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Correlation between body mass index and haemoglobin level of adolescent girls in a stunting locus area at Tangerang, Indonesia

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ABSTRACT

Introduction: In Indonesia, anaemia is known to be extremely common in female adolescents. In addition, the problem of overweight/obesity in teenagers is becoming more prevalent, even in stunting locus areas. This study aimed to examine the correlation between body mass index (BMI) and haemoglobin levels among adolescent girls in Tangerang's stunting locus area. **Methods:** This cross-sectional study included 171 adolescent girls attending four junior and senior high schools in Tangerang's stunting locus area. Adolescents who matched the inclusion criteria— healthy, having lived in Sukamantri for more than six months, and willing to participate were chosen by a multistage cluster sampling procedure. Body weight and fat were measured, and Z-score for BMI-for-age was determined. Haemoglobin levels were measured by the Mission Hb Testing System. Multiple linear regression test was applied for the analysis. **Results:** The prevalences of thinness/severe thinness, normal, and overweight/obesity were 5.3%, 70.8%, and 23.9%, respectively. There were 20% of anaemic girls. Among anaemic girls, there were 26% overweight/obese and no thin/very thin girls. A weak, negative correlation between BMI with haemoglobin levels was observed (R^2=0.054, p<0.001). **Conclusion:** The correlation between BMI and haemoglobin level was weak in our sample of adolescent girls in the stunting locus area. The current study emphasised the importance of additional research that includes several haematological and inflammatory biomarkers to better understand the complex relationship between nutritional status and haemoglobin level.

Keywords: adolescent girls, anaemia, body fat, body mass index

INTRODUCTION

Anaemia is a serious global public health issue that particularly affects female adolescents. It is known to be extremely common in low-income countries and more common in the female population. Anaemia is defined as haemoglobin (Hb) levels <12.0 g/dL in women (Varghese *et al*, 2019). Untreated anaemia in adolescence increases anaemia risk in pregnancy. The latest national data showed that there is a dramatic increase in anaemia prevalence among pregnant women reaching 48.9%. The prevalence of anaemia in female adolescents is also increasing at an alarming rate (Ministry of Health Republic of Indonesia, 2019). Anaemia in adolescence results

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in decreased mental and physical capacities, as well as educational performance (Sari *et al.,* 2022). It also causes a serious threat to future safe pregnancy in adolescent girls (Handari, Anies & Nugraheni, 2022).

Anaemia is caused by a poor intake of nutrients, particularly iron. Although it is known that a deficiency in iron causes 50.0% of all anaemia cases, it is still important to assess the cause of anaemia based on specific and local factors. Deficiencies in protein, vitamins A and B12, copper, and folate can also cause anaemia, as well as malaria, human immunodeficiency viruses (HIV), tuberculosis, and parasitic infections (Mrimi *et al,* 2022). Anaemia results in a variety of symptoms, including fatigue, weakness, sleepiness, shortness of breath, and dizziness. In addition, anaemia has been linked to lower levels of academic achievement and productivity.

On the other hand, overweight/obesity is one of the most frequently stated problems in adolescents and a growing public health concern. After Singapore, Indonesia has the second highest percentage of obese teenagers (12.2%), followed by Thailand (8%), Malaysia (6%), and Vietnam (4.6%) (Liberali, Kupek & Assis, 2020). Based on a national survey, the prevalence of obesity among teenagers has increased two to three times from 1993 to 2014 (Oddo, Maehara & Rah, 2019).

Indonesia has a 20% prevalence of overweight and obese teenagers between the ages of 13 and 15 years and a 13.6% prevalence of obese adolescents between the ages of 16 and 18 years. Compared to 2013, there has been a rise in the prevalence of obese teenagers in Indonesia. The prevalence of obesity among adolescents aged 13 to 15 years has climbed by 0.4%, while the prevalence of obesity among adolescents aged 16 to 18 years has increased by 2.2% (Ministry of Health Republic of Indonesia, 2019). The prevalence of overweight/obesity is increasing more in adolescent girls than in boys (Rachmi, Li & Alison Baur, 2017).

