9)
P value	0.3	0.4	0.5
Physical activity (min/week)			
<150	107.0 (104.3 - 109.6)	64.8 (63.0 - 66.7)	21.7 (20.9 - 22.4)
≥150	111.0 (109.7 - 112.3)	66.9 (66.1 - 67.8)	21.6 (21.2 – 22.0)
P value	0.007	0.04	0.9

Unadjusted analyses.

Table 3 Systolic and diastolic blood pressures (mmHg) according to BMI (kg/m^2) for males. N=569.

		Systolic BP	P-value	Diastolic BP	P-value
Unprocessed foods					
1st tertile		118.8 (114.2 - 123.3)	0.02	66.4 (62.9 – 70.0)	0.2
2nd tertile		123.7 (119.2 - 128.1)		69.5 (66.0 – 73.0)	
3rd tertile		118.0 (114.0 - 121.9)		68.1 (65.0 - 71.2)	
Moderately processed					
1st tertile		120.2 (115.8 - 124.6)	0.9	69.0 (65.7 - 72.4)	0.9
2nd tertile		120.0 (115.6 - 124.4)		68.3 (65.0 - 71.5)	
3rd tertile		119.4 (115.2 - 123.6)		68.7 (65.5 - 71.8)	
Ultra-processed foods					
1st tertile		123.7 (118.7 - 128.7)	0.09	69.9 (66.0 - 73.8)	0.6
2nd tertile		119.5 (115.3 - 123.7)		68.2 (64.9 - 71.5)	
3rd tertile		118.6 (114.6 - 122.6)		67.9 (64.8 – 71.0)	
Unprocessed foods			<0.001*		0.08*
1st tertile	< 25	115.6 (111.6 - 119.7)	0.6**	65.6 (62.5 - 68.8)	1.0**
	≥ 25	121.9 (115.1 - 128.7)		67.2 (61.9 - 72.5)	
2nd tertile	< 25	117.0 (112.9 - 121.1)	<0.001**	65.9 (62.7 - 69.1)	0.06**
	≥ 25	130.3 (123.8 - 136.8)		73.1 (68.0 - 78.1)	
3rd tertile	< 25	113.6 (109.6 - 117.6)	0.02**	63.0 (59.9 - 66.2)	<0.001
	≥ 25	122.3 (116.9 - 127.8)		73.1 (68.9 - 77.4)	
Moderately processed			0.01*		<0.001*
1st tertile	< 25	113.8 (109.4 - 118.1)	<0.001**	65.5 (62.1 - 68.8)	<0.001**
	≥ 25	126.6 (120.5 - 132.7)		72.5 (68.6 - 76.5)	
2nd tertile	< 25	116.7 (112.6 - 120.8)	0.4**	64.7 (61.6 - 67.8)	<0.001**
	≥ 25	123.3 (117.0 - 129.6)		71.8 (67.7 - 75.8)	
3rd tertile	< 25	115.2 (111.3 - 119.2)	0.2**	65.1 (62.2 - 68.1)	<0.001**
	≥ 25	123.5 (117.2 - 129.8)		72.2 (68.2 - 76.2)	
Ultra-processed foods			<0.001*		<0.001*
1st tertile	< 25	116.6 (112.4 - 120.7)	<0.001**	65.6 (62.4 - 68.9)	0.1**
	≥ 25	130.7 (122.9 - 138.6)		74.1 (67.9 - 80.3)	
2nd tertile	< 25	115.4 (111.4 - 119.4)	0.09**	65.7 (62.6 - 68.8)	0.4**
	≥ 25	123.6 (117.5 - 129.7)		70.7 (65.9 - 75.5)	
3rd tertile	< 25	114.1 (110.0 - 118.2)	0.01**	63.9 (60.7 - 67.1)	0.002**
	≥ 25	123.1 (117.6 - 128.6)		71.9 (67.6 - 76.2)	

***** P-value for overall results of the association between BMI and tertiles of intake of the food groups. ** P-value for comparisons between BMI categories adjusted for Sidak method for multiple comparisons. Analysis adjusted for age, years of school, smoking, physical activity, and energy intake.

Table 4 Systolic and diastolic blood pressures (mmHg) according to BMI (kg/m^2) for females. N=569.

		Systolic BP	P-value	Diastolic BP	P-value
Unprocessed foods					
1st tertile		106.6 (103.0 - 110.2)	0.9	67.0 (64.1 - 69.8)	0.8
2nd tertile		107.6 (104.0 - 111.2)		66.5 (63.6 - 69.4)	
3rd tertile		106.7 (103.1 - 110.3)		67.5 (64.6 - 70.4)	
Moderately processed					
1st tertile		108.0 (104.7 - 111.3)	0.06	66.2 (63.5 - 68.9)	0.7
2nd tertile		104.0 (100.3 - 107.7)		66.8 (64.1 - 69.4)	
3rd tertile		108.5 (104.5 - 112.6)		67.4 (64.8 - 70.1)	
Ultra-processed foods					
1st tertile		110.5 (107.1 - 113.9)	0.003	69.2 (66.5 – 72.0)	0.03
2nd tertile		106.5 (102.6 - 110.3)		65.4 (62.3 - 68.5)	
3rd tertile		103.9 (100.4 - 107.3)		65.9 (63.0 - 68.7)	
Unprocessed foods			0.02*		<0.001*
1st tertile	< 25	102.9 (99.7 - 106.1)	0.09**	64.1 (61.6 - 66.7)	0.1**
	≥ 25	110.3 (104.9 - 115.7)		69.8 (65.4 - 74.1)	
2nd tertile	< 25	104.4 (101.2 - 107.5)	0.4**	65.5 (62.9 – 68.0)	1.0**
	≥ 25	110.8 (105.0 - 116.6)		67.5 (62.8 - 72.2)	
3rd tertile	< 25	106.6 (103.0 - 110.2)	1.0**	66.3 (63.4 - 69.2)	1.0**
	≥ 25	106.8 (101.2 - 112.4)		68.8 (64.3 - 73.3)	
Moderately processed			<0.001*		0.1*
1st tertile	< 25	104.6 (101.2 – 108.0)	0.08**	64.6 (61.9 - 67.2)	0.3**
	≥ 25	111.4 (106.7 - 116.1)		67.7 (64.4 - 71.1)	
2nd tertile	< 25	103.8 (100.6 – 107.0)	1.0**	65.2 (62.7 - 67.7)	0.3**
	≥ 25	104.1 (98.3 – 110.0)		68.4 (65.0 - 71.8)	
3rd tertile	< 25	104.8 (101.6 - 107.9)	0.4**	65.9 (63.4 - 68.3)	0.3**
	≥ 25	112.3 (105.4 - 119.1)		69.0 (65.6 - 72.5)	
Ultra-processed foods			0.001*		0.01*
1st tertile	< 25	106.0 (102.8 - 109.1)	0.005**	65.8 (63.3 - 68.4)	0.01**
	≥ 25	115.0 (110.0 - 120.1)		72.6 (68.6 - 76.7)	
2nd tertile	< 25	105.2 (102.0 - 108.5)	1.0**	65.5 (62.8 - 68.1)	1.0**
	≥ 25	107.7 (101.4 – 114.0)		65.3 (60.2 - 70.4)	
3rd tertile	< 25	102.8 (99.4 - 106.2)	1.0**	64.6 (61.9 - 67.4)	1.0**
	≥ 25	104.9 (99.4 - 110.4)		67.1 (62.7 - 71.5)	

***** P-value for overall results of the association between BMI and tertiles of intake of the food groups. ** P-value for comparisons between BMI categories adjusted for Sidak method for multiple comparisons. Analysis adjusted for age, years at school, smoking, physical activity, and energy intake.

