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Original article

ASSESSMENT OF MICRONUTRIENT STATUS OF CONSCRIPTS IN ARCTIC ZONE OF RUSSIAN FEDERATION

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Abstract. *The aim of the study* is to assess the micronutrient status in the autumn and winter periods of conscripted military personnel serving in the Arctic zone of the Russian Federation (Arctic); to perform a comparative analysis of the laboratory and clinical methods used to determine micronutrient insufficiency.
Materials and methods of research. The study involved 154 conscripts (all male) aged 18-25 years, healthy, service experience in the Arctic – from 4 months. In the autumn (2 points) and spring (one point) phases the following issues were studied: a set of physical health indicators; laboratory indicators of 8 vitamins (A, E, D, C, B_1, B_2, B_{12}, folic acid) and 8 minerals (Fe, Ca, P, Co, Mn, Cu, Se, Cr) in the blood; symptoms of vitamin deficiency. The state of health, physical fitness, morbidity and hospitalization of the subjects were evaluated.
Research results and their analysis. Data were obtained on the prevalence of hidden (subclinical) forms of vitamin deficiency, including more than 50% – for folic acid, vitamins A, E, D, C, as well as all the studied minerals - in the autumn-winter period, which is more dangerous in terms of the incidence of respiratory infections in organized contingents. The classical view of the prevalence of hypovitaminosis in the spring was revised, which was only partially confirmed for vitamins C and B_1. It was found that the classical methods of diagnosis based on clinical symptoms used to determine manifest forms of hypo-and avitaminosis are ineffective for early detection of subclinical forms (prehypovitaminosis).
The necessity is substantiated of wider implementation of modern means of laboratory diagnostics of micronutrient deficiency in the body using a proven method of freezing transported samples in combination with already used hygienic methods.

Key words: *Arctic zone of the Russian Federation, conscripts, disadaptation, extreme conditions, hypovitaminosis, micronutrients, trace elements, vitamins*

Conflict of interest. The authors declare no conflict of interest

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Оригинальная статья

ОЦЕНКА МИКРОНУТРИЕНТНОГО СТАТУСА У ВОЕННОСЛУЖАЩИХ ПО ПРИЗЫВУ В УСЛОВИЯХ АРКТИЧЕСКОЙ ЗОНЫ РОССИЙСКОЙ ФЕДЕРАЦИИ

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Резюме. *Цель исследования* – оценить микронутриентный статус в осенний и зимний периоды у военнослужащих по призыву, проходящих службу в условиях Арктической зоны Российской Федерации (Арктика); выполнить сравнительный анализ применяемых лабораторных и клинических методов определения микронутриентной недостаточности.
Материалы и методы исследования. В исследовании участвовали 154 военнослужащих по призыву (все – мужчины) в возрасте 18–25 лет, здоровые, стаж службы в условиях Арктики – от 4 мес. В осеннюю (2 точки) и весеннюю (одна точка) фазы исследовались: комплекс показателей физического здоровья; лабораторные показатели содержания 8 витаминов (A, E, D, C, B_1, B_2, B_{12}, фолиевой кислоты) и 8 минеральных веществ (Fe, Ca, P, Co, Mn, Cu, Se, Cr) в крови; симптомы витаминной недостаточности. Оценивались состояние здоровья, физической подготовленности, заболеваемость и госпитализация обследуемых.

Результаты исследования и их анализ. Получены данные о распространенности скрытых (субклинических) форм дефицита витаминов, в том числе свыше 50% – по фолиевой кислоте, витаминам А, Е, D, С, а также всех исследованных минеральных веществ – в осенне-зимний период, более опасный в части заболеваемости инфекциями органов дыхания в организованных коллективах. Пересмотрено классическое представление о распространённости гиповитаминозов весной, которое подтвердилось только частично для витаминов С и B_1. Установлено, что классические методы диагностики по клиническим симптомам, применяемые для определения манифестных форм гипо- и авитаминозов, неэффективны для раннего выявления субклинических форм (прегиповитаминозы).

Обоснована необходимость более широкого внедрения в практику современных средств лабораторной диагностики недостаточности микронутриентов в организме с использованием апробированного способа заморозки транспортируемых образцов в комбинации с уже применяемыми гигиеническими методами.