Anaemia is often multifactorial and not an independent phenomenon. Recently, considerable literature has grown around the theme of the co-occurrence of overweight/obesity and anaemia. A cross-sectional study using the most recent Health Surveys of 52 countries showed an increased tendency of anaemia and obesity concomitantly in adolescent girls (Irache, Gil & Caleyachetty, 2022). Studies undertaken in Indonesia provided conflicting evidence concerning the relationship between body mass index (BMI) and anaemia or Hb level. Some cross-sectional studies observed that adolescent girls with overweight were more at risk for anaemia (Sandy et al., 2021; Syah, 2022). However, other cross-sectional studies showed that there were no relationships between overweight/obesity with anaemia (Adiyani *et al.,* 2020; Mulyani, Lupiana & Yunianto, 2021). On the other hand, some observed that underweight female adolescents had a higher risk of anaemia (Risna'im *et al.,* 2022; Enggardany et al., 2021).

In Indonesia, the problem of overweight/obesity in teenagers is becoming more prevalent, as is the problem of anaemia, even in stunting locus areas. Numerous initiatives have been put in place by the Indonesian government with the goal of eliminating stunting and reaching the target of 14% by 2024. Combating anaemia in teenage females was where the programme strategy started, particularly in some of Indonesia's stunting locus areas. Nevertheless, overweight and obesity, which have recently increased significantly among girls, even in stunting locus areas, have not been taken into consideration by these programmes aimed at eliminating anaemia. The programme's efficacy may be hampered if the growing issue of obesity among teenagers in stunting locus areas, who are also susceptible to anaemia, is not taken into account.

There are limited studies on the relationship between BMI and Hb levels in stunting locus areas in Indonesia. This study, therefore, set out to examine the correlation between BMI and Hb levels among adolescent girls in Tangerang's stunting locus area, Indonesia.

MATERIALS AND METHODS

Study design and sampling

This cross-sectional study was conducted in Sukamantri village, a village with significant stunting issues in the Tangerang Regency. Sukamantri has a large population. The high population density was triggered by the establishment of many manufacturing industries. This research was carried out from May to December 2022. This research received ethical approval from the Esa Unggul University Code of Ethics Enforcement Council, Research Ethics Committee, with an ethical review number 0922-10.027 /DPKE-KEP/ FINAL-EA/UEU/X/2022.

In this stunting locus, there were eight junior and high schools, with 756 teenage girls enrolled in total. The study involved adolescent girls attending four schools in Sukamantri village, which included two junior high schools (*SMPN 2 Pasarkemis* and *SMP Tunas Harapan*) and two senior high schools (*SMK Persada* and *SMK Tunas Harapan*). These four schools were chosen over the other four in this stunting locus area due to their higher proportion of female students.

Sample size was counted using the Lemeshow formula (Lwanga *et al*, 1991). This study was a subset of a parent research, which had used the sample size formula to assess the output of an anaemia reduction programme (percentage of anaemia in adolescent girls) in this stunting locus. According to a 23.9% prevalence of anaemia among adolescent girls, a total of 171 samples were taken at a 95% confidence interval and 6.0% absolute deviation of the sample from the population rate. The samples were selected using a multistage cluster sampling method. Firstly, cluster sampling was carried out proportionally to the number of female students in each school. Secondly, a systematic random sampling technique was applied to select samples from each class. The interval in systematic random sampling was determined by dividing the total number of teenage girls enrolled in the school by the required sample size. Based on the sequence of female students' names in the attendance book from classes 1 through 3, the resulting interval number was utilised to choose the subjects.

Criteria for selecting the subjects were as follows: 1) Has lived in Sukamantri for more than six months; 2) Healthy; 3) Not having period at the time of blood collection; and 4) Willing to be a respondent. Exclusion criteria were: 1) Sick; and 2) Absent during the data collection process. Prior to data collection, the respondents received an explanation of the purpose and benefits of the study. Respondents who were willing and agreed to be respondents signed an informed consent sheet.

