Sources of variation of energy and nutrient intake among adolescents in São Paulo, Brazil

Fontes de variação da ingestão de energia e nutrientes entre adolescentes do Município de São Paulo, Brasil

Eliseu Verly Junior [1]
Regina Mara Fisberg [1]
Chester Luis Galvão Cesar [1]
Dirce Maria Lobo Marchioni [1]

[1] *Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, Brasil.*

Correspondence
D. M. L. Marchioni
Departamento de Nutrição, Faculdade de Saúde Pública, Universidade de São Paulo.
Av. Dr. Arnaldo 715, São Paulo, SP 01246-904, Brasil.
marchioni@usp.br

Abstract

The aim of the current study was to describe the sources of variation of energy and nutrient intake and to calculate the number of repetitions of diet measurements to estimate usual intake in adolescents from São Paulo, Brazil. Data was collected using 24-hour dietary recalls (24hR) in 273 adolescents between 2007 and 2008. Individuals completed a repeat 24hR around two months later. The sources of variation were estimated using the random effect model. Variance ratios (within-person to between-person variance ratio) and the number of repetitions of 24hR to estimate usual intake were calculated. The principal source of variation was due to within-person variance. The contribution of day of week and month of year was less than 8%. Variations ranged from 1.15 for calcium to 7.31 for vitamin E. The number of 24hR repeats required to estimate usual intake varied according to nutrient and gender, numbering 15 for males and 8 for females.

Eating; Energy Intake; Nutritional Epidemiology; Adolescent

Introduction

Dietary information, collected using methods such as the 24-hour dietary recall (24hR) or food records, is extensively used in epidemiological studies for a number of different purposes including: (1) to estimate nutrient and energy intake [1]; (2) to investigate the association between dietary patterns and health-related outcomes [2,3], and (3) to assess the performance of other methods, particularly the food frequency questionnaires (FFQ) [4].

For most epidemiological studies, usual intake, as opposed to intake on a single day or over the short-term, is the variable of interest. However, given that the 24hR and food records are highly sensitive to variations in day-to-day food intake, they are unable to provide a precise estimate of the usual intake of individuals or populations [5]. An increase in overall intake variability as a result of variation in day-to-day consumption by an individual, i.e. intra-person variability, has been identified as a problem in the analysis and interpretation of dietary data [6,7]. Studies which seek to calculate the prevalence of nutrient inadequacy without taking into account intra-person variance are likely to lead to biased results [1,8]. Moreover, measures used to assess the diet-disease relationship such as regression coefficients and relative risk become attenuated [5,7,9]. Increasing the number of the days of collection of dietary data these estimates become more accurate for each individual of the population [1,6]. However, the number of collection days is determined according to the nutrient examined and the population studied [10].

Based on the ratio between intra- and inter-person variance (defined as the variance in consumption between one individual and another), it is possible to calculate the number of days needed to obtain usual intake for each nutrient [10]. The estimates of intra- and inter-person variance can also be employed to correct the distribution of intake based on a single collection day, removing the effect of intra-personal variance and estimating usual intake for each nutrient [11,12]. This represents a useful procedure, particularly given the high cost of conducting multiple 24hR collections in population-based studies.

Current data on intake variability of nutrients and energy are available for adults and the elderly in Canada [13,14] and Asian countries [15,16,17,18]. Such studies in adolescents are rare however [19], with the only study of this kind conducted in Brazil being limited to macronutrient intake among adolescents of public schools in an interior municipal district of São Paulo [20]. Since these components of variance are influenced by economic and social factors [7], the use of data obtained in other countries, whether applied in study planning or the analysis of dietary data, may not be appropriate.

Therefore, the aim of the present study was to describe the sources of variation in energy and nutrient intake, and to calculate the ratios of intra-person to inter-person variance in energy and nutrient intake, among adolescents from São Paulo. In addition, the number of days required to estimate usual intake of energy and nutrients was determined.