Ключевые слова: *Арктическая зона Российской Федерации, витамины, военнослужащие по призыву, гиповитаминоз, дизадаптация, микроэлементы, микронутриенты, экстремальные условия*

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Introduction

The fundamentals of the governmental policy in the Arctic zone of the Russian Federation until 2035 (approved by the Decree of the President of the Russian Federation dated March 5, 2020 No. 164), as well as the Strategy for the development and for ensuring national security of the Arctic zone of the Russian Federation for the period until 2035 (approved by the Decree of the President of the Russian The Federation of October 26, 2020 No. 645) provide for the further implementation of strategic planning programs, according to which in the Arctic zone of the Russian Federation (Arctic) the presence of general-purpose troops (forces) of the Armed Forces (VS) is to be increased and strengthened, Arctic integrated emergency rescue centers and their base infrastructure are developing.The establishment of favorable conditions for a quick adaptation of servicemen to the conditions of the Arctic, including comprehensive research on nutrition, is one of the priorities of the state policy for the development of the North [1].

The provision of body with macro- and micronutrients, in volumes which do not correspond to the level of physiological need, creates potential risks of a decrease in adaptive reserves, general resistance of the body and, as a consequence, of an increase in morbidity [2, 3].

By "extreme factors" is meant the deviation of the organism's living conditions from the usual optimum of external and internal factors[4]. A large amount of scientific data has been accumulated confirming the negative impact on human health of extreme ecological conditions in the North[5]. The state of human health, the working capacity in extreme conditions is ultimately determined by the volume of adaptive reserves of the body [3].

As a result of such a functional overstrain with insufficient compensation, the syndrome of chronic environmental and occupational overstrain (SHEPP) develops with a high probability of pre-illness and illness as an outcome [1, 3]. The main elements of the pathogenesis of SHEPP are increased energy production associated with increased accumulation of peroxide compounds. The deficiency of essential micronutrients, especially those with antioxidant properties, is the most important prerequisite for the development of SHEPP. On the other hand, SHEPP is accompanied by an increased consumption and by a subsequent depletion of antioxidant factors, including essential micronutrients. Thus, ensuring an adequate level of essential micronutrients in the body is both a means of preventing the development of SHEPP and an element of compensation for the depletion of antioxidant systems during its development. Therefore, it provides an increase in the efficiency of immunity systems and of nonspecific resistance of the body [1, 3].

A laboratory assessment of the vitamins and minerals supply to the body is a more accurate and objective diagnostic method, but it is often not available in remote locations for military personnel [6, 7]. Among the modern diagnostic methods introduced into practice, one should single out high-performance liquid chromatography – HPLC and enzyme-linked immunosorbent assay – ELISA [8, 9].

For a long time, the scientific literature was dominated by the idea of the "spring" nature of hypovitaminosis, which was based on the data on a decrease in the concentration of ascorbic acid in fruits and vegetables and further extrapolated to all micronutrients. On the basis of this idea, as part of the food ration from April 15 to June 15 (in the Far North – from April 15 to August 15), military personnel receive a multivitamin preparation, one tablet per day [10].

The issue of the provision of the body with micronutrients in autumn and winter is less studied.

The purpose of the study – is to assess the micronutrient status during autumn and winter in conscripts serving in the Arctic zone of the Russian Federation; to perform a comparative analysis of the applied laboratory and clinical methods for determining micronutrient deficiency.

Materials and research methods. ИThe study was carried out on the basis of a military unit in the settlement of Pechenga, Murmansk region in autumn and spring phases: 2 survey points – in October and November – in the autumn phase; one survey point – in March – in the spring phase. The study included 154 conscripts – all men aged 18 to 25, healthy, bearing a mission in the Arctic for at least 4 months. The subjects were suitable for comparative analysis, since they were of the same age group, physical condition, for at least 4 months they were in the same climate. Their professional activity, residence, daily routine and physical activity were similar. They ate together according to the norm of combined arms ration No. 1, i.e. should have received approximately equal amounts of nutrients from food.