Data collection

Sociodemographic characteristics of female adolescents, including age, parent's education, family size, experience of receiving counselling on anaemia, menstrual status, and menarche age, were collected using a structured interviewing questionnaire. Body weight and fat were measured by the Bioelectrical Impedance Analyser

(BIA) Tanita BC-541 (Tanita Corp., Tokyo, Japan). Weight measurement was conducted at least two hours after eating or exercise. After tuning on the unit, the setting of respondent's age, gender, and height proceeded. Before stepping on the measuring platform, respondents removed their socks, shoes, and heavy clothing, and were requested to ensure that their feet were clean. Then, respondents were asked to step onto the scale once "0.0" appeared on the display. Weight was displayed first and as respondents continued standing on the scale, body fat percentage reading then appeared on the display.

Height measurement was obtained using a microtoise mounted to a wall. Before taking the measurement, respondents were requested to remove their shoes and stood with their backs to the wall, facing ahead. The backs of their feet, calves, bottom, upper back, and head should be in touching the wall. They should be directly beneath the drop-down of the measurement instrument. Measurements were carried out by trained enumerators.

Hb level was identified by taking capillary blood at the fingertip using the Mission Hb Testing System (Hb within run precision ≤3%; Hb total precision CV ≤3%; accuracy: venous blood R^2:0.992, capillary blood R^2:0.993) (ACON Laboratories Inc, 2023). Some studies observed that Hb concentration determined by the Mission Hb Testing System has comparable and acceptable agreement with that determined by a haematology analyser (Dua, Aggarwal & Sharma, 2021). It works using the reflectance photometry method. The blood sampling techniques were: 1) Remove the first drop of blood; 2) Apply light pressure to get a second drop of blood; 3) Collect 10 μL of capillary blood using a capillary transfer tube or pipette; 4) Hold the tube slightly down and touch the tip of the tube to the drop of blood. Automatically, the blood sample will be drawn up to the filling line; and 5) Align the tip of the tube with the strip area so that a drop of blood (about 10 μL) can be applied to the strip area. Hb measurement was performed by a laboratory analyst.

Data analyses

In descriptive analysis, continuous data were shown as mean and standard deviation (*SD*). Frequency distribution was described based on age, menstruation, nutrition status, percent body fat, family size, parents' education, and experience of getting counselling on anaemia. Based on Nelson Textbook (Kliegman *et al,* 2020), adolescence is a period from 10 to 21 years of age. It is divided into three stages, namely early (10-13 years), middle (14-17 years), and late (18-21 years) adolescence. Age was constructed based on these three age stages for descriptive analysis.

BMI data was determined by BMI-for-age. Z-score for BMI-for-age was determined and classified using the World Health Organization AnthroPlus software (WHO, 2009). BMI was classified into thinness/severe thinness (<-2.01*SD*), normal body weight (-2.00*SD* to +1.00*SD*), and overweight/obesity (>+1.01*SD*) (WHO, 2007). Classification of percent body fat was based on age-specific cut-offs from the body fat reference curves (McCarthy *et al.,* 2006) and divided into two groups (normal and overfat). Hb level was classified as normal if it was 12.0 g/dL or more and anaemic if less than 12.0 g/dL (Varghese *et al*, 2019).

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 29.0 (IBM Corp., Armonk, N.Y., USA). The normality test used was Kolmogorov–Smirnov. Independent *t*-test and one-way analysis of variance

(ANOVA) were used to compare mean Hb levels by each group. The correlation between BMI and Hb level was analysed using multiple linear regression. The level of statistical significance was set at 5.0%.

RESULTS

The mid-adolescence age range (14–17 years) accounted for the majority (50.9%) of adolescent girls. Typically, the parents have graduated from senior high school. The majority of teenage girls (60.2%) were from small households (≤4 people). Most of the adolescent girls (72.5%) admitted they had never received counselling on anaemia.

A small proportion of adolescent girls were thin or very thin (5.3%). The majority (70.8%) had normal BMI. Prevalence of overweight/obese was 23.9% (14.4% overweight; 9.5% obese). This was a high level (>10.0%) of overweight problem, based on the cut-off for nutrition problems of public health significance (WHO, 2018). The proportion of overweight/obese adolescent girls was nearly five times that of thin/very thin, and higher than the national average (23.9% vs. 13.0%).

Almost one-third (23.4%) of respondents were overfat, whereas 76.6% had normal body fat. The average age of menarche was 11.6+0.9 years. Almost all (97.1%) of them had menstruated. The average Hb concentration was 13.1±1.5 g/dL. Anaemia affected about one in five adolescent girls, which indicates a nutrition problem of moderate public health significance (20.0-39.0%) based on WHO (2015).