Methods

Study population

The adolescents who participated in the present study were recruited from a sample drawn from the project entitled *Health Survey of São Paulo* (ISA-Capital) conducted in 2003. The ISA-Capital was a transversal study devised to collect data on health status and access to health services, in addition to life habits, socio-economic levels and dietary conditions in a representative sample from São Paulo city. The sampling process entailed two stages: primary sampling units were census sectors, while secondary units were domiciles. Sampling selection was performed by grouping the sectors into three sub strata according to percentage of heads of households with University-level education: less than 5%, 5% to 24.9%, and 25% or greater. Eight sampling domains were defined by gender and age, for which equal numbers of interviews were planned: individuals aged younger than 1 year, 1 to 11 years, women aged 12 to 19 years, men from 12 to 19 years, men 20 to 59 years, women aged 20 to 59 years, men aged 60 years or older, and women aged 60 years or older.

An initial total of 813 adolescents were interviewed and those within the age bracket (younger than 20 years) at the start of data collection for the present study (March/2007) were invited to participate. This gave a sample of 412 adolescents, of whom 2.7% (n = 11) refused to take part, 15.3% (n = 63) had changed address and could not be located, and 15.3% (n = 65) were not home during three separate visits at different times and days of the week. The final sample therefore comprised 273 adolescents, 140 males and 133 females. The proportion of individuals in the three strata of schooling (head of household) in the initial sample did not differ between initial and final study samples (p = 0.19).

Data collection

The interviews were conducted at households by previously trained interviewers between 2007 and 2008. Food consumption data was collected using the 24hR method adopting the procedure recommended by Thompson & Byers [21]. Intra-person intake variability was calculated by inviting all of the adolescents (n = 273) to answer another 24hR after an interval of approximately two months. The repeat data collection was carried out by telephone and the response rate was 57% (n = 80) and 62% (n = 83) for males and females, respectively. The median interval in days between the recalls was 68 days, with an interquartile interval of 35 days. The data collections, both at domiciles and by phone were carried out so as to cover all days of the week and months of the year. For the purpose of analysis, the days of the week were grouped into weekends (Friday, Saturday and Sunday) and week days (Monday to Thursday). Prior to keying in the food intake data gathered, the information contained in each data collection session were checked in order to monitor the quality of interviews and to define the standardization for quantity of foods and recipes of preparations reported.

Data analysis

Nutritional status was classified using the cut-off points for body mass index (BMI) by gender and age proposed by Cole et al [22]. Reported consumption was converted into energy and nutrient values using the Nutrition Data System for Research – NDS –, 2007 version (Nutrition Coordinating Center, University of Minnesota, Minneapolis, USA) whose main database is the North American table of the United States Department of Agriculture (USDA Food and nutrition database for dietary studies 3.0. Beltsville, USA). Three nutrients were calculated based on their dietary equivalents: vitamin A (the sum of retinol and β-carotene equivalents) [23], niacin (the sum of niacin in mg and the quantity converted from tryptophan) [24] and folate (dietary folate equivalents) [24]. For iron and folate, mandatory supplements in wheat and corn flour were considered, compulsory in Brazil since 2004.

Extreme intake values (outliers) were removed as described in the study by Thompson et al. [25] and the distribution of the intake of each nutrient was normalized using the box-cox transformation. The maximums of outliers removed were 5 for vitamin D (males) and 9 for vitamin K (females). The supposition of normality after transformation to normality was verified for each nutrient by the skewness-kurtosis test with a significance level of 5%. The ratio of intra- to inter-person variance was calculated for each nutrient by the formula σ_w^2/σ_b^2 and energy was estimated using the normalized data.

The sources of intake variance were: inter-person (variation between the intake of one individual and another); week day or weekend; month of the year; and intra-person (variation in day-to-day intake of the same individual). The data were analysed using the following random effects model [26,27,28]:

$$y_{ijk} = \mu + individual_i + a_j + b_k + \varepsilon_{ijk}$$

where, μ: is mean nutrient and energy intake; *individual*: is the random variable representing intake variation among individuals; a_j and b_k: represents the random effects of day of the week and month of the year, respectively; ε_{ijk} : is the residual error representing intra-person variance. The intake of each nutrient was analyzed as a dependent variable using a model constructed for each gender. Variance components, namely, the percentage variation attributed to each factor, were obtained by estimating maximum likelihood, whereas variances were estimated using the XTMIXED routine of the Stata software, version 9.1 (Stata Corp., College Station, USA).