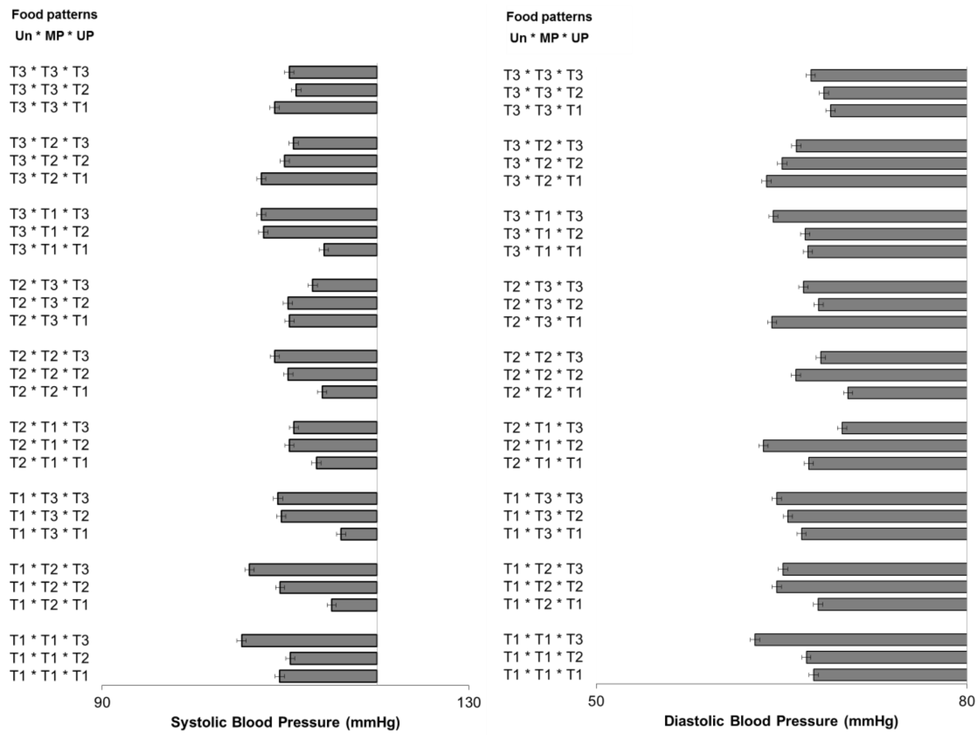

Figure 1 Systolic and diastolic blood pressures according to the food patterns of unprocessed, moderately, and ultra-processed food groups. Analysis adjusted for age, years at school, smoking, physical activity, body mass index, and total energy intake. Legend: T = Tertile; Un = Unprocessed; MP = Moderately Processed; UP = Ultra-Processed food products.

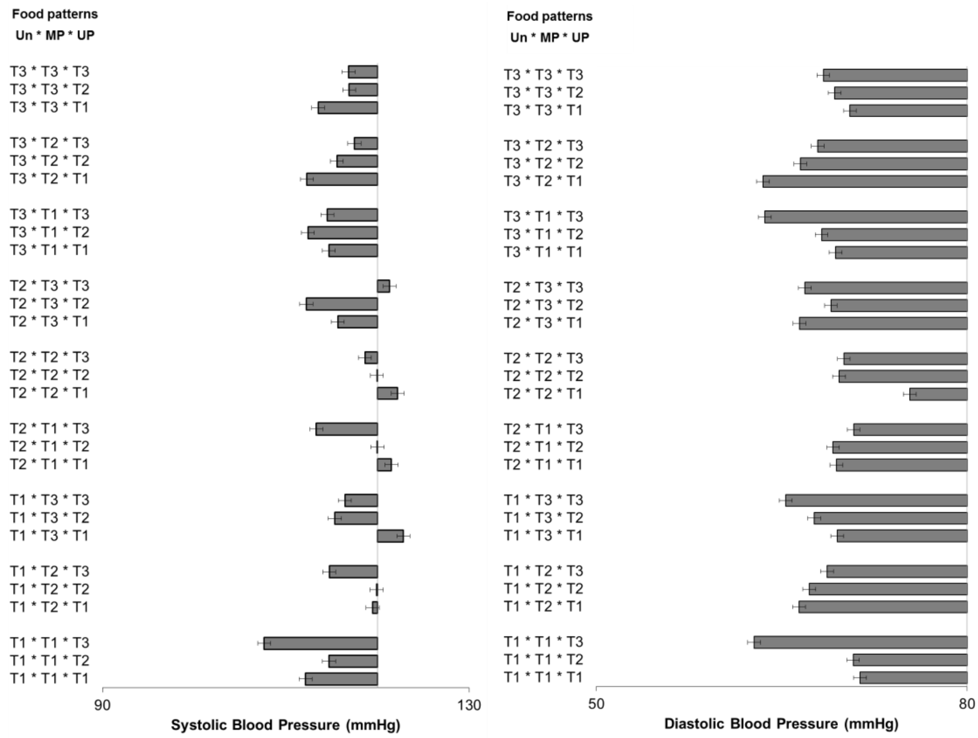

Figure 2 Systolic and diastolic blood pressures for males according to the food patterns of unprocessed, moderately, and ultra-processed food groups. Analysis adjusted for age, years at school, smoking, physical activity, body mass index, and total energy intake. Legend: T = Tertile; Un = Unprocessed; MP = Moderately Processed; UP = Ultra-Processed food products

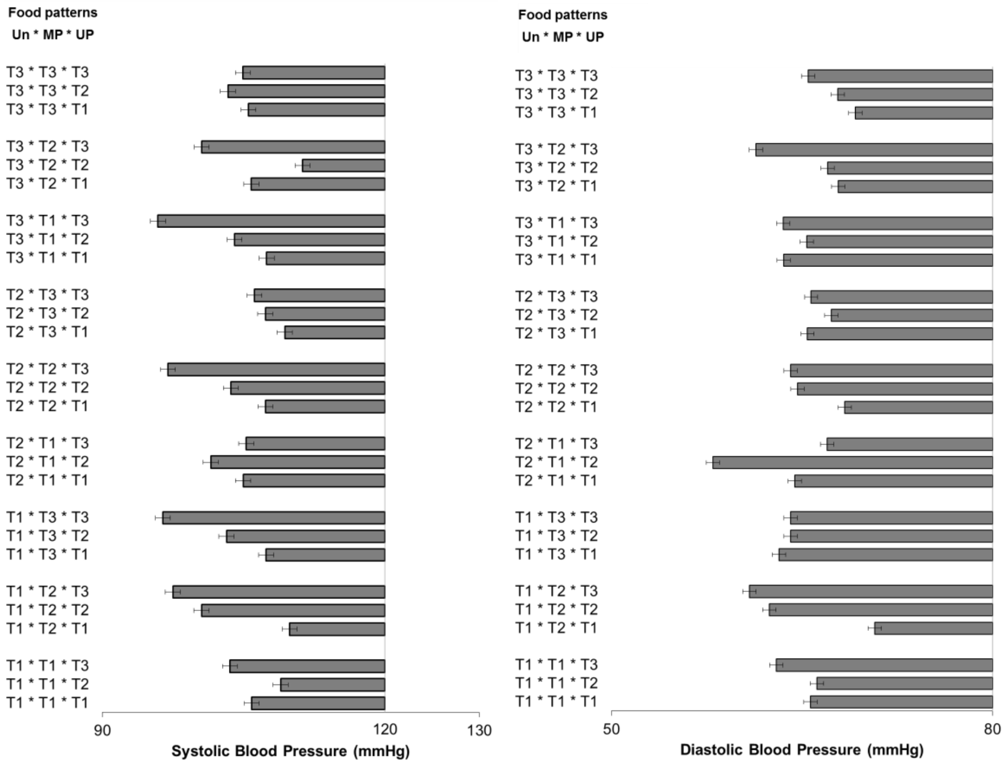

Figure 3 Systolic and diastolic blood pressures for females according to the food patterns of unprocessed, moderately, and ultra-processed food groups. Analysis adjusted for age, years at school, smoking, physical activity, body mass index, and total energy intake. Legend: T = Tertile; Un = Unprocessed; MP = Moderately Processed; UP = Ultra-Processed food products.

