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Body mass index of the elderly derived from height and from armspan

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The body mass index (BMI) has been promoted as a useful indicator for chronic energy deficiency, and to a lesser extent to indicate obesity. For the growing sector of elderly in developing countries, such as Indonesia, both issues are taking on public health relevance. The aging process leads to a progressive loss of height, and questions have been raised as to the appropriate value to include in the denominator of the BMI formula, WT(kg)/HT(m^2), when applied in this age-group. The armspan has been advanced as a surrogate for height, correcting for the lifelong loss of stature. In a data-set from 69 elderly in Indonesia, 36 women and 33 men, aged 60 to 69 y, we have examined the interrelationships of height and armspan. The correlation coefficient for the regression of the two measures were $r = 0.83$ and $r = 0.81$ ($p < 0.001$), for women and men, respectively.

Substituting the armspan term in the denominator to compose a Body Mass using Armspan (BMA) Index, we observe for this population a 32% increase in estimates for Chronic Energy Deficiency (CED) for women and 24% increase in estimates of CED for men. Corresponding estimates for obesity rates declined by 45% and 81% respectively. The senescent changes in stature raise important questions for our capacity to estimate prevalences of body composition disorders in the older population.

Introduction

Poor nutritional status is common among the elderly, and is associated with increased mortality and morbidity1,2. Yet, until recently, there has been little research on the nutritional status of the elderly3. Aging is accompanied by changes in body composition and stature4. Furthermore, racial differences have been reported in anthropometric indices5-8, making the analysis of nutritional status in elderly more complex and discouraging.

Numerous methods are available to assess nutritional status by way of body composition, also applicable for the elderly[9,10]. Body mass index (BMI) has usually been the index of choice in studies, because its components - height and weight - are rapid and simple to measure. The robustness of the BMI as an indicator of chronic energy deficiency (CED) has been vigorously championed[8,11,12], and, to a lesser extent, defended as an index of overweight as well[12-14]. Furthermore both extremes of BMI have proven to be strong predictors of increased mortality and morbidity[15-17].

Functional decline is a reality for the elderly[18] and the superimposition of age and CED would be expected to compound an adverse situation. How well, we might ask, does the BMI serve as a predictor of CED in those of advanced age, and are the cut-off points proposed in the classification applicable for the elderly? Using height in calculating BMI could be inappropriate because of height-loss with aging due to the compression of vertebrae, kyphosis and osteoporosis[19-21]. Solomons et al[22] have raised the question of an appropriate weight to cover a frame in which the vertical dimension (height) is shrinking. Correction of the measured height by an estimate of the stature that existed in young adulthood was suggested[23]. It might be that by using height in calculating BMI the prevalence of CED in elderly is under-estimated. Armspan is relatively independent of aging and is highly related to the height of an individual[23]. Therefore, to predict the prevalence of CED in elderly it may be more reliable to use armspan in the determination of weight related to body stature.

Asian populations are notable for their low BMIs, putatively reflecting risk of CED[24]. Thus, the aim of the present study was to examine the nutritional status of the elderly by measuring BMI, and then substituting the armspan term for the BMA. We also examine the level of correspondence between the two measures (armspan and stature) in Indonesian elderly, providing novel information on the body composition of the older population in urban Jakarta.

Materials and methods

The study was carried out in the community of Kelurahan Kemayoran, a low income area in Central Jakarta, Indonesia during April/May 1993. The elderly were selected by simple random sampling out of community lists. If somebody had moved away or died, or could not be located after trying twice, another elderly person of the same sex and from the same subdistrict of Kelurahan Kemayoran was chosen.

In the collection of the anthropometric data, weight, height and armspan measurements were taken after standardising of the examiner. The subjects were measured barefoot with light-weight clothing. Body weights were recorded with an exactness of 0.1 kg using SECA digital weighing scale (Hamburg, Germany). To measure height, the barefoot subjects were requested to stand straight on a horizontal surface, heels together, the eyes straight forward. The height measuring equipment consisted of a microtoise fixed to the wall. Armspan was measured in the same position as the height, but with the extended arms in a 90° angle to the body, using a flexible tape. It was measured across the

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Table 1. Age and selected anthropometric data of a group of elderly females and males from Jakarta Indonesia (mean, standard deviation and range).