The formula by Black et al. was used to calculate the number of days needed to estimate subjects' usual intake. [10]:

$$D = \frac{r^2}{1 - r^2} x \frac{\sigma_w^2}{\sigma_b^2}$$

where, D: is number of collection days needed; σ_w^2/σ_b^2 : is the ratio of intra- to inter-person variance; and r: is the hypothetical correlation between actual and observed intake of nutrients, in this case assumed to be 0.9. Subsequently, the variance components and the number of days were calculated according to household head educational level, categorized into "up to Primary School complete" and "Secondary School incomplete and higher".

Differences in proportions among the categories nutritional status, alcohol consumption, tobacco use and household head educational level, by gender were verified by the chi-square test.

The study was approved by the Research Ethics Committee of the Faculty of Public Health of University of São Paulo.

Results

Table 1 shows the distribution of interviews by day of the week, end of the week and months of the year.

Table 2 shows the socio-demographic characteristics of the adolescents by gender. The mean age of adolescents studied was 17.8 years (standard-deviation – SD = 1.23) and 17.8 years (SD = 1.20) for male and female genders, respectively.

The transformation of dietary variables to normality yielded asymmetry and kurtosis values which were close to those expected for a normal

Table 1

Distribution of data collections (%) for days of the week and months of the year.

Days of the week/ Months of the year	Distribution of collections (%)
Weekdays	58
Weekends	42
January	11
February	3
March	13
April	6
May	12
June	9
July	14
August	10
September	4
October	5
November	7
December	6

Table 2

Socio-demographic characteristics, nutritional status and life-style among adolescents from São Paulo, Brazil, 2007-2008.

Characteristics	Male		Female		p-value
	n	%	n	%	
Overweight					
Yes (overweight and obese)	21	17.9	17	15.3	
No (eutrophic and underweight)	96	82.1	94	84.7	0.59
Consume alcoholic beverages					
Yes	96	68.6	87	66.9	
No	44	31.4	43	33.1	0.97
Tobacco use					
Yes	17	12.2	14	10.5	
No	122	87.8	120	89.5	0.64
Household head educational level					
Up to Primary school complete	69	51.5	56	43.1	
Up to Secondary school complete	50	37.3	58	44.6	
Beyond Secondary school complete	15	11.2	16	12.3	0.34

distribution, i.e. asymmetry equal to 0 and kurtosis of around 3. The test detected normality in all cases exception for vitamins C and K (for female gender). However, visual inspection of the histograms of these variables revealed a near normal distribution.

Day of the week and month combined contributed to no more than 5% of total intake variance of each nutrient among males, and no more than 8% among females. In both genders, more than 50% of the variance observed was explained by intra-person variation, where this was greater for vitamin E and potassium among males, and vitamin B12 among females. The variance ratios for all nutrients were greater than 1, and higher mostly of cases among males compared to females. The higher the variance ratio, the greater the number of days of 24hR collection required. Thus, vitamin E and potassium for males, and vitamins B12 and K for females, were the nutrients that required the greatest number of days of 24hR application to estimate usual intake. The means and SD were obtained from data not transformed to normality (Tables 3 and 4).

The stratified analysis revealed lower variance ratios, and consequently fewer collection days, for the higher household educational level, although only for micronutrients. The mean days needed for the lower stratum was 14 days versus 10 days for the group with higher stratum.

Discussion

The present study sought to investigate the factors contributing to overall variability of intake and to calculate the variance ratios for nutrients and energy. Our results showed that total variance of consumption essentially involved two main sources: (i) inter-person variance, representing variation between one individual and another; (ii) and intra-person variance, representing an individual's variation over time. Lower relative contribution of inter-person variance leads to higher variance ratios for some nutrients.

In the present study, the variance ratios for males were higher than those for females for most nutrients. The same pattern was seen in American adolescents, although not in Russian adolescents [19]. Overall, the variance ratios of Brazilian adolescents from São Paulo were much higher than the ratios of Russians and Americans counterparts. Among Russians for instance, the variance ratio ranged from 0.8 for energy to 1.7 for thiamin, American variance ratios ranged from 0.7 for magnesium to 2.2 for fats, while variance ratio reached 7.31 for vitamin E in the Brazilians of the present study.