ARTIGO 3

Relação entre o grau de processamento de alimentos e razão potássio sódio com pressão arterial em adultos

Relation between food processing grade and potassium-to-sodium ratio on blood pressure in adults.

Short title: Food processing grade and blood pressure in adults

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Abbreviations used: BP, blood pressure; BMI, body mass index; FFQ, food frequency questionnaire.

To be submitted to the American Journal of Clinical Nutrition

Abstract

Ultra-processed foods are increasingly replacing the presence of unprocessed foods in the diet and might be related to blood pressure elevation through the potassium-to-sodium ratio mechanism and indirect body mass index effect. We aimed to evaluate the association between food processing grade and blood pressure in adults, taking into account the indirect effects of the K/Na ratio and body mass index. A cross-sectional study with a probabilistic sampling of 1,858 adults between the ages of 18 and 90 years was conducted in southern Brazil. Blood pressure, weight, and height were evaluated with calibrated devices and according to international recommendations. Information regarding sex, age, years of schooling, physical activity, smoking, and alcohol intake were obtained with a standardized questionnaire. Food intake was evaluated with FFQ, and the ingredients from recipes were estimated. The listed foods were sorted into the food groups unprocessed, moderately, and ultra-processed, and each food group was classified in tertiles of consumption. After adjustment for energy through the residual method, the K/Na ratio was estimated. Analysis was carried out with the generalized linear model with robust estimator. The interaction effect between food processing grade and body mass index and the food patterns generated by combinations of the three food groups were evaluated. Food processing grade was significantly associated with the K/Na ratio, blood pressure, and body mass index. In the overall analysis, food processing grade was not associated with blood pressure, and we observed a significant interaction effect between food processing grade and BM. Systolic blood pressure was below 120 mmHg when the food pattern was composed of intake of tertiles 3, 3, and 1 of unprocessed, moderately, and ultra-processed foods, respectively. The same was observed for diastolic blood pressure; moreover, the diastolic blood pressure of individuals with intake of tertiles 1, 3, and 1 of unprocessed, moderately, and ultra-processed food products, respectively, was similarly lower.

In conclusion, food patterns consisting of a higher intake of unprocessed and moderately processed foods and a lower intake of ultra-processed food products might be related with lower systolic and diastolic blood pressures. Furthermore, diastolic blood pressure may be more affected than systolic blood pressure by changes in intake of moderately processed foods. In addition, the effect of food processing grade depended on BMI, and the K/Na ratio is a potential mechanism of causation. However, prospective studies may confirm these findings.

Key words: Food processing, blood pressure, Body mass index, potassium-to-sodium ratio

Introduction

Hypertension is the most important preventable cause of premature deaths, cardiovascular disease, and disability-adjusted life years (1, 2). Sodium intake is the key risk factor for hypertension, and the beneficial effect of its reduction has been consistently shown (3, 4). Besides sodium, potassium has a remarkable protector effect against high blood pressure. Populations with a high intake of salt treated with high contents of potassium were able to reduce systolic blood pressure by 9.5 mmHg and diastolic by 6.4 mmHg. On the other hand, patients with low dietary sodium content might benefit less from the effects of potassium treatment (5). In this sense, the synergic effect of the potassium-to-sodium relationship on blood pressure has been highlighted (6). Sodium intake exceeds from 100 mmol/day in Europe and North America to more than 200 mmol/day in Asian countries (7). While processed foods are rich sources of sodium (8), unprocessed foods have a substantial contribution for dietary potassium increment (9). Populations with a diet rich in natural foods usually have a potassium-to-sodium ratio (K/NA ratio) from three to ten, and the prevalence of hypertension is negligible when compared to industrialized nations (6).

Thermal processing leads to the development of advanced glycoxidation end products, substances involved in the inflammatory processes (10). Synthetic substances added to foods might be involved in obesity development (11). Since food processing is related with nutrient imbalance and obesity, both of which are strongly associated with blood pressure and the most important predictors of hypertension in different populations (12, 13, 14), it may be indirectly related to blood pressure elevation and the potassium-to-sodium ratio. This study aimed to evaluate the association between food processing grade and blood pressure and how body mass index and the potassium-to-sodium ratio influence this relationship.

SUBJECTS AND METHODS

Study population

Recruitment for the Syndrome of Obesity and Risk Factors (SOFT) study with a population-based, cross-sectional design was performed in 2006-07. The target population consisted generally of adults living in Porto Alegre, southern Brazil, recruited through a multistage probability sampling. Details are described elsewhere (15). A random sample of households in a geographically defined area of Porto Alegre was selected from 106 out of 2,157 census sections (16). One block and street corner was randomly selected, followed by a systematic sampling of houses from each block. From all selected households, adults were randomly recruited for the sample provided they were available for interview with certified research assistants. A subsampling was done at random to perform a short version of the questionnaire, for quality control purposes.

From 1,858 enrolled individuals, 174 were excluded from the analysis because their energy intakes were > 5000 or < 500 kcal per day. Of the remaining 1,684, eleven individuals had no blood pressure measurement due to a problem with the device, and seventeen participants were not able to stand up to measure weight and height.

The research protocol was approved by the Institution Review Board, which is accredited by the US Office of Human Research Protections, and all participants signed a consent form.

Measurements

Blood pressure was measured four times during the interview, using a validated automatic device (OMRON – HEM 705-CP, Matsuzaka, Mie, Japan) and following standardized guidelines (17). The average was used in the analysis. Weight (kg) was assessed with a calibrated scale, with the subject wearing light clothes and no shoes, rounded to the nearest 100g scale (Plenna, model TINN 00088 Plenna S.A., Sao Paulo, Brazil). Height was measured to the nearest 0.1 cm. Body mass index [BMI = weight (kg)/(height (m))^2] was calculated and categorized as underweight, normal, overweight, and obese. Dietary intake was inquired through a validated Food Frequency Questionnaire (FFQ) with 136 food items (18).

Information on demographics, self-reported skin color, lifestyle, and dietary habits was gathered using a standardized questionnaire applied in the household. Variables under study included: sex, age, skin color, education level, smoking, alcohol consumption, and physical activity. Age was categorized into 20-39, 40-59, and 60-90 years old. Skin color was informed and categorized into white or nonwhite. Education level was defined according to the number of years successfully completed at school, categorized as ≤ 4, 5-8, 9-11, and 12-23. Physical activity was evaluated through the International Questionnaire of Physical Activity (IPAQ, short version) and was defined according to intensity level: intense, moderate, and low (19). The smoking habit was categorized into non-smokers or current smokers (participants who have smoked 100 cigarettes or more during a lifetime and continue to smoke). Alcohol consumption was evaluated by asking about type of beverage, quantity, and frequency of consumption. Daily average alcohol consumption was estimated and categorized into non-drinkers (subjects who do not drink alcoholic beverages), social consumers, and alcohol abusers (≥ 30 g/day for men and ≥ 15 g/day for women).