The state of health was assessed basing on complaints, anamnesis, medical records, examination, hemodynamic parameters (pulse, blood pressure – BP), thermometry, general blood test, general urine analysis, basic biochemical parameters – 15 items. Nutritional status was assessed on the basis of calculated indicators (body mass index – BMI, waist – hip index) using caliperometry at four points according to Brock based on the measurement results: of height – standing (stadiometer); of body weight (medical scales); of waist circumference and of hip circumference (measuring tape) [1, 11].

Capillary blood sampling from a finger in the morning on an empty stomach for a complete blood count (CBC) and analysis were performed in the clinical laboratory of the hospital at the study site. Hemoglobin, erythrocytes, leukocytes, ESR, hematocrit were tested. Blood sampling from the cubital vein up to 25 ml (2 dry vacuum tubes of 8 ml – for plasma; one dry vacuum tube 9 ml – for serum) with centrifugation at a speed of 3 thousand rpm to obtain plasma and serum. Plasma and serum were collected in polymer microcontainers and frozen in a freezer to a temperature of –18 ° C [1, 11]. The exposure of the samples before the freezing averaged no more than 40 minutes.

Samples were transported frozen in a continuous cold chain. Laboratory testing of the samples was carried out on the basis of the Kirov Military Medical Academy (VMedA).

The work assessed the following laboratory parameters:
– indicators of a general blood test – the number of erythrocytes, leukocytes; manual cytometry – microscope, Goryaev camera; calculation of hematocrit; hemoglobin concentration – cyanmethemoglobin method; ESR.
– biochemical parameters – total protein, albumin, total cholesterol, triglycerides, transferrin, ALT, AST, C-reactive protein – a highly sensitive method; IgA, IgG – automatic biochemical Beckmann-Coulter analyzer AU 480, USA;
– content of vitamins in the blood – folic acid, vitamin B_{12} – Beckmann-Coulter analyzer DxI 800, USA, immunochemiluminescence; vitamin B_1 – fluorimetry – "Fluorat-02-ABLF-T" fluorimeter, Russia, indirect method; vitamin B_2 – Birch, Bessey, Lowry analysis – spectrophotometer SF-2000, Russia; vitamin C – Tillmans titration with an electrochemical detector; vitamins A, E, vitamin D total, determined by the sum of two active metabolites 25(OH)D_3, 25(OH)D_2 – high-performance liquid chromatography, HPLC Agilent-1200 apparatus, USA;
– content of minerals in the blood – copper, manganese, cobalt, chromium, selenium – atomic absorption spectrometer MGA-915M, Russia; calcium, serum phosphates, magnesium, unbound serum iron, total serum iron – automatic biochemical analyzer Beckmann-Coulter AU 480, USA.

As a result of comparing indicators of the content of vitamins and minerals with the range of normal values, participants of the survey were ascribed to one of three categories: “below normal”, “normal”, “above normal” [1, 11]. The distribution by category relative to the norm was analyzed as a percentage of the total number of subjects with a 95% confidence interval.

Research results and their analysis. The authors made an assumption that an insufficient content of essential nutrients in the body of military personnel, taking into account the specifics of the occupational and environmental factors of the Arctic, should manifest itself not only in the spring-summer, but also in the epidemically dangerous autumn-winter period. Replenishment of micronutrient deficiencies at early (subclinical) stages is an essential element in the prevention of dysadaptation and development of SHEPP. An excessive introduction of essential micronutrients into diet does not have a significant prophylactic effect in individuals with normal micronutrient status [9, 12]. The very fact that hypovitaminosis and diselementosis are naturally accompanied by inhibition of specific and nonspecific protective factors, increasing the risk of diseases, can hardly be questioned [13].

The incidence rate for class X ICD-10 (respiratory diseases) among conscripts in the surveyed military unit exceeded the incidence among the adult population of Russia in 2014 and 2015. by 4.5 and 4 times, respectively; morbidity in the adult population of the Northwestern Federal District in 2014 and 2015 – by 3.7 and 3.1 times, respectively, $p < 0.001$. Such a significant difference is explained by extreme environmental and professional factors affecting military personnel (Table 1).

The study checkpoints were linked to cycles of ARI incidence in the troops, where the seasonal rise in incidence usually begins on the second week of November, and the first peak is attained by the end of December – early January [11].