In this and other studies involving other age groups [5,15,16,18,29,30], the intra-person variance component proved the greatest source of variation of nutrients and energy intake, yielding variance ratios of greater than 1. Exceptions include the studies by Herbert et al. [17] (in older adults) and by Janhs et al. [19] (in adolescents), which found variance ratios of less than 1 for the so-

Table 3

Mean, standard-deviation (SD), variation sources (%), variance ratios and number of 24-hour recall (24hR) collections needed to estimate usual energy and nutrient intake, in male adolescents.

Nutrients	Mean	SD *	Variance sources				Variance ratio **	Collections ***
			Inter-person	Day	Month	Intra-person		
Energy (kcal)	2,374	896	19.20	0.65	0.00	80.15	4.17	18
Fats (g)	86.1	37.0	19.68	0.10	1.92	78.30	3.98	17
Carbohydrate (g)	309.1	119.2	20.28	0.00	0.98	78.74	3.88	17
Protein (g)	87.8	38.4	44.36	0.00	0.12	55.53	1.25	5
Fiber (g)	17.5	8.1	26.49	0.13	0.05	73.33	2.77	12
Vitamin A (retinol equivalent) #	546	1,974	21.25	0.28	4.11	74.36	3.50	15
Vitamin D (μg)	4.3	9.3	34.54	0.00	0.85	64.61	1.87	8
Vitamin E (mg) ##	5.5	3.1	11.46	0.00	4.73	83.80	7.31	31
Vitamin K (μg)	93.0	127.8	17.94	0.00	0.74	81.33	4.53	19
Vitamin C (mg)	75.4	543.6	18.99	0.00	0.92	80.09	4.22	18
Thiamin (mg)	1.6	0.7	22.73	0.43	1.40	75.44	3.32	14
Riboflavin (mg)	1.7	1.1	25.02	0.17	1.09	73.72	2.95	13
Pantothenic acid (mg)	4.4	2.6	24.48	0.42	2.57	72.53	2.96	13
Vitamin B6 (mg)	1.6	0.8	19.67	0.52	2.56	77.26	3.93	17
Vitamin B12 (μg)	5.6	15.2	38.95	0.00	1.07	59.98	1.54	7
Calcium (mg)	663	456	45.73	1.69	0.00	52.58	1.15	5
Phosphorus (mg)	1,193	561	39.92	0.00	1.40	58.68	1.47	6
Magnesium (mg)	263	123	29.74	0.00	0.88	69.38	2.33	10
Iron (mg)	14.7	6.7	23.60	0.00	1.07	75.32	3.19	14
Zinc (mg)	12.7	5.9	39.42	0.22	0.87	59.49	1.51	6
Copper (mg)	1.5	3.0	27.30	0.00	1.50	71.20	2.61	11
Selenium (μg)	133.3	59.4	28.01	0.09	0.96	70.94	2.53	11
Sodium (mg)	4,109	1,627	33.62	0.09	1.07	65.23	1.94	8
Potassium (mg)	2,198	1,209	14.80	0.00	1.24	83.96	5.67	24
Folate (μg) ###	562	227	26.46	0.00	1.15	72.39	2.74	12
Niacin (mg) §	39.5	17.3	37.00	0.00	2.09	60.91	1.65	7

* Standard-deviation of the mean;
** Variance ratio: intra-person variance/inter-person variance;
*** Number of collections needed;
# Expressed as retinol activity equivalents;
Expressed as α-tocopherol;
Expressed as dietary folate equivalents;
§ Expressed as niacin equivalents.

dium, riboflavin, carbohydrate, magnesium, and energy.

Contribution to total variation in terms of day of the week and month of the year were small, similar to studies conducted in China [17,18,31]. This finding indicates that variation in quantities of nutrients consumed over time is random and cannot be predicted for a specific day of the week or month of the year. The studies cited [5,17,18,31] also took into account interview sequence and interviewer effect, which were both found to be equally insignificant as sources of variation in nutrient and energy intake. Notably, gender was an important determinant of intake variation in the present study.

The results of this study have implications for both planning and analysis of dietary surveys. With regard to planning of studies in populations similar to the one studied, where there is a need to ascertain usual nutrient and energy intake, the analysis of the main sources of variation suggest that 24hR data can be collected randomly on any day of the week. Similarly, the inclusion of all the months of the year may be unnecessary for esti-

Table 4

Mean, standard-deviation (SD), variation sources (%), variance ratios and number of 24-hour recall (24hR) collections needed to estimate usual energy and nutrient intake, in male adolescents.