Definition of outcome

The specific aim of the study was to test the effects of food processing grade and the potassium-to-sodium ratio on blood pressure and body mass index. We have taken into account the potassium-to-sodium ratio and DASH Diet score because both may mediate food processing grade effects on blood pressure. Blood pressure was evaluated as a continuous variable, categorized into optimal and non-optimal blood pressure. Body mass index was tested as a continuous and categorical variable (MBI < 25 kg/m^2 and ≥ 25 kg/m^2).

Ascertainment of diet

The dietary intake was evaluated with a semi-quantitative FFQ that included 136 food items, information on frequency of consumption during the last year, and a given number of pre-defined portion sizes. Food processing grade was determined by sorting food items into three food groups: unprocessed, moderately, and ultra-processed foods. The unprocessed food group comprised of fresh, chilled, frozen, vacuum-packed, and dried fruits; fruits and natural fruit juices (not bottled or canned); whole grains (oat); every kind of milk and plain yogurt; vegetables; legumes; seeds; nuts; every kind of coffee, tea, and mate (specific kind of tea from southern Brazil); and cooked potato and manioc (cassava). Moderately processed foods are mostly used in recipes and not usually consumed as a single food. In order to estimate the food items of this group, 59 recipes were broken down according to procedures previously performed with 24-hour dietary recalls with an acceptable confidence level (9). Moderately processed foods or culinary ingredients included: refined grains, *requeijão* (particular kind of soft, salty cream), cream, cheese, butter, margarine, mayonnaise, jelly, honey, salt, vegetable oil, vinegar, glutamate monosodium, yeast, and rice. Finally, the ultra-processed food group included: refined, light, or whole bread; *pão de queijo* (Brazilian cheese bread); sweet bread; cookies; biscuits and crackers; cheese; soy milk; bottled or canned fruit juices; soda; pasta; gnocchi; tomato sauce; thermal-processed meat; poultry and fish; processed meat (ham, sausage, hot dog frank, hamburger); fried egg; fried potato; fried manioc (cassava); canned fish (tuna and sardine); candies; chocolates; and popcorn. According to the original classification of foods, plain yogurt or fermented milk would be listed under unprocessed foods. Because we have not distinguished the kind of yogurt and because flavored yogurt is the most commonly consumed, we classified yogurt as an ultra-processed food. Rice is included in the moderately processed food group because it is refined; brown rice is included in unprocessed foods. Food groups were expressed in grams per day. Unprocessed, moderately, and ultra-processed food groups were analyzed, firstly as continuous and secondly as categorical variables. When categorized into tertiles of consumption: unprocessed - tertile 1 ≤ 1693.6 (Mean=1256.5) g/day; tertile 2 = 1694.6 – 2637.1 (Mean=2140.2) g/day; tertile 3 = ≥ 2637.2 (Mean=4017.4) g/day; moderately processed - tertile 1 = ≤ 91.7 (Mean=58.5) g/day; tertile 2 = 91.8 – 164.8 (Mean=125.4) g/day; tertile 3 = ≥ 165.2 (Mean=275.8) g/day; ultra-processed foods - tertile 1 = ≤ 356.1 (Mean=230.6) g/day; tertile 2 = 356.1 – 672.8 (Mean 494.9) g/day; tertile 3 = ≥ 5000.4 (Mean=1194.8) g/day.

After calculating the ingredients, energy, macro- and micronutrients were estimated based on the TACO – Brazilian Food Composition Table (20) and USDA – National Nutrient Database for Standard Reference – Release 22 tables United States Department of Agriculture (21). Macro- and micronutrients were adjusted for energy by the residual method (22), and then the potassium-to-sodium ratio (K/Na ratio) was calculated by dividing potassium by sodium intake.

Statistical analysis

The statistical analysis was conducted using the SPSS®, version 18.0. We used generalized linear regression models with robust estimator and maximum likelihood estimation owing to the non-linear relationship between dependent variables and predictors. The initial analysis was carried out to investigate crude differences in unprocessed, moderately, and ultra-processed food intake according to characteristics of the sample and blood pressure and BMI levels.

The second step was to investigate crude differences in K/Na ratio according to characteristics of the sample through an unadjusted analysis with GLM. For individuals with optimal and non-optimal blood pressure, with BMI levels (< 25 and ≥ 25 kg/m^2), and those who consumed tertiles 1, 2, and 3 of unprocessed, moderately, and ultra-processed foods, the K/Na ratio was estimated and adjusted by sex, age, years at school, smoking, alcohol consumption, physical activity, and for blood pressure plus adjustment for BMI.

With the global sample, we examined the effect of increasing unprocessed, moderately processed, and ultra-processed food consumption on systolic and diastolic blood pressures and BMI averages. Blood pressure and body mass index were analyzed as dependent variables, and food processing grade was categorized into tertiles, as predictors. For model 1, sex, age, years at school, physical activity, smoking, and alcohol consumption were added as a black box multivariate model. Model 2 included energy and K/Na ratio as additional potential confounders. In this case, the analysis was adjusted for sex, age, years at school, physical activity, smoking, alcohol consumption, and energy intake.

In order to clarify the influence of blood pressure, BMI, and the K/Na ratio on the association between food processing grade and blood pressure, we investigated the interaction effect between BMI levels and tertiles of intake of unprocessed, moderately, and ultra-processed foods.

Finally, food patterns were estimated by combining tertiles of intake of unprocessed, moderately, and ultra-processed food products. Systolic and diastolic means according to food patterns were predicted by the generalized linear regression model. Results were based on the estimation of marginal means and 95%

confidence intervals, taking into account a cutoff of 5% for significance levels for simple comparisons and interaction effect. Multiple comparisons were adjusted for Sidak method, and the statistical model was checked by Akaike's Information Criterion (AIC) method.

Results

Among the 1,629 adults involved in this study, differences in food intake were more apparent according to sex. Men (39%) were more likely to consume higher amounts of unprocessed, moderately processed, and ultra-processed foods (**Table 1**). A higher intake of unprocessed foods was observed among middle-aged adults (33%). The elderly (33%) consumed lower amounts of moderately processed foods, while young adults (34%) consumed the highest. The intake of moderately processed foods increased linearly with years of study. More intense physical activity corresponded with a higher intake of unprocessed foods. Non-smokers (79%) were more likely to consume higher amounts of unprocessed foods. Alcohol consumption was directly associated with all the food groups, but a greater association was observed for ultra-processed foods. Individuals classified as having optimal blood pressure levels consumed less moderately and ultra-processed foods than those classified as having non-optimal BP. Individuals with BMI < 25 kg/m^2 consumed more moderately and ultra-processed foods than those who were classified with BMI ≥ 25 kg/m^2.

K/Na ratio was no different according to increasing intake of unprocessed foods; however, it was inversely related to increasing intake of moderately and ultra-processed foods.

Table 2 shows the association between food processing grade and blood pressure, which was analyzed using age and sex as confounding factors in Model 1 and the complete adjustment in Model 2. However, in both models there were no statistically significant associations.

Figure 2 shows a significantly high K/Na ratio according to optimal and non-optimal blood pressure. Adults with optimal blood pressure were more likely to have a higher K/Na ratio than those with non-optimal blood pressure. According to BMI, there was a higher K/Na ratio for adults with a high BMI level (**Figure 3**).

Figure 4 shows the interaction effect between BMI and unprocessed, moderately processed, and ultra-processed foods on systolic and diastolic blood pressures. For individuals who were classified in the first tertile of unprocessed food intake, systolic blood pressure was 6.5 mmHg higher for overweight or obese individuals than for under- or normal-weight individuals. In the second tertile of moderately and ultra-processed foods, there was a tendency for systolic blood pressure to increase with augmentation of BMI level. Diastolic blood pressure was 5.8 and 4.3 mmHg higher for overweight and obese individuals in the first and second tertiles of unprocessed food intake. Although there was an interaction effect in multiple comparisons between BMI and tertiles of moderately processed foods, there were no statistically significant differences. In the second tertile of ultra-processed food intake, diastolic blood pressure increased 5.8 mmHg in overweight and obese subjects in relation to under- or normal-weight individuals.