	Females (n=36)			Males (n=33)		
	Mean	SD	Range	Mean	SD	Range
Age	64.6	± 2.9	60-69	63.6	± 2.9	60-69
Weight (kg)*	46.7	± 10.2	30.2-70.4	52.9	± 10.5	32.1-75.9
Height (cm)**	146.8	± 4.7	136.1-154.3	157.9	± 5.7	143.0-166.3
AS (cm)**	154.0	± 6.0	141.2-164.0	165.7	± 6.8	152.1-176 8
HT/AS	0.96	± 0.05	0 9-1.01	0.95	± 0.06	0.84-1.02
BMI (kg/m^2)	21.7	± 4.7	14.3-30.2	21.3	± 4.2	13.8-30.0
BMA (kg/m^2)	19.7	± 4.3	13.5-26.8	19.3	± 3.8	11.6-27.7

AS - Armspan; HT - Height; BMI - Body mass index; BMA - Body mass index calculated by height

* Significant difference mean values between females and males: $p < 0.05$; ** Significant difference mean values for females and males: $p < 0.01$

chest from the longest finger of the left hand to the longest finger of the right hand. Three readings were taken for each measurement and the median has been taken as the representative value. Two indices of nutritional status were used: Body Mass Index (BMI), or weight/height^2 (kg/m^2), and Body Mass Index using armspan (BMA), weight/armspan^2 (kg/m^2). The classification of James et al[8] was used for identification of CED.

The International Guidelines for Ethical reviews of Epidemiological Studies[25] served as a basis for the ethical considerations of the implementation of this study. For the statistical analysis first, the distribution of all variables were tested against a normal distribution using the Kolomogrov-Smirnov Test to check for differences at a significance level of $p < 0.05$. Differences in mean values between sexes were analysed using Student's t-test for independent samples with a confidence interval of 95% ($p,<0.05$). Correlation analysis of anthropometric variables was carried out to calculate the Pearson product - moment correlation coefficient.

Results

Sixty-nine subjects, 36 women and 33 men aged 60 to 69 y, were examined. Table 1 lists sex-specific means, standard deviations and ranges of the age and anthropometric measurements for the subjects. Women had significantly lower weight, height and armspan than men ($p < 0.05$). No significant differences between sexes were found for the height/armspan-relationship (HT/AS), the BMI and the BMA.

On average the armspan of the females was 7.3 cm longer than height; that of the males was 7.6 cm longer (Table 2). The range of difference between armspan and height was wide, from -2.4 cm up to 17.0 cm in both genders. The BMA was, on average, 2.0 kg/m^2 lower than the BMI for both sexes on average.

Table 2. Difference between armspan and height and between BMA and BMI in a selected group of elderly males and females from Jakarta.

Group	N	Mean	SD	Range
AS - HT (cm)				
All	69	7.9	± 4.0	-2.4-17.0
Women	36	7.3	± 3.3	-0.9-16.7
Men	33	7.6	± 3.6	-2.4-17.0
BMA - BMI (kg/m^2)				
All	69	2.0	± 1.0	-0.7-6.1
Women	36	2.0	± 0.9	-0.2-4.3
Men	33	2.0	± 1.2	-0.7-6.1

AS - Armspan; HT - Height; BMI - Body mass index; BMA - Body mass index calculated by height

Figures 1 and 2 show the correlation coefficients of the linear regression between armspan and height, for females (0.83) and males (0.81), respectively; their significance was $p<0.001$. A similar statistical significance was observed for the relation between the BMI and the BMA; the correlation coefficients of the latter were 0.98 for women and 0.96 for men (Figures 3 and 4).

Figure 1. Correlation between height and armspan in a selected group of elderly females from Jakarta.