Nutrients	Mean	SD *	Variance sources				Variance ratio **	Collections ***
			Inter-person	Day	Month	Intra-person		
Energy (kcal)	1,893	896	43.49	0.00	2.13	54.36	1.25	5
Fats (g)	69.8	37.0	40.67	0.00	0.94	58.38	1.40	6
Carbohydrate (g)	245.7	119.2	40.56	0.00	1.19	58.23	1.43	6
Protein (g)	67.4	38.4	31.20	0.27	5.53	62.89	2.01	9
Fiber (g)	13.8	8.1	36.99	0.33	1.41	61.25	1.65	7
Vitamin A (retinol equivalent) #	500	1974	33.34	3.01	4.97	58.66	1.75	7
Vitamin D (µg)	3.7	9.3	38.99	0.04	0.77	60.18	1.55	7
Vitamin E (mg) ##	4.8	3.1	45.03	0.00	0.00	54.96	1.22	5
Vitamin K (µg)	91.0	127.8	21.95	0.00	1.04	77.00	3.50	15
Vitamin C (mg)	120	543	24.14	0.00	0.00	75.85	3.14	13
Thiamin (mg)	1.3	0.7	42.11	0.00	2.33	55.54	1.31	6
Riboflavin (mg)	1.5	1.1	40.94	0.27	4.82	53.95	1.31	6
Pantothenic acid (mg)	3.5	2.6	37.64	0.00	3.04	59.31	1.57	7
Vitamin B6 (mg)	1.3	0.8	24.91	0.00	0.79	74.29	2.98	13
Vitamin B12 (µg)	4.7	15.2	17.27	0.00	0.90	81.82	4.73	20
Calcium (mg)	548	456	35.73	0.00	0.56	63.70	1.78	8
Phosphorus (mg)	949	561	38.50	0.00	4.08	57.40	1.49	6
Magnesium (mg)	213	123	36.39	0.00	5.22	58.38	1.60	7
Iron (mg)	12.0	6.7	28.71	0.00	2.51	68.77	2.39	10
Zinc (mg)	10.0	5.9	25.59	0.00	3.75	70.65	2.76	12
Copper (mg)	1.2	3.0	41.13	0.00	2.61	56.24	1.36	6
Selenium (µg)	104.7	59.4	39.23	0.40	5.38	54.96	1.40	6
Sodium (mg)	3,138	1,627	34.50	0.00	3.55	61.86	1.79	8
Potassium (mg)	1,896	1,209	35.68	0.00	1.89	62.41	1.75	7
Folate (µg) ###	450	227	32.25	0.00	3.09	64.64	2.00	9
Niacin (mg) §	30.7	17.3	28.97	0.00	4.62	66.39	2.29	10

* Standard-deviation of the mean;
** Variance ratio: intra-person variance/inter-person variance;
*** Number of collections needed;
# Expressed as retinol activity equivalents;
Expressed as α-tocopherol;
Expressed as dietary folate equivalents;
§ Expressed as niacin equivalents.

mating the usual diet of adolescents given the low contribution of month to total variability. However, in view of a possible correlation amongst intakes of several consecutive days, data should ideally be collected on alternate days [32].

The high percentage contribution of intra-person variance implies a low level of precision for estimates of usual individual intake when these are based on only two measurements, as was the case in the present study. Although the mean intake of a group can be obtained based on a single measurement, the presence of intra-person variance may distort the percentiles above and below the mean by increasing total variance of the distribution [6,7].

A reduction in the effects of intra-individual variability, and consequently improved accuracy of the estimate, may be achieved by increasing the number of collection days for the same individual, i.e. by increasing the number of repetitions of dietary measurements [7] as opposed to increasing sample size [6]. Therefore, the calculation of the number of days needed to estimate usual intake can serve to guide the planning of studies since this total is dependent on intra- and inter-person variances. As observed in the present study, around 15 repetitions of the 24hR will suffice for most nutrients in studies among male adolescents, whereas approximately eight replications appears to be sufficient in studies among women.

The fewer replications seen in females was due to the lower variance ratios observed. The nutrients vitamin E and potassium in males, and vitamin B12 in females, may require a greater number of repetitions. The high number of days needed to assess energy in males is noteworthy (17 days). This suggests a less stable pattern of caloric consumption in this group, characterized either by higher or lower intake. The same can be observed for other nutrients related to caloric intake such as fats and carbohydrates.