The averages of systolic and diastolic blood pressures according to food patterns were shown in **figure 5**. Systolic and diastolic blood pressures were described based on a cutoff for optimal levels (Systolic BP=120 mmHg and Diastolic BP=80 mmHg). The systolic blood pressure was below the target for individuals who had a food pattern of tertiles 3, 3, and 1 of unprocessed, moderately, and ultra-processed food products, respectively. Systolic and diastolic blood pressures were linearly higher with an increasing intake of ultra-processed foods when the diet was composed of higher amounts of unprocessed and moderately processed foods (**Tertile 3**).

Discussion

This study showed that the food processing grade is associated with biological, socioeconomic, and lifestyle characteristics; body mass index; and non-optimal blood pressure in unadjusted analyses. Greater body mass, particularly in men, and less age may explain the association with blood pressure through mechanisms not directly related to the processing grade. However, the inverse association of the potassium-sodium ratio with moderately and ultra-processed food intake, identified in this study, is a mechanism potentially responsible for increasing blood pressure, which was confirmed. Therefore, there was no association between food processing grade and blood pressure. Finally, food patterns with a higher intake of unprocessed and moderately processed foods were more sensitive to an increased intake of ultra-processed food products, suggesting that blood pressure is not affected by independent food groups but by their combinations.

We identified an interaction effect between food processing grade and BMI, showing that the relationship between food processing grade and blood pressure depends on BMI. In the case of an interaction effect, the association between outcome and predictor depends on levels of a third variable (23). Among adolescents, the interaction effect was detected as a suppressive effect (24) of BMI, which explained most of the increased blood pressure (25) since it is in the causal pathway. Among adults, there are several pathways linked to hypertension development, including sodium intake, which could be balanced with an increase in potassium in the diet (26). Considering that the potassium-sodium ratio accounts for both sodium and potassium and is part of the causal pathway, it could not be considered a confounding factor (24).

The novelty of this study is the assessment of the relation between food processing grade and blood pressure and the interaction effect with BMI. The classification of foods by processing grade (27) and the food patterns based on it (9, 25) are also a new pathway to explore the development of chronic conditions such as hypertension. In this case, we took one step forward suggesting a few changes in the original classification (27), as we have done with another study in adolescents (25). For instance, meat was first included in the unprocessed food group because it was considered a fresh food (28). Since we gathered information using a FFQ, validated by 24-hour recalls, it was verified that there are plenty of recipes with cooked, baked, and fried meat. Therefore, we classified meat as an ultra-processed food (9).

The FFQ did not provide information regarding salt intake, which was estimated by breaking down recipes (9). Regardless, the ascertainment of ingredients was not validated, and this is a limitation of the study. The estimation of salt is a key point in blood pressure studies, and it has been criticized (30). Processed breads, cereals, and grains contributed to 34 percent of the total dietary sodium content, while red meat, poultry, and eggs contributed to 20.4 percent in the United Kingdom. In the United States, salt had the greatest contribution to dietary sodium content (29%), followed by bread, cereals, and grains (19.5%), and then by red meat, poultry, and eggs (12%). These estimations have taken into account a great part of added salt, except for the Republic of China, where urinary sodium was significantly lower than sodium estimated by diet (31). In Brazil, salt and salty seasonings are the most important sources of sodium (76.2%), followed by ultra-processed foods, which can reach 25 percent (32).

This study showed that food processing grade was not independently associated with blood pressure; however, the combination of food groups might expressively affect the systolic and diastolic blood pressures. Additionally, there was a significant interaction effect between food processing grade and body mass index.

Table 1 Unprocessed, moderately, and ultra-processed food intake [Mean (95% CI)] according to characteristics of sample, blood pressure, and body mass index (n=1629)

Characteristics	n (%)	Unprocessed	P-value	Moderately processed	P-value	Ultra-processed	P-value
Sex			<0.001		<0.001		<0.001
Men	661 (39)	2602.9 (2485.4 - 2720.5)		168.8 (161.5 - 176.1)		697.4 (663.1 - 731.7)	
Women	1022 (41)	2327.3 (2232 - 2422.6)		127.1 (121.2 - 133.1)		533.5 (505.7 - 561.3)	
Age (years) [b]			0.008		<0.001		<0.001
20-40	573 (34)	2507.9 (2380.2 - 2635.7)		174.2 (166.4 – 182.0)		726.4 (689.7 - 763.0)	
40 - 59	555 (33)	2530.1 (2401.6 - 2658.5)		146.7 (138.8 - 154.6)		613.6 (576.8 - 650.5)	
60-90	555 (33)	2270.1 (2141.3 - 2398.9)		109.5 (101.6 - 117.3)		453.3 (416.3 - 490.3)	
Year at school			0.8		<0.001		0.05
≤ 4	321 (19)	2445.4 (2274.0 - 2616.8)		113.1 (102.4 - 123.8)		540.6 (490.1 - 591.2)	
5 - 8	477 (28)	2489.3 (2350.0 - 2628.7)		142.4 (133.6 - 151.1)		603.8 (562.7 - 644.9)	
9 - 11	493 (29)	2401.1 (2263.4 - 2538.8)		147.9 (139.3 - 156.5)		633.5 (592.9 - 674.1)	
12 - 23	393 (23)	2409.9 (2257.3 - 2562.5)		164.2 (154.7 - 173.7)		595.1 (550.1 - 640.1)	
Physical activity			<0.001		0.2		0.4
Low	531 (32)	2242.0 (2109.5 - 2374.6)		137.8 (129.3 - 146.2)		575.4 (536.0 - 614.7)	
Moderate	758 (45)	2435.8 (2325.8 - 2545.9)		147.0 (140.0 - 154.0)		606.4 (573.7 - 639.1)	
Vigorous	395 (23)	2691.1 (2540.0 - 2842.3)		145.0 (135.4 - 154.6)		613.8 (568.8 - 658.7)	
Smoking			0.09		0.5		0.5
Smoker	348 (21)	2404.1 (2320.8 - 2487.5)		144.4 (139.1 - 149.7)		144.4 (139.1 - 149.7)	
Non-smoker	1336 (79)	2561.6 (2398.1 - 2725.0)		140.8 (130.4 - 151.1)		140.8 (130.4 - 151.1)	
Alcohol consumption			0.02		<0.001		<0.001
Teetotaler	155 (9)	2313.8 (2197.7 – 2430.0)		122.0 (114.7 - 129.2)		526.9 (492.9 - 560.9)	
Moderate	839 (50)	2511.7 (2406.9 - 2616.5)		156.9 (150.4 - 163.5)		630.4 (599.7 - 661.1)	
Heavier	690 (41)	2571.9 (2327.6 - 2816.2)		167.3 (152.1 - 182.6)		742.3 (670.7 - 813.9)	
Body mass index (kg/m^2)			0.7		<0.001		0.009
< 25	724 (43)	2528.0 (2412.8 – 2641.3)		170.8 (131.8 – 148.1)		678.4 (640.2 - 716.5)	
≥ 25	966 (57)	2426.5 (2328.5 – 2524.5)		140.2 (161.7 – 179.9)		611.6 (578.6 - 644.6)	
Blood pressure			0.3		<0.001		0.003
Optimal	1036 (62)	2404.5 (2310.1 - 2498.8)		136.2 (130.3 - 142.2)		572.4 (544.6 - 600.2)	
Non-optimal	638 (38)	2489.0 (2368.5 - 2609.5)		155.7 (148.1 - 163.3)		641.1 (605.6 - 676.6)	

P-values for simple comparison among categories. Unadjusted analysis. Food group intake in grams per day.