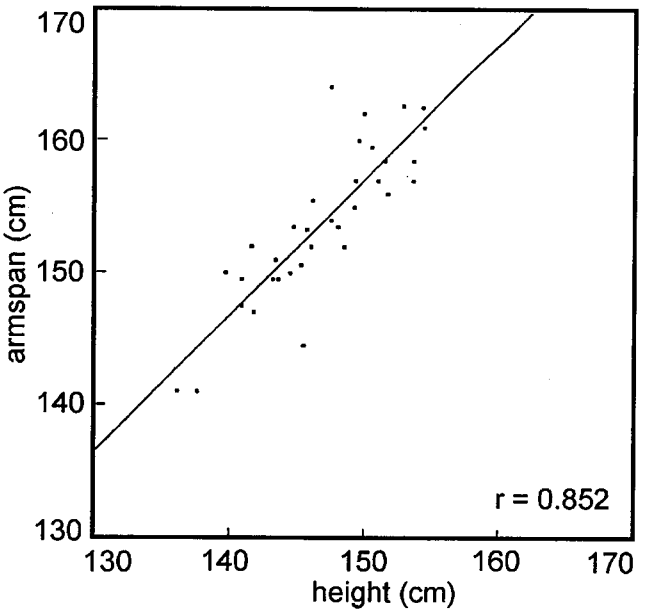


Figure 2. Correlation between height and armspan in a selected group of elderly males from Jakarta.

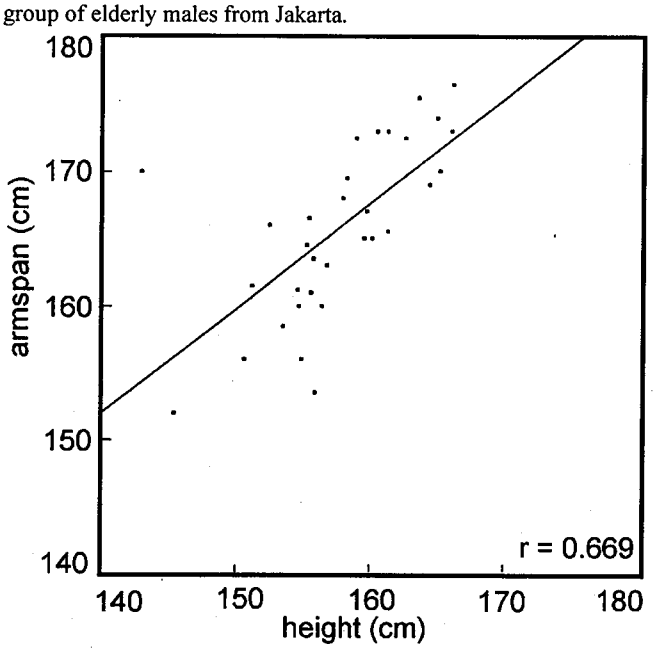


Figure 3. Correlation between BMI and BMA in a selected group of elderly females from Jakarta

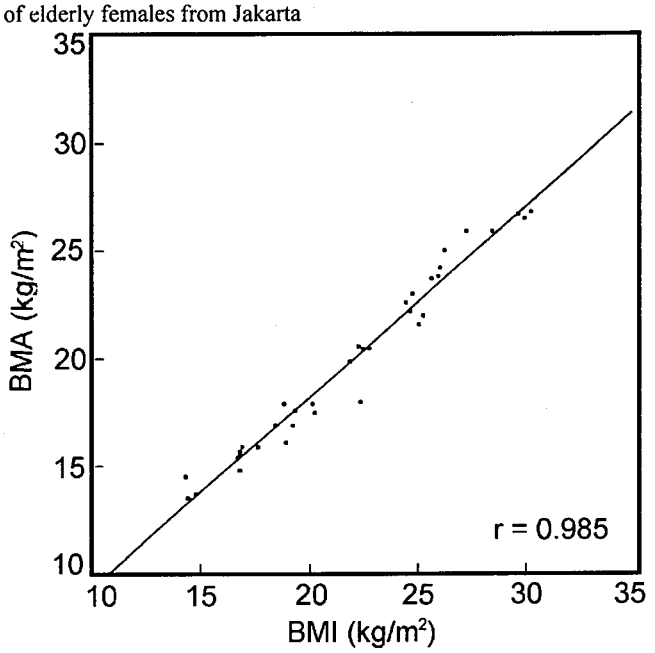


Figure 4. Correlation between BMI and BMA in a selected group of elderly males from Jakarta.