There was no anaemia found in thin or very thin female adolescents. Anaemia was more prevalent in overweight/obese and normal-weight girls compared to thin/very thin girls (Table 1). There were no differences in mean haemoglobin levels based on menstrual status, nutrition status (BMI-for-age), level of percent body fat, parents' education, household size, and having received anaemia counselling.

There was no significant correlation between BMI (p>0.05) and Hb levels (Figure 1). A significant correlation between BMI and Hb level was observed (β=-0.550, R^2=0.054, p<0.001) after adjusting for body fat in the multiple linear regression (Figure 2). BMI demonstrated a weak, negative correlation with Hb levels in adolescent girls. Although R^2 was only 5.4%, this does not imply that it is meaningless as it is dependent on the field of study. Studying Hb levels in adolescent girls, which have a wide range of influencing factors, will make it very difficult to obtain much higher r-squared values.

DISCUSSION

This study demonstrated that BMI had a weak, negative correlation with Hb levels in adolescent girls. This finding confirmed a study in India that discovered a negative correlation between BMI and Hb levels (Acharya *et al.*, 2018), as well as another study showing that overweight adolescent girls were more at risk of anaemia (Eftekhari, Mozaffari-Khosravi & Shidfar, 2009).

The present result differs from that of a research on Korean adolescents, which observed that BMI was positively correlated with Hb level (Jeong *et al.*, 2022). The Korean study included boys and girls aged 10-18 years old. The current study was also different from a research on women aged 15-49 years old in Bangladesh, which found that the risk of anaemia was higher in underweight women and decreased in obese/ overweight women when compared to normal women (Kamruzzaman, 2021). The difference in results could be due to the fact that the Korea and Bangladesh studies had, respectively, both genders

Table 1. Distribution of adolescent girls according to sociodemographic characteristics and nutrition status (*n*=171)

Characteristics	*n (%)*	*Haemoglobin (g/dL)*	
		Mean±SD	$p^{\dagger\dagger}$
Haemoglobin level	171 (100.0)	13.1±1.5	-
Anaemia status			
Normal	137 (80.1)	13.1±1.5	-
Anaemia	34 (19.9)	10.9±0.9	
Age (years), mean±*SD*	13.7±1.5		-
Age range†			0.331
Early adolescence	77 (45.0)	13.0±1.4	
Middle adolescence	87 (50.9)	13.1±1.5	
Late adolescence	7 (4.1)	13.1±1.6	
BMI-for-age *z-score,* mean±*SD*	0.1±1.4		-
Nutrition status‡			0.683
Thinness/severe thinness	9 (5.3)	13.0±1.5	
Normal	121 (70.8)	13.4±0.9	
Overweight/obesity	41 (23.9)	13.1±1.3	
Body fat %, mean±*SD*	27.5±8.6		-
Percent body fat level			0.509
Normal	131 (76.6)	13.0±1.5	
Overfat	40 (23.4)	13.2±1.2	
Menarche age (year), mean±*SD*	11.6±0.9		
Menstrual status			0.417
No	5 (2.9)	13.6±0.9	
Yes	166 (97.1)	13.0±1.5	
Mother's education§			0.651
Low	67 (39.2)	13.0±1.4	
High	104 (60.8)	13.1±1.5	
Father's education§			0.979
Low	52 (30.4)	13.1±1.4	
High	119 (69.6)	13.1±1.5	
Number of household members (person), mean±*SD*	4.3±1.2		
Household size¶			0.360
Small	103 (60.2)	12.9±1.5	
Moderate	59 (34.5)	13.2±1.4	
Big	9 (5.3)	13.3±1.7	
Having received counselling on anaemia			0.313
Never	124 (72.5)	13.0±1.5	
Ever	47 (27.5)	13.2±1.4	

†Age range: early (10-13 years), middle (14-17 years), and late (18-21 years)
‡Nutrition status: thinness/severe thinness (<-2.01*SD*), normal body weight (-2.00*SD* to +1.00*SD*), and overweight/obesity (>+1.01*SD*)
§Education: low (< senior high school) and high (≥ senior high school)
¶Household size: small (≤4 people), moderate (5-6 people), big (≥7 people)
Classification of percent body fat was based on age-specific cut-offs from the body fat reference curves (McCarthy *et al.,* 2006)
††Independent *t*-test and one-way ANOVA