The level of procurement of the body with vitamins was determined using two methodological approaches. The symptoms of vitamin deficiency were assessed by two doctors of the unit's medical service independently of each other on the basis of the Guidelines for determining vitamin deficiency in military personnel, approved by the directive of the head of the Main Military Medical Directorate (GVMU) of the Min-

Таблица 1/Table 1

Заболеваемость болезнями органов дыхания (X класс МКБ-10) у военнослужащих по призыву и взрослого населения в 2014–2015 гг., чел./‰

Incidence of respiratory diseases (class X ICD-10) in conscripts and adult populationin 2014–2015, people/‰

Место дислокации /территория проживания – субпопуляция The place of dislocation – subpopulation	2014	2015	Уровень значимости различий, р Significance of differences, р
Н.п. Печенга, военнослужащие Community Pechenga, military personnel	1729/ 679,1	1490/ 621,6	<0,001
Н.п. Спутник, военнослужащие Community Sputnik, military personnel	411/ 453,6	1272/ 1268,2	<0,001
Северный Флот, военнослужащие Northern Fleet, military personnel	–/ 604,0	–/ 682,0	<0,001
Северо-Западный федеральный округ, взрослое население* North-Western Federal District, adult population*	–/ 183,1	–/ 197,8	–
Российская Федерация, взрослое население* Russian Federation, adult population*	–/ 151,3	–/ 154,3	–

* Согласно официальным данным ч. III статистических материалов «Заболеваемость взрослого населения России» в 2014 и 2015 годах, опубликованных Департаментом мониторинга, анализа и стратегического развития здравоохранения Минздрава России
* According to official data, part III of statistics "Morbidity of adult population of Russia" in 2014 and 2015, published by the Department of monitoring, analysis and strategic development of health service of Health Ministry of Russia

istry of Defense of Russia dated March 13, 1997 No. 161 / DM-5 (DM-5). Also, the laboratory assessment of the content of vitamins in the blood of the subjects was made. It was also interesting to compare the results of these two methods with each other.

The DM-5 directive contains an excessive list of 51 symptoms of clinical signs of vitamin deficiency, but does not include clear criteria for diagnosing hypovitaminosis. To objectify the results of clinical assessment, it was necessary to translate the observation results into a quantitative – in points or percentages – format, which was implemented based on the following formula:

$$H_x = \frac{\sum_1^m s \times k}{\sum_1^n s_{max} \times k_{max}} \times 100\%$$, where

H_x – the relative clinical severity of vitamin X deficiency;
s – the severity of the symptom of hypovitaminosis in points – from 0 to 2;
s_{max} – the maximum possible severity of the symptom (= 2);
k – symptom weighting coefficient – from 1 to 2;
k_{max} is the maximum possible symptom weighting factor (= k);
m – the number of identified symptoms – from 0 to n;

The resulting Hx value reflects in percentage the clinical severity of hypovitaminosis relative to its possible maximum in totality of all clinical signs.

During the subsequent analysis of the data obtained, it turned out that out of 51 symptoms listed in DM-5 as clinical symptoms of vitamin deficiency, a significant part (46%) were never detected, while other symptoms, such as "dry skin" or "follicular hyperkeratosis " were detected very often. To assess the interconnections of clinical symptoms of vitamin deficiency presented in DM-5, a correlation analysis was carried out. The results of the analysis refuted the assumption that at the preclinical stage the severity of signs of vitamin deficiency has a stable correlation with a corresponding laboratory indicator (Table 2).

At the head line of the Table 2 there is a laboratory indicator – the concentration of the studied vitamin; in the lines

Таблица 2/Table 2

Матрица корреляционных связей клинических признаков гиповитаминозов с лабораторными данными, n=154

Matrix of correlations of clinical signs of hypovitaminosis with laboratory data, n=154