The correlation coefficient (r) used in the calculation of number of days measures the linearity between actual and observed consumption. The higher the value of r, the greater the proportion of individuals correctly ranked into their terciles, quartiles etc. of the true distribution of consumption. Thus, the higher the correlation desired, the greater the number of days needed. In the present study, the value of 0.9 was used for the correlation coefficient, by which over 75% of individuals are expected to be correctly classified into the extremes of the real distribution of consumption [29]. The use of a lower r value will mean fewer days are needed for data collection, but will lead to a significant increase in errors classifying individuals, and to attenuation of measurements of effect in studies associating dietary pattern with outcomes.

Alternatively, several 24hR can be applied in each individual to estimate usual intake and dietary measures can be repeated in at least one subsample of the study population. When replication is precluded, the use of variance ratios obtained in studies on similar populations is recommended. Using statistical methods such as those proposed by the National Research Council [33] and by Iowa State University [34], intake distributions can be corrected based on variance components of the sample itself (when repeat measurements have been made) or by using external variance components, thereby generating more accurate estimates of usual ingestion [12,35]. In studies of prevalence of nutrient intake inadequacy, the impact of correction is marked, since estimates based on distribution of non-adjusted intake are either under or overestimated owing to the influence of intra-person variability [31]. The present study therefore gains relevance in providing appropriate variance ratios for correcting dietary data in adolescent studies.

The sample employed in the present study was based on a representative sample of a population of adolescents from São Paulo. However, because of the large number of individuals that came of age between the random selection of the initial sample in 2003 and the return to households to new data collection in 2007, the sample may have lost its representativeness. Nevertheless, of the 59 census sectors used in the original sample, 53 remained in the second collection, representing the many regions of the municipality of São Paulo in the same fashion. In addition, no statistical difference was found between the strata (according to percentage of heads of family with University-level education) obtained in the 2003 and 2007 samples.

The majority of studies on variability of nutrient intake have been carried out by applying several recalls in each individual from the sample. However, comparisons of surveys collecting 24, 12, 8 and 5 measurements per individual revealed similar variance components across the studies and little or no variation attributed to day of the week or time of the year. Moreover, the intra-individual variance can be obtained accurately through the use of at least two 24hR in a representative sub-sample of the study population [33,36].

Conclusion

Day-to-day variation was the greatest source of energy and nutrient intake variation. Hence, the ideal number of 24hR repetitions should be a priority consideration in planning studies which need to ascertain the usual energy and nutrient intake among adolescents. The proportional distribution for days of the week and months of the year in the application of dietary measurements carry less weight, where this knowledge may ultimately reduce data collection costs. Future studies in adolescents from populations with different sociodemographic characteristics are warranted, with special focus on results for macronutrients.

Resumo

Este estudo propôs-se a descrever as fontes de variação da ingestão de energia e nutrientes e calcular o número de dias necessários para a estimativa da ingestão habitual em adolescentes do Município de São Paulo, Brasil. Foi aplicado um recordatório alimentar de 24 horas (R24h) em 273 adolescentes, durante os anos de 2007 e 2008, e posteriormente cada indivíduo foi convidado a responder a outro R24h. Foram estimadas as fontes de variação da ingestão utilizando-se modelo de efeitos aleatórios. A variância intrapessoal foi o componente de variância que mais contribuiu para a variabilidade da ingestão de energia e nutrientes, ao passo que a contribuição do dia da semana e mês do ano foi pequena (< 8%) para a variabilidade total da ingestão. As razões de variância variaram de 1,15 para o cálcio a 7,31 para a vitamina E. O número de R24h necessário para estimar a ingestão habitual variou de acordo com o nutriente: em torno de 15 para o sexo masculino e 8 para o feminino.

Ingestão de Alimentos; Ingestão de Energia; Epidemiologia Nutricional; Adolescente

Contributors

E. Verly Junior participated in the writing of the manuscript and the statistical analyses. R. M. Fisberg and C. L. G. Cesar collaborated in the planning of the study and review of the manuscript. D. M. L. Marchioni contributed in the planning of the study, as well as the writing and review of the manuscript.

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