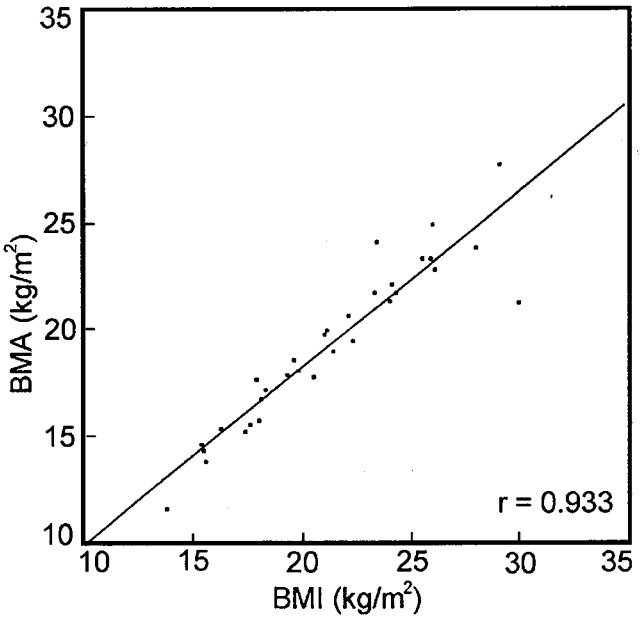
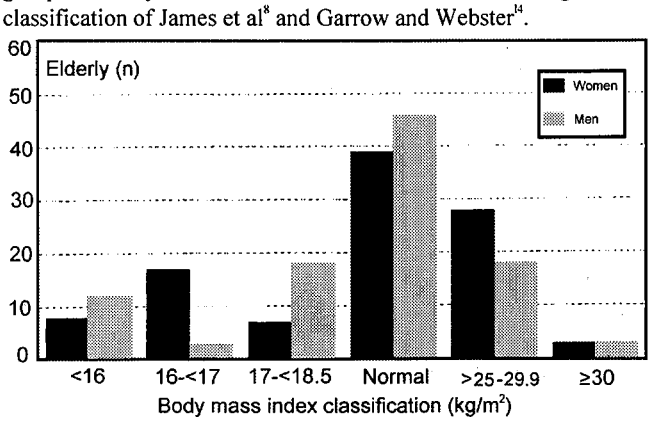
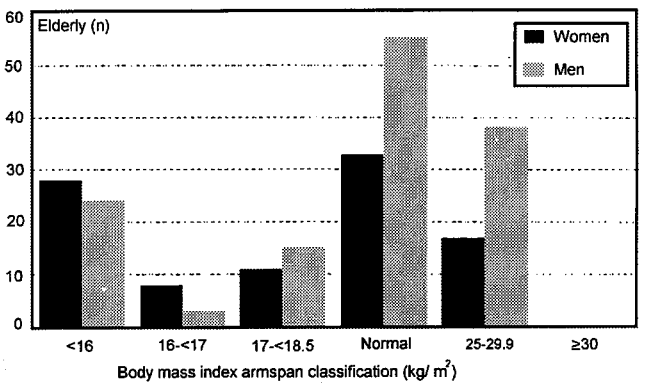


Figure 5. Distribution of body mass index BMI of a selected group of elderly females and males from Jakarta according to the classification of James et al[8] and Garrow and Webster[14].



Figures 5 and 6 show the proportion of the elderly falling into the different classes of chronic energy deficiency and obesity, for females and males, respectively. About one-third of the subjects had a BMI below 18.5 kg/m^2. A remarkably high proportion of the male subjects (12%) had a BMI below 16.0 kg/m^2 which is remarkably high, just as the percentage of females (17%) below the value of 17.0 kg/m^2. Thirty-nine percent of the females and 46% of the males had a nutritional status considered to be normal. Thirty-one percent of the female subjects and 21% of the male subjects were obese. Using the armspan instead of the height calculating the body mass using armspan (BMA), 46% of the elderly were classified as undernourished. The portion of the elderly with a BMA of < 16.0 kg/m^2 became especially high at 27%. No elderly were classified as obese using BMA (≥30).

Figure 6. Distribution of body mass index calculated by armspan (BMA) of a selected group of elderly females and males from Jakarta according to the classification of James et al[8] and Garrow and Webster[14].