Лабораторный показатель Клиническая выраженность Laboratory parameter Clinical severity	Фолиевая кислота Folic acid	Витамин B_{12} Vitamin B_{12}	Витамин А Vitamin A	Витамин Е Vitamin E	Витамин Д общ. Vitamin D com.	Витамин B_1 Vitamin B_1	Витамин B_2 Vitamin B_2	Витамин С Vitamin C
Гиповитаминоз А Hypovitaminosis A	0,138 p=,208	0,0859 p=,434	0,1285 p=,241	0,1573 p=,151	-0,078 p=,478	0,264 p=,015	0,277 p=,010	0,156 p=,154
Гиповитаминоз B_1 Hypovitaminosis B_1	0,064 p=,562	0,042 p=,703	0,202 p=,064	0,210 p=,054	-0,077 p=,485	0,223 p=,040	0,282 p=,004	0,183 p=,094
Гиповитаминоз B_2 Hypovitaminosis B_2	0,092 p=,402	0,255 p=,019	0,150 p=,171	0,104 p=,344	-0,083 p=,450	0,211 p=,053	0,290 p=,001	0,274 p=,011
Гиповитаминоз С Hypovitaminosis C	0,083 p=,449	0,046 p=,676	0,144 p=,188	0,128 p=,242	-0,114 p=,298	0,208 p=,056	0,245 p=,024	0,176 p=,107
Гиповитаминоз B_6 Hypovitaminosis B_6	0,114 p=,298	0,253 p=,020	0,118 p=,282	0,076 p=,488	-0,080 p=,467	0,191 p=,081	0,290 p=,007	0,267 p=,013
Гиповитаминоз РР Hypovitaminosis PP	0,111 p=,310	0,186 p=,088	0,117 p=,287	0,094 p=,392	-0,034 p=,756	0,230 p=,034	0,251 p=,021	0,259 p=,017
Гиповитаминоз Р Hypovitaminosis P	0,083 p=,450	0,045 p=,686	0,145 p=,186	0,129 p=,239	-0,113 p=,304	0,208 p=,056	0,2462 p=,023	0,177 p=,105
Полигиповитаминоз Polyhypovitaminosis	0,153 p=,162	0,157 p=,151	0,123 p=,264	0,134 p=,222	-0,051 p=,646	0,244 p=,025	0,282 p=,009	0,245 p=,024

– the relative magnitude of the severity of clinical signs of deficiency of the corresponding vitamin (polyhypovitaminosis). In the cells of the table, the upper number is the Pearson correlation coefficient r, the lower number is the criterion for the significance of p. For the purposes of the study, the correlation was defined as significant in the presence of two conditions: significant relationship – at $p < 0.05$; strong correlation – for $r > 0.7$. No pairs of features satisfying the given condition were found. The absence of a significant correlation between clinical signs and laboratory indicators of is clearly seen in the example of vitamin C (See Figure).

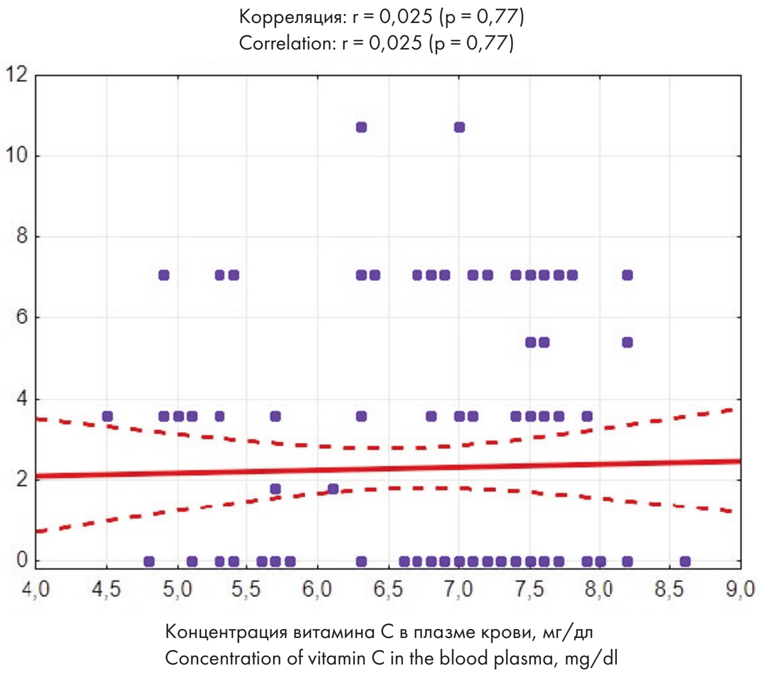

Рисунок. График рассеяния относительной клинической выраженности гиповитаминоза С – % от максимальной – в поле концентрации витамина С в крови, n=137