[a] 55 individuals were excluded due to missing data from food group classification.

[b] Description of subjects taking into account missing data for age (1).

Table 2 Unprocessed, moderately, and ultra-processed food intake associated with Systolic and Diastolic blood pressures among adults from southern Brazil (n=1629[1,2]) [Mean (95% CI)]

	Systolic BP (mmHg)		**Diastolic BP (mmHg)**	
	Model 1	**Model 2**	**Model 1**	**Model 2**
Unprocessed food				
1	128.5 (126.1 - 130.8)	127.7 (124.6 - 130.7)	78.1 (76.1 – 80.0)	77.9 (75.2 – 80.5)
2	128.1 (125.3 – 130.9)	126.8 (124.7 – 128.9)	78.3 (75.8 - 80.8)	77.2 (76.0 – 78.5)
3	127.9 (125.6 – 130.2)	128.1 (125.7 - 130.6)	78.3 (76.4 – 80.2)	78.8 (77.0 – 80.6)
P value	0.9	0.6	0.9	0.3
Moderately processed food				
1	128.5 (126.6 - 130.3)	126.6 (124.3 – 128.9)	78.1 (77.0 - 79.2)	77.1 (75.7 – 78.5)
2	129.5 (126.3 – 132.8)	128.3 (125.2 – 131.3)	79.1 (76.2 – 82.1)	78.2 (75.7 - 80.8)
3	126.4 (124.1 - 128.8)	127.8 (124.8 – 130.9)	77.4 (75.3 – 79.4)	78.7 (76.3 - 81.1)
P value	0.2	0.6	0.6	0.6
Ultra-processed food				
1	128.0 (126.1 - 130.0)	127.0 (124.6 – 129.4)	77.3 (76.1 – 78.6)	77.0 (75.6 – 78.3)
2	127.6 (125.2 - 129.9)	127.5 (124.7 - 130.3)	78.4 (76.4 - 80.4)	78.6 (76.2 – 81.0)
3	128.9 (125.6 – 132.3)	128.1 (125.2 - 131.0)	78.9 (75.8 – 82.1)	78.3 (76.1 - 80.4)
P value	0.8	0.8	0.6	0.4

[1] 55 individuals were excluded due to missing data from food group classification;
[2] Description of subjects taking into account missing data for age.
Model 1: Analysis controlled for sex and age.
Model 2: Analysis controlled for sex, age, years at school, smoking, alcohol consumption, physical activity, BMI, energy intake.

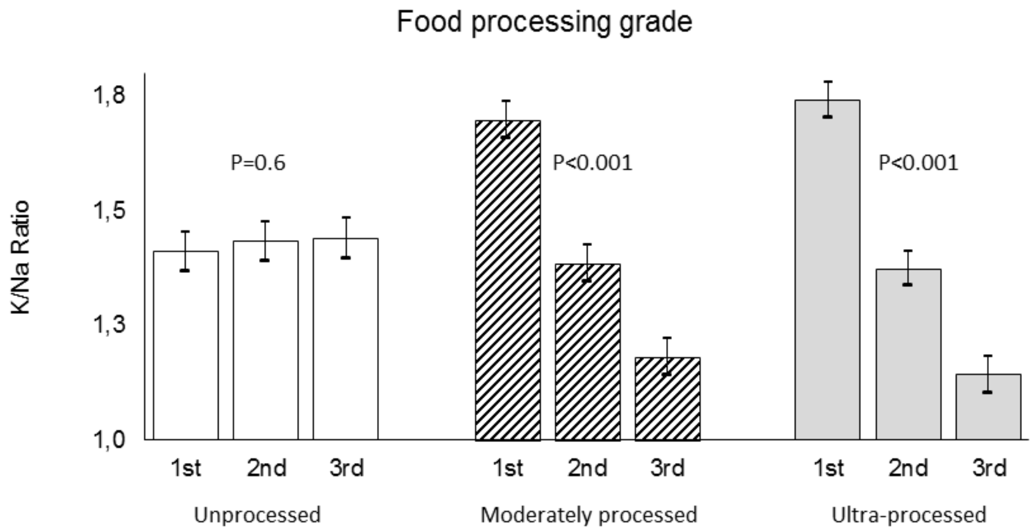

Figure 1 K/Na ratio according to systolic and diastolic blood pressures. P-value adjusted for sex, age, years at school, smoking, alcohol consumption, physical activity, and energy intake.

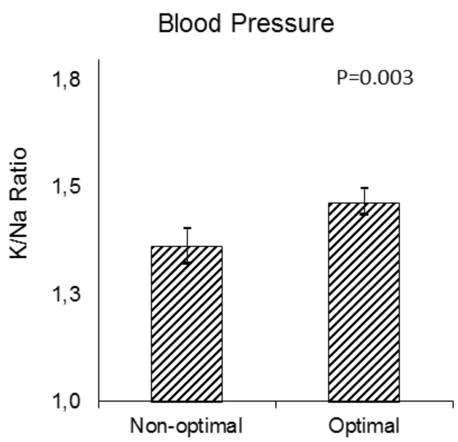

Figure 2 K/Na ratio according to systolic and diastolic blood pressures. P-value adjusted for sex, age, years at school, smoking, alcohol consumption, physical activity, and energy intake.

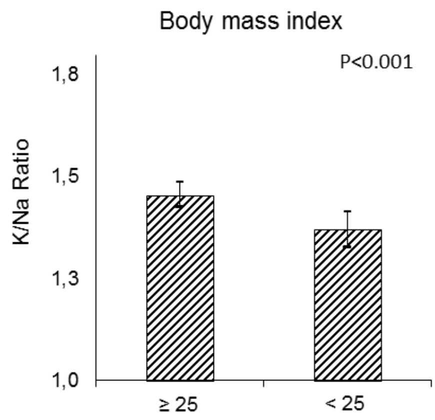

Figure 3 K/Na ratio according to body mass index. P-value adjusted for sex, age, years at school, smoking, alcohol consumption, physical activity, and energy intake.

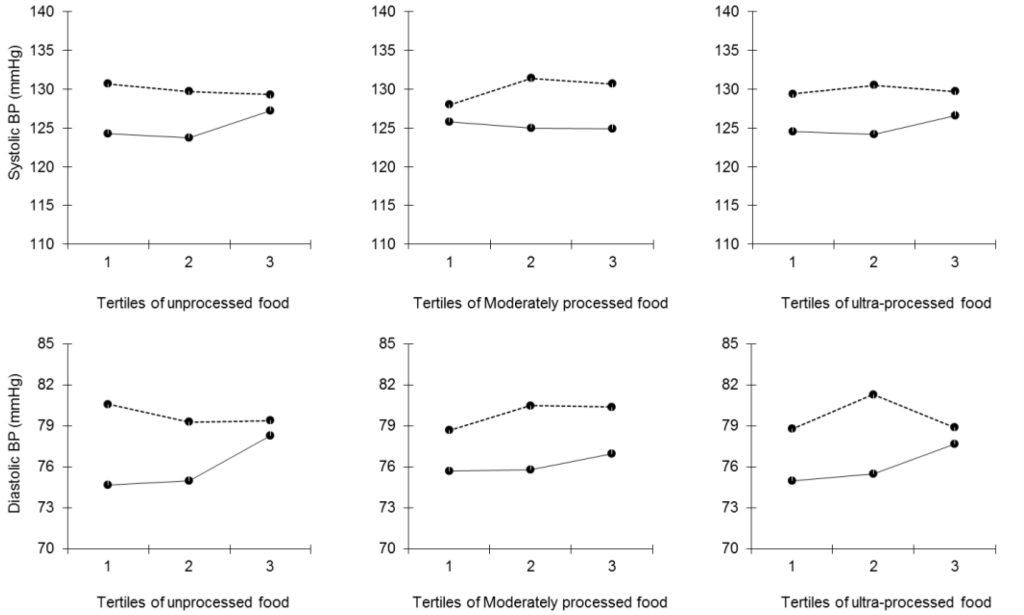

Figure 4 Systolic and diastolic blood pressures according to interaction effect between body mass index and tertiles of consumption of foods sorted into food processing grade groups (N=1629). Interaction effect statistically significant for all food groups (P<0.01).