Discussion

Indonesian elderly in this sample are dramatically smaller and lighter than their American counterparts[26]. The difference in mean height between Indonesian and American subjects was 20 kg for both sexes. Furthermore the mean values of BMI in this study were found to be lower than those of developed countries. The EC/EURONUT SENECA Study, which assessed representative samples aged 75 to 81 in 12 European countries[27], found a range in mean values of BMI from 23.9 to 30.5 kg/m^2 for women, and from 24.4 to 30.3 kg/m^2 for men. Our mean BMIs of 21.7 kg/m^2 for females and 21.3 kg/m^2 for males, were below the lowest mean BMIs of any European subsample. These findings support those of other studies, which found that small stature as well as low body weight, seems to be more common in developing countries than in developed countries[5,12]. Reasons for differences have been suggested to have genetic or environmental bases[5,28-30]. Furthermore, racial differences in the relationship between body composition and BMI have been reported[6-8]. Because BMI reflects body fat mass as well as lean body mass, the same BMI can represent a completely different body composition in different races. Therefore, comparison between different populations have to be viewed cautiously.

James et al[8] proposed a classification with three cut-off points for Chronic Energy Deficiency (CED). Low values of BMI reflect low fat and lean-body masses, a state of greater concern than low fat mass alone, and are perhaps more typical of Chronic Energy Deficiency than low fat mass alone[5]. Values below 18.5 kg/m^2 were in general considered as incompatible with normal good health[6,8]; values below 17.0 kg/m^2 were found to be related to evidence of poor productivity, and increased morbidity and mortality. With values below 16.0 kg/m^2, the mortality risk increased progressively. This is of great concern because values outside the range considered as normal have been shown to be

incompatible with health. Grade III of CED, (10% of the subjects) showed a tripling of mortality rates compared to the normal range - a situation demanding special attention. Grade II of CED has been related to an increasing evidence of poor productivity, and increased morbidity and mortality[8]. The finding that 31% of female subjects and 21% of the males were classified as obese is also of concern because obesity classified by BMI has been established as a risk factor of morbidity and mortality[16,31,32]. These results have to be judged carefully. Although the classification of James et al[8] was based on findings of developing countries, the anthropometric data were derived from adults aged 20 to 45 y. However, mean values of BMI have been reported to decrease with aging[6] and it is clear that values in the elderly Indonesians are low (although we do not have a young adult population from Jakarta which with to assess age-related trends).

On the other side of the BMI equation, cut-off points for obesity correspond in their classification to the grades of obesity of Garrow and Webster[14]: 25.0 to 29.9 kg/m^2 (Grade I - as overweight); 30.0 to 39.9 kg/m^2 (Grade II - as obese); and ≥ 40.0 kg/m^2 (Grade III - or morbid obesity). As shown in Figures 5 and 6, in the upper panels, a parallel percentage of women, 32 and 31%, respectively, had some degree of CED or obesity, with none of the latter in the Grade III extreme. For men, the rates of all classes of obesity, at 21% was only two-thirds of their respective rate of underweight.

The high correlation between height and armspan of 0.83 for females and 0.81 for males, found in this sample of Indonesian elderly, confirmed that armspan approximates the same rank-ordering of a population as height. Although aging could have produced differential effects on stature in different people, some greater disordering of the relationship between the two measures might have developed. In a cross-sectional study such as this (and without a representative young-adult control population), however, it could not be determined how much these relationships were the original ones of youth or the weaker relationship in the aged due to irregular height decrease. Height/armspan ratio racial differences have been reported, too[33], but the population of this section of Jakarta were largely Javanese.

According to the classification system of James et al[8], about one-third of the examined female and male subjects had CED whereas a little less than one-third of the elderly were obese. A comparison of the upper and lower panels in the Figures 5 and 6, reveals visually the effect of substituting armspan in the denominator of the body mass index formula. The total percentage of the female population in some stage of chronic energy deficiency would rise from 32 to 47% if armspan is, indeed, a more valid representation of the biologically relevant length of an older, shortened individual. Estimates of obesity of any grade, on the other hand falls from 31 to 17% in this gender. For men, the proxy use of armspan raises the overall apparent CED prevalence from 33 to 42%, while lowering that of obesity from 21 to 3%.