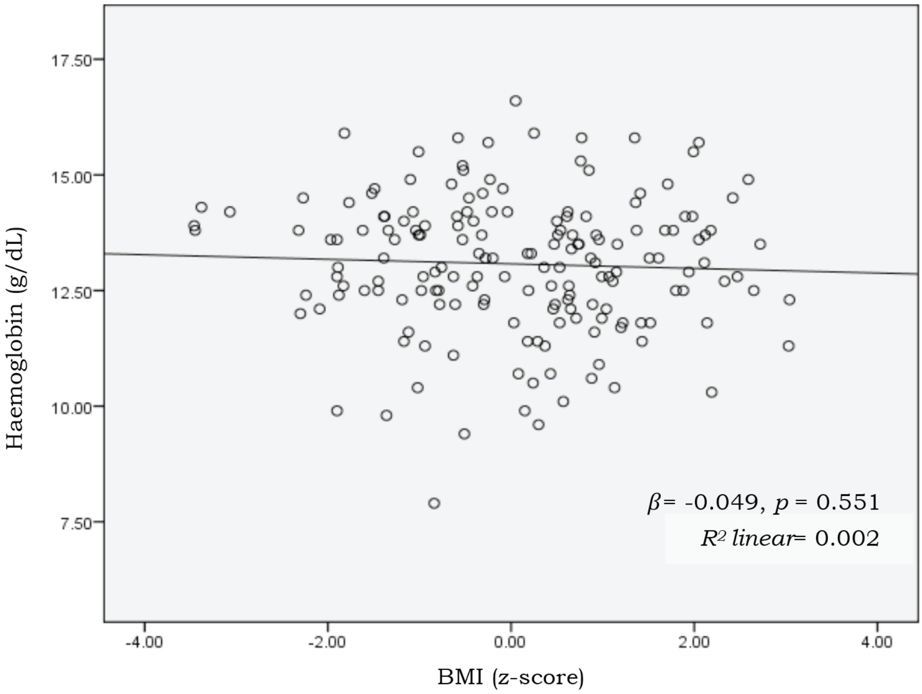

Figure 1. The correlation between BMI and Hb levels among adolescent girls

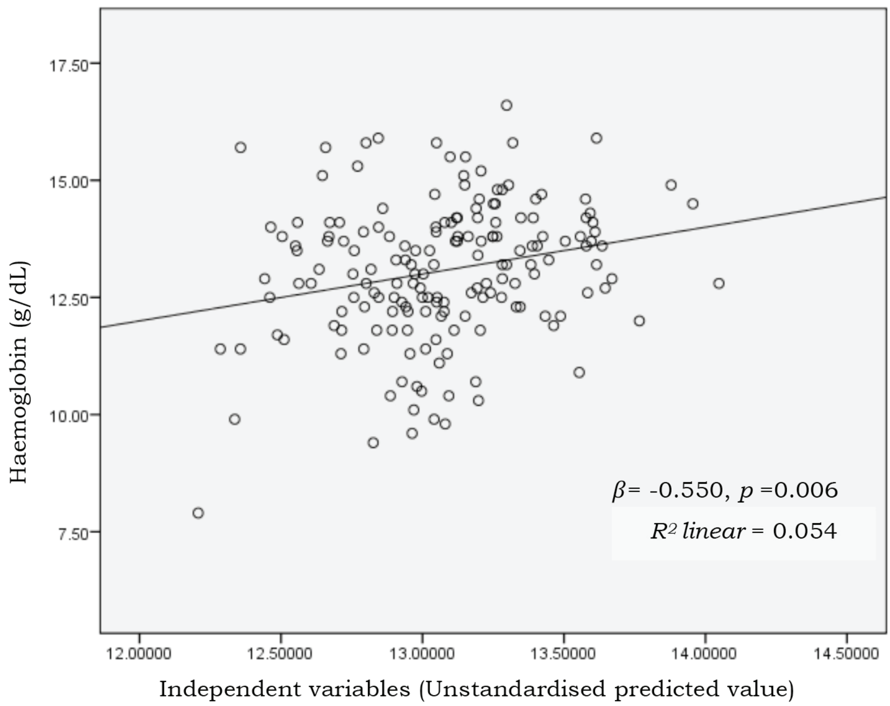

Figure 2. Multiple linear regression on BMI and Hb levels in adolescent girls, after adjusting for body fat.

and a broader age range of respondents than this study, which only included adolescent girls aged 10 to 18 years.