* 55 individuals were excluded due to missing data from food group classification; the analyses were adjusted for sex, age, years at school, smoking, alcohol consumption, physical activity, energy intake.

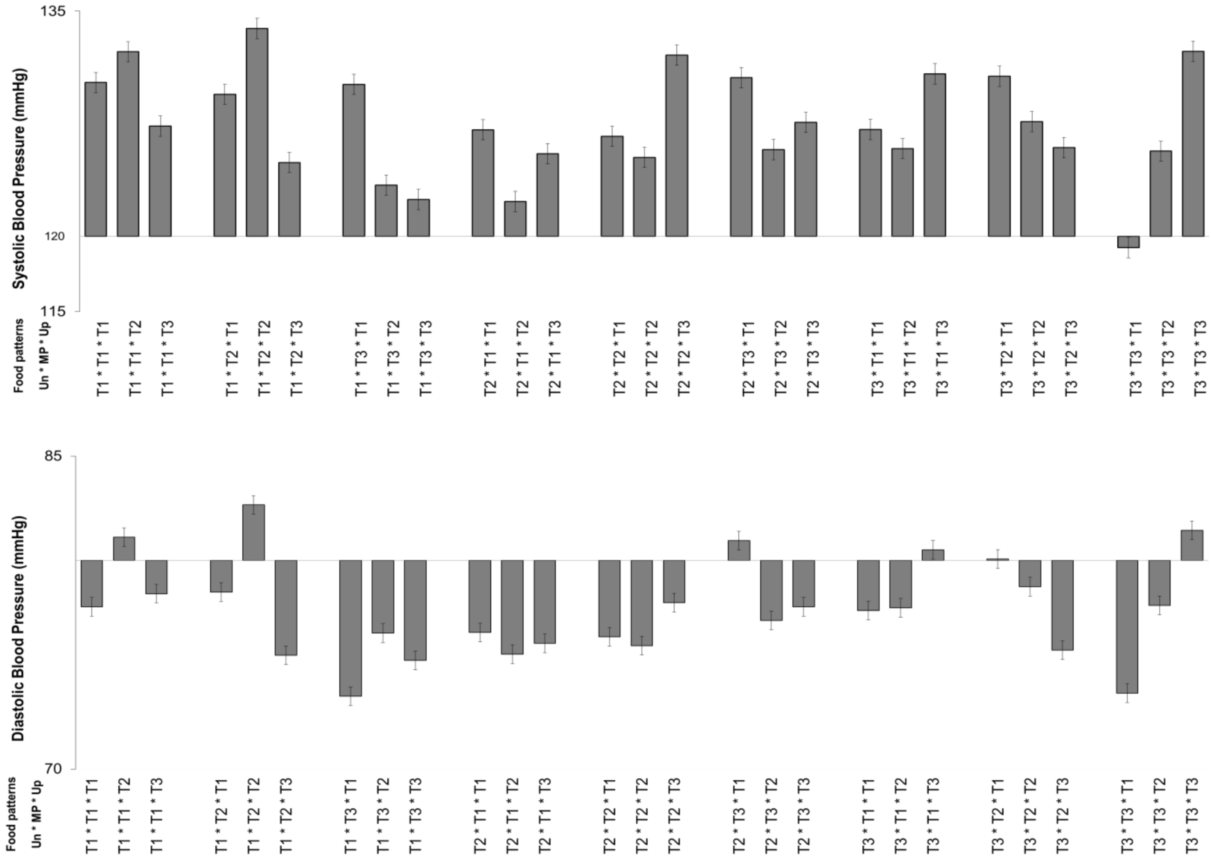

Figure 5 Systolic and diastolic blood pressures according to food patterns of unprocessed, moderately, and ultra-processed food groups. Analysis adjusted for sex, age, body mass index, and total energy intake. Legend: T = Tertile; Un = Unprocessed; MP = Moderately Processed; UP = Ultra-Processed food products.

CONCLUSÕES E CONSIDERAÇÕES FINAIS

O impacto da transição nutricional na saúde da população tem sido evidenciado e fortemente atribuido ao aumento do consumo de alimentos processados e consumidos fora de casa, em fast-foods e restaurantes. Há evidências demonstrando efeito nocivo do alto consumo de alimentos processados. Neste sentido, a classificação de alimentos de acordo com o grau de processamento foi proposta por Monteiro e colaboradores, viabilizando o estudo do efeito do grau de processamento sobre desfechos em saúde na população de forma padronizada.

Alimentos classificados como ultra-processados são fonte de nutrientes associados ao aumentos da pressão arterial. Com os resultados deste estudo, observou-se que os alimentos não processados são potencialmente protetores contra hipertensão pois associam-se significativamente com maiores teores de fibras, cálcio, magnésio e potássio, conhecidos pelo efeito sinérgico sobre prevenção da hipertensão e controle dos níveis pressóricos. Também realizou-se adapatações da proposta original para adequar a diferentes métodos de avaliação de dieta. Entre adolescentes, não foi evidenciado o efeito positivo do grau de processamento devido a um significativo efeito supressor do IMC sobre o desfecho avaliado. A relação inversa entre o grau de processamento de alimentos e pressão aterial foi evidenciada pela presença do IMC, que suprimiu e inverteu o efeito da dieta por ter, nesta população, um efeito muito mais forte sobre a pressão arterial. Entre adultos, incluiu-se como potencial exposição, além do grau de processamento, a razão potássio sódio, por ter sido associada ao desfecho e ao preditor do estudo. Sugere-se que o efeito independente do grau de processamento de alimentos sobre a pressão arterial não foi obsevado por duas razões: a razão K/Na tiveram ação indireta sobre a pressão arterial. O primeiro por ser um mecanismo de ação dos alimentos ultra-processados sobre a pressão arterial, e o segundo por ter agido nesta população como um moderador de efeito e por estar envolvido na via de causalidade do aumento de níveis pressóricos. Por não se tratar de uma variável de confusão, análises ajustadas pelo IMC não são suficentes para testar o efeito da dieta independentemente.

ANEXO 1 – Aprovação no comite de ética e pesquisa do HCPA.

HCPA - HOSPITAL DE CLÍNICAS DE PORTO ALEGRE
Grupo de Pesquisa e Pós-Graduação
COMISSÃO CIENTÍFICA E COMISSÃO DE PESQUISA E ÉTICA EM SAÚDE

A Comissão Científica e a Comissão de Pesquisa e Ética em Saúde, que é reconhecida pela Comissão Nacional de Ética em Pesquisa (CONEP)/MS como Comitê de Ética em Pesquisa do HCPA e pelo Office For Human Research Protections (OHRP)/USDHHS, como Institutional Review Board (IRB00000921) analisaram o projeto:

Projeto: 00-176 **Versão do Projeto:** 06/07/2000 **Versão do TCLE:** 06/07/2000

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LUCIANO DE FREITAS ANGLADA
ANDREA CHRISTMANN
IARA REGINA DA SILVA MARTINS

Título: SÍNDROME DA OBESIDADE E FATORES DE RISCO CARDIOVASCULAR: UM ESTUDO DE BASE POPULACIONAL (ESTUDO SOFT).