If we were concerned about a high degree of CED in this aging urban Indonesian population based on the BMI pattern based on height, while also worrying about abnormal overweight, as well, the substitution of the armspan in the denominator should tranquillise us with respect to the latter and truly alarm us with regard to the former. Recent unpublished work in Guatemala[34], that at least for that Central American population, the height/armspan index in young adulthood is not 1.00. It is slightly less in women and substantially less in men. Thus, the BMA would cause an overcorrection to the left of the BMI distribution. Given the ethnic differences in the relationship of height to armspan, the reference height/armspan ratio of youth should be established for each geographic region of interest.

In conclusion, extended longevity make the nutrition of the elderly, and residents in urban areas allows for a two-way concern for nutritional imbalance: under- and over-nutrition. Conceptual advances for the use of a the simplest of all body compositions indices, the body mass index, have been offered[12], but their applicability in the elderly must be tested. We have confirmed here in a group of older residents of slum area in Jakarta the previously reported close correlation of the armspan and the height. It is still conjectural whether the armspan is a more valid indicator of the appropriate length of an older person who might have suffered senescent and pathological shortening of stature by the seventh decade[22]. Our study illustrates the magnitude of the deviation in the distribution that would occur if the armspan is indeed a better term. Furthermore, more research is needed on the functional consequences of low BMI and BMA in elderly.

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從身高及臂距（arm span）得出的老年體質指數（BMI）

摘要

體質指數已成爲慢性能量缺乏（CED）和評定肥胖的指標。在老年人日益增多的發展中國家，如印度尼西亞，二者均在公共衛生中應用。衰老過程使身高逐步減少，因而產生了 BMI 公式，$\frac{\text{體重（公斤）}}{[\text{身高（米）}]^2}$ 應用在這些年齡組是否恰當的問題。用臂距代替身高，可校正由於衰老而喪失的身高。我們用 69 位印尼老年人爲對象（36 位女性，33 位男性，年齡在 60－69歲），測定了他們身高和臂距的關係，結果發現其相關係數分別爲 r＝0.83（女性）和 r＝0.81（男性），$p < 0.001$。用體質臂距（BMA）指數代替 BMI，我們在這些對象中觀察到慢性能量缺乏在女性增加了 32%；而男性增加了 24%；而肥胖症卻分別下降了 45% 和 81%。最後作者指出，衰老過程中身高的變化提出了一個估計老人群身體組成疾病發病率的重要問題。

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Abstrak

Indeks Massa Tubuh (BMI) telah dikenal sebagai indikator yang berguna pada masalah defisiensi energi yang kronik dan juga dapat mengindikasi masalah kegemukan/obesity. Di negara berkembang seperti Indonesia dimana sektor lanjut usia (lansia) makin berkembang, kedua masalah tersebut sangat relevan dalam kesehatan masyarakat. Dengan terjadinya penurunan tinggi badan yang diakibatkan oleh proses penuaan, menimbulkan pertanyaan apakah nilai BMI untuk sektor lansia ini masih sesuai bila tinggi badan digunakan sebagai penyebut pada formula BMI, berat(kg)/tinggi^2(m^2). Panjang rentang lengan (armspan) telah banyak digunakan sebagai pengganti tinggi badan untuk mengoreksi penurunan tinggi badan akibat penuaan. Hubungan antara tinggi badan dan panjang rentang lengan ini telah diteliti pada 69 orang lansia Indonesia, 36 perempuan dan 33 laki-laki, berumur antara 60-69 tahun. Koefisien korelasi untuk regresi dua pengukuran tersebut adalah berturut-turut untuk perempuan dan laki-laki r=0.83 dan r=0.81 ($p<0.001$). Penggantian tinggi badan dengan panjang rentang lengan sebagai penyebut pada formula Indeks Massa Tubuh berdasarkan Panjang Rentang Lengan (BMA) ditemukan bahwa terjadi peningkatan sebesar 32% penderita defisiensi energi pada perempuan dan 24% pada laki-laki. Estimasi pada penderita obesity adalah penurunan sebesar 45% dan 81%. Perubahan tinggi badan karena penuaan sangat penting pengaruhnya dalam mengestimasi kelainan komposisi tubuh pada populasi lansia.

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