The contradictory results of several studies studying the relationship between BMI and Hb levels could be influenced by variances in the growing phase among study participants. Late adolescence differs from early and middle adolescence in the puberty process, including the patterns of growth spurt and body fat growth. Furthermore, male and female body fat growth rates differ. There is a different pattern in the development of percent body fat between girls and boys. The addition of body fat for female adolescents increases significantly, in contrast to male adolescents who tend to experience a decrease in body fat (Rodríguez *et al.,* 2005). The process of puberty, including growth spurt, moving from childhood to adolescence, affects body fat. These are due to the presence of puberty development factors, such as breast growth, in teenage girls. Increases in skinfold thickness and lean body mass (LBM) are all physiologically related to increases in Hb, haematocrit, and total iron binding capacity (Micozzi, Albanes & Stevens, 1989).

Some overweight/obese adolescents (22.0%) had anaemia in this study and this might be due to the presence of fat accumulation in body fat. Fat accumulation can interfere with iron absorption (Hilton *et al.,* 2023). Iron deficiency anaemia (IDA) is common in adolescents with overweight/obesity. A study found that anaemia in overweight/obesity was not caused by a lack of iron intake or lower food security in the households of adolescent girls (Jones *et al.,* 2017). Another study found that there were no differences between normal weight and overweight/obese adolescent girls in intakes of heme and non-heme iron or other nutrients that influenced iron absorption, even though iron intake was higher in obese adolescent girls than in normal adolescent girls (Hendarto, Febriyanto & Kaban, 2018).

A study involving 62 healthy and non-anaemic women found that iron absorption in overweight/obese women was only two-thirds that of normal-weight women (Cepeda-Lopez *et al.,* 2015). The mechanism underlying the increased risk of anaemia in overweight/obesity remains unknown. Possible causes include dilutional hypoferremia, inadequate iron intake, increased iron requirements, and impaired iron absorption in overweight/obese adolescents because of inflammation (Yanoff *et al.,* 2007).

The strength of the current study was that the study data was primary, meaning there was complete control over the study design and measurement techniques. Aside from that, the use of BIA to estimate percent body fat (PBF) measurement may not have introduced a significant bias, as evidenced by studies showing that the bias in BIA measurement versus dual-energy X-ray absorptiometry (DXA) is minor, whether in European or Asian populations (Carpenter *et al.,* 2013).

Due to practical constraints, this study could not provide a comprehensive measure of the effect of BMI to Hb levels. Our work had some limitations that should be considered in future research. Firstly, Hb was the only haematological biomarker used without taking into account other biomarkers such as serum ferritin, iron, and inflammatory biomarkers such as hepcidin, CRP, and others. As a result, it is difficult to explain differences with other study findings regarding anaemia prevalence, Hb level, or iron level across obese and underweight individuals. Secondly, the number of underweight and overweight/obese adolescent girls was lower, which may have been an issue in determining the correlation between BMI and Hb levels among adolescent girls. As a result, the current study emphasises the importance of including numerous anaemia indicators in future studies in order to solve these constraints and properly explain the relationship between BMI and Hb level. In addition, with a small sample size, these results need to be interpreted with caution.

CONCLUSION

In conclusion, our study on adolescent girls found that there was a weak, negative correlation between BMI and Hb level after adjusting for body fat. The current study emphasised the importance of additional research that includes several haematological and inflammatory biomarkers to better understand the complex relationship between BMI and Hb level.

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Authors' contributions

Nadiyah, principal investigator, conceptualised and designed the study, led the data collection, prepared the draft of the manuscript, and reviewed the manuscript; Jus'at I, advised on data analysis and interpretation, and reviewed the manuscript.

Conflict of interest

Authors have no conflict of interest to disclose.

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