Este projeto foi Aprovado em seus aspectos éticos e metodológicos, inclusive quanto ao seu Termo de Consentimento Livre e Esclarecido, de acordo com as Diretrizes e Normas Internacionais e Nacionais, especialmente as Resoluções 196/96 e complementares do Conselho Nacional de Saúde. Os membros do CEP/HCPA não participaram do processo de avaliação dos projetos onde constam como pesquisadores. Toda e qualquer alteração do Projeto, assim como os eventos adversos graves, deverão ser comunicados imediatamente ao CEP/HCPA. Somente poderão ser utilizados os Termos de Consentimento onde conste a aprovação do GPPG/HCPA.

Porto Alegre, 06 de julho de 2000.

Profª Nadine Clausell
Coordenadora do GPPG e CEP-HCPA

ANEXO 2

Do <MÊS> do ano passado até agora, quantas vezes por dia ou por semana ou por mês ou por ano você comeu os alimentos que eu vou citar? Quantos meses do ano? Quantas <PORÇÕES> você comeu a cada vez?

Alimentos	Quantas vezes												Unidade de tempo					Quantidade
	0	1	2	3	4	5	6	7	8	9	10	Outro	D	S	M	A	Meses/Ano	
Cacetinho/Bisnaguinha																		() UP () UG
Sanduíche de presunto e queijo/ Torrada																		() Unidade
Pão (sanduíche/forma/leite/caseiro/ manteiga/batata)																		() Fatia
Pão (integral/centeio/trigo/aveia)																		() Fatia
Pão light																		() Fatia
Sanduíche natural																		() Unidade
Cuca/Pão doce																		() FP () FM () FG
Bolo																		() FP () FM () FG
Pão de queijo																		() UP () UM () UG
Bolacha (doce/recheada)																		() Unidade () Pacote
Bolacha salgada																		() Unidade () Pacote
Sucrilhos																		() 1/2 PS () PS () XP () XM () XG
Aveia/Germe de trigo/Granola																		() CSopa
Barra de cereal																		() Unidade
Nescau, Toddy ou outros																		() CChá () CSopa
Milk shakes/Batida																		() CP () CM () CG
Leite integral																		() CP () CM () CG
Leite desnatado																		() CP () CM () CG
Leite semi-desnatado																		() CP () CM () CG
Leite de soja																		() CP () CM () CG
Iogurte integral																		() Pote () GP () GG
Iogurte (desnatado/light)																		() Pote () GP () GG
Requeijão normal/Käshimier																		() Ponta de faca () CChá
Requeijão light																		() Ponta de faca () CChá
Queijo (mussarela/lanche/colonial/ provolone)																		() FP () FM () FG
Queijo (branco/minas/ricota)																		() FP () FM () FG
Creme de leite/Nata																		() CChá () CSopa
Leite condensado																		() CChá () CSopa
Manteiga/Margarina normal																		() Ponta de faca () CChá
Margarina light																		() Ponta de faca () CChá
Maionese normal																		() Ponta de faca () CChá
Maionese light																		() Ponta de faca () CChá
Mortadela/Salame/Murcilha/Presunto gordo																		() FP () FM () FG
Presunto magro/Peito de peru/ Chester																		() FP () FM () FG
Mel/Geléia/Chimia/Uvada/Goiabada/ Figada/Pessegada/Marmelada																		() Ponta de faca () CChá
Geléia diet/Chimia diet																		() CChá () CSopa
Salada de frutas																		() CP () CM () CG () Pote

Do <MÊS> do ano passado até agora, quantas vezes por dia ou por semana ou por mês ou por ano você comeu os alimentos que eu vou citar? Quantos meses do ano? Quantas <PORÇÕES> você comeu a cada vez?

Alimentos	Quantas vezes												Unidade de tempo					Quantidade
	0	1	2	3	4	5	6	7	8	9	10	Outro	D	S	M	A	Meses/Ano	
Tomate cru																		() UP () UM () UG
Legumes variados																		() CSopa
Legumes empanados fritos																		() Ramo () Rodela
Sopa de legumes ou de verduras																		() CoP () CoM () CoG
Sopa com arroz/massa/capeletti																		() CoP () CoM () CoG
Ovo/Omelete/Ovo mexido																		() Unidade () CSopa
Cachorro-quente/Xis de carne ou frango																		() Unidade
Pastelão/Empadão/Quiche																		() PP () PM () PG
Pizza																		() FP () FM () FG
Pastel/Coxinha/Rissoles/Croquete (fritos)																		() UP () UM () UG
Guisado/Almôndega																		() CSopa () Unidade
Churrasco																		() PP () PM () PG
Carne de gado																		() PP () PM () PG
Frango com pele																		() PP () PM () PG
Frango sem pele																		() PP () PM () PG
Carne de porco																		() PP () PM () PG
Carne de soja																		() CSopa
Bucho/Mondongo																		() CSopa () Prato
Vísceras (moela/fígado)																		() Pedaço () CSopa
Coraçãozinho																		() Unidade
Bacon/Toucinho																		Registrar só a freqüência
Lingüiça/Salsichão																		() Unidade () CSopa
Salsicha																		() UP () UM () UG
Peixe (fresco/congelado)																		() PP () PM () PG
Tofu																		() Fatia
Sushi																		() Unidade
Sashimi																		() Fatia
Sardinha/Atum (conserva)																		() Lata () CSopa
Camarão																		() CSopa () Unidade
Chocolate em barra/Bombom																		() UP () UM () UG
Brigadeiro/Negrinho/Doce com chocolate																		() Unidade
Pudim/Ambrosia/Doce de leite/Arroz doce/Flan																		() CSopa () PP () PM () PG
Sorvete																		() CSopa () Bola
Sorvete light																		() CSopa () Bola
Tortas em geral																		() PP () PM () PG
Fruta em calda																		() PP () PM () PG
Café preto passado																		() XP () XM () XG
Café expresso																		() XP () XM () XG
Café solúvel																		() CChá
Café cappuccino																		() XP () XM () XG
Café sem cafeína																		() XP () XM () XG

Do <MÊS> do ano passado até agora, quantas vezes por dia ou por semana ou por mês ou por ano você comeu os alimentos que eu vou citar? Quantos meses do ano? Quantas <PORÇÕES> você comeu a cada vez?

Alimentos	Quantas vezes												Unidade de tempo					Quantidade
	0	1	2	3	4	5	6	7	8	9	10	Outro	D	S	M	A	Meses/Ano	
Chá																		() XP () XM () XG
Chimarrão																		() Cuia () Térmica
Água (fora café/chá)																		() CP () CM () CG
Refrigerante																		() CP () CM () CG
Refrigerante (diet/light)																		() CP () CM () CG
Açúcar																		() CChá () CSopa
Adoçante (liquido/pó)																		() Gotas () Sachês
Amendoim/Nozes/Castanha-do-Pará/ Castanha de caju																		() Punhado () Unidade
Uva passa																		() CSopa
Guloseimas/Paçoquinha/ Rapadurinha/Maria-mole/ Merenguinho/Puxa-puxa																		() Unidade
Bala/Chiclete																		() Unidade
Pipoca																		() SaP () SaM () SaG
Chips/Fandango/Milhopã																		() SaP () SaM () SaG
Outro																		