Figure. Scatter plot of the relative clinical severity of hypovitaminosis C – % from max– in the field of vitamin C concentration in the blood, n=137

Likewise, the study attempted to establish, through continuous correlation analysis, which among frequently used laboratory parameters are “indicative” and would be able to replace complex and expensive micronutrient testing. However, correlation analysis did not reveal any significant corellations here. Thus, modern laboratory methods for assessing the body's supply of micronutrients are the most accurate and objective and have no equivalent alternative for assessing subclinical (prenosological) forms of micronutrient deficiencies.

When studying the data at the starting point (autumn), a wide prevalence of deficiency of fat-soluble vitamins A, E, D was revealed (the prevalence of deficiency of retinol and α-tocopherol is close to total), which practically does not change by spring.

The procurement with other vitamins is also far from optimal with the prevalence of subclinical hypovitaminosis in the range of 30-60% in autumn. In particular, the vitamin C deficiency was revealed in 51.1% of the surveyed. The situation with vitamins B_{12} and B_1 can be called relatively favorable only in autumn phase. Thus, for vitamins A, E, D, B_2, B_{12} and folic acid, the prevalence of vitamin deficiency states among conscripts in the Arctic in spring and autumn does not correlate with the “sanitary indicative” vitamin C deficiency and is approximately at the same level, which is not satisfactory (Table 3).

Таблица 3/Table 3

Распространённость субклинических витаминодефицитов у военнослужащих по призыву осенью и весной,чел./%, по данным лабораторного исследования

Prevalence of subclinical vitamin deficiencies among conscripts in the fall and spring periods, people/%, according to a laboratory study

Исследуемый витамин Vitamin under study	Осень, n=154 Fall, n=154	Весна, n=68 Spring, n=68	Уровень значимости различий, p Significance of differences, p
Фолиевая кислота Folic acid	87/(56,5±4,6)	36/(52,9±1,5)	>0,05
Витамин B_{12} Vitamin B_{12}	42/(27,3±2,2)	21/(30,9±1,4)	>0,05
Витамин А Vitamin A	112/(81,2±6,5)	59/(86,8±1,0)	>0,05
Витамин Е Vitamin E	131/(97,0±7,8)	64/(94,1±0,7)	>0,05
Витамин Д общ. Vitamin D com.	68/(58,1±4,7)	38/(55,9±1,5)	>0,05
Витамин B_1 Vitamin B_1	41/(28,5±2,3)	46/(67,6±1,4)	**<0,001**
Витамин B_2 Vitamin B_2	60/(44,1±3,6)	29/(42,6±1,5)	>0,05
Витамин С Vitamin C	71/(51,1±4,1)	54/(79,4±1,2)	**<0,05**

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Conclusions

1. Classical diagnostic methods based on clinical symptoms, which remain relevant for determining the manifest

forms of hypo- and avitaminosis, are not very informative for the early detection of subclinical forms (prehypovitaminosis).

2. Modern means of laboratory diagnostics are more effective for diagnosing subclinical (non-manifest) forms of vitamin and mineral deficiency. Further improvement of methods for laboratory assessment of micronutrient deficiency and their widespread implementation meet the requirements of modern medicine, focused on early (prenosological) diagnosis of pathological conditions.

3. The micronutrient provision of conscripts in the extreme conditions of the Arctic is characterized by a wide prevalence of subclinical forms of deficiency of all studied vitamins, including over 50% deficiency for folic acid, A, E, D, C, as well as some minerals, including over 50% deficiency for Se, Co, Ca. A seasonal increase in the prevalence of subclinical hypovitaminosis in spring compared to autumn was found only for vitamins C and B_1. Deficiency of vitamins and minerals is all-seasonal.

4. For conscripts, who are under the influence of extreme environmental and professional factors of service in the Arctic zone of the Russian Federation, it is necessary to constantly – in regular courses – add essential micronutrients in the form of vitamin and mineral complexes to the diet throughout the epidemiologically dangerous autumn-winter period.

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