

Body composition of HIV-positive candidates for and recipients of a kidney transplant: comparative analysis between DEXA and anthropometric indices

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Objective: To determine body composition (BC) and the correlation, if any, between indices measured by anthropometry and dual-energy X-ray absorptiometry (DEXA).

Design: Cross-sectional descriptive.

Setting: National sample of HIV-positive patients on the 'positive-to-positive' kidney transplant programme, South Africa.

Methodology: 34 participants categorised as (i) HIV-positive transplant recipients from an HIV-positive donor ($n = 16$); and (ii) HIV-positive transplant candidates on the waiting list to receive a kidney from an HIV-positive donor ($n = 18$). Pearson's coefficient was used to correlate anthropometry with DEXA.

Outcome measures: Body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) were compared with DEXA-derived percentage body fat (%BF), truncal fat (TF) and visceral adipose tissue (VAT). Mid arm muscle circumference (MAMC) was correlated with DEXA lean indices namely lean mass (LM), lean mass index (LMI) and appendicular lean mass index (ALMI).

Results: Pearson's correlation coefficient between BMI and %BF was strong ($r = 0.773$, $p < 0.001$). The correlation between WC with TF ($r = 0.799$, $p < 0.001$) and VAT ($r = 0.885$, $p < 0.001$) was highly significant, as was the correlation for WHtR with TF and VAT ($r = 0.778$, $p = 0.013$ and $r = 0.830$, $p < 0.001$). MAMC best correlated with ALMI ($r = 0.511$, $p = 0.011$).

Conclusion: BMI, WC, WHtR and MAMC are suitable indicators of overall and regional adiposity as well as musculature, based on correlations with DEXA derived %BF, TF, VAT and ALMI respectively. The findings support the use of these anthropometric indices for measurement of BC in this patient group as a cost-effective alternative to DEXA.

Keywords HIV-infected, body composition, anthropometric indices, dual-energy X-ray absorptiometry, HIV-positive renal transplant, visceral adipose tissue

Introduction

As body composition (BC) is an important component of physical health, regular assessment is important for observing changes in musculature and adiposity. In kidney transplant candidates and recipients, substantial deviations in BC can affect morbidity and mortality, presenting a threat to graft and patient survival.^{1–3}

BMI is the most widely used indicator of nutritional status and is a surrogate measure of adiposity. However, it is unable to distinguish fat from muscle mass or regional distribution of fat.⁴ This differentiation is important to identify transplant candidates and recipients at risk of adverse outcomes. For example, undernutrition characterised by a low body mass index (BMI) predisposed candidates to an increased mortality risk while awaiting transplant,⁵ or greater graft loss and post-transplant mortality.² A higher BMI was associated with a lower mortality risk.^{6,7} This protective advantage is attributed to a higher muscle mass.¹

Among transplant recipients, overall obesity negatively impacts graft and patient outcomes in some^{8,9} although not all¹⁰ transplant recipients. However, central obesity and excess visceral adipose tissue (VAT) is associated with increased cardio-metabolic risk in the general population^{11,12} and is related to a higher all-cause mortality following transplantation.³ Less is known about the implications of coexisting human

immunodeficiency virus (HIV) on BC in kidney transplant candidates and recipients. However, it is likely to be morphologically significant as HIV and antiretrovirals are related to muscle wasting and lipodystrophy.¹³

These links between adiposity, muscularity and clinical outcomes that have an impact on kidney transplantation are well described, and clearly necessitate the inclusion of in-depth BC measures for assessment, monitoring and prognosis. It is therefore essential that the methods used provide information with a high degree of accuracy.¹⁴ Anthropometry is one of the more common BC methods and is known to provide valid information on fat and muscle composition when compared with magnetic resonance imaging.¹⁵ Waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) are commonly used proxy measures of abdominal obesity and the health risks accompanying obesity.¹⁶ MAMC, for example, is one of several proxy measures to estimate lean body mass.¹⁷ With the measurement of anthropometric indices, however, there is potential for human error as it requires skill and equipment of a high quality.¹⁸

Dual-energy X-ray absorptiometry (DEXA) accurately measures BC and generates similar findings when compared with magnetic resonance imaging.¹⁹ As it is costly, its use in resource-limited settings is not practical. Moreover, it involves some,

albeit slight, exposure to X-ray radiation.¹⁹ Consequently it is more often used as a reference to verify less precise methods.¹⁹ Hence the aim of the current study was to correlate selected anthropometric measures of BC against DEXA-derived indices of BC as a reference standard in order to determine the use of anthropometric measurements in the evaluation of BC in HIV-infected kidney transplant candidates and recipients.

Methods

Participants

The HIV 'positive-to-positive' kidney transplant programme is a national programme with candidates and recipients resident across South Africa; however, it is run from a single centre: Groote Schuur Hospital (GSH) in Cape Town. Potential candidates are referred by their attending nephrologist to determine whether they meet the waiting list inclusion criteria. Whilst awaiting a donor, candidates continue to receive dialysis at a private or state-run dialysis centre in their home province. When a donor becomes available, patients travel to GSH to undergo the transplant and return to their home province where they are again followed up by their nephrologist. At the time of the study the programme was still in its infancy and was in the process of establishing a formal database. For the purposes of this study, the most recent list of transplant recipients and potential candidates was obtained from GSH. In 2015, at the time of the study, the number of candidates and recipients in this programme was still small, but represented 100% of the global population of this unique group. There were 92 prospective participants who were contactable either telephonically or via outpatient clinics. Figure 1 indicates an overview of participant enrolment.

Seventy-six patients were assigned to two categories, namely (i) HIV-positive transplant recipients who received a kidney from an HIV-positive donor; and (ii) HIV-positive transplant candidates on the waiting list to receive a kidney from an HIV-positive donor. Patients were invited to undergo a DEXA evaluation. Written informed consent was obtained by dietitians. Ethics approval was obtained from the University of KwaZulu-Natal's Biomedical Research Ethics Committee (Approval number BE 327/13). Approval was also obtained from the relevant institutional authorities.

Of the 76 participants, only 56 could access or were willing to travel to their nearest DEXA centre, thereby excluding 20 participants. Of these centres, only three radiology centres (Cape Town, Durban and Pietermaritzburg) were able to provide an assessment of BC along with bone density information, thus reducing the study sample to 34 (44.7%).

DEXA measurements of body composition

Body composition was determined using the Hologic Discovery W (Hologic, Marlborough, MA, USA) and the GE Lunar Prodigy (Advance, GE Healthcare, USA) by radiographers trained and experienced in machine operation and patient positioning,²⁰ according to standard operational procedures. DEXA provides information on bone and BC as a result of X-ray beam variations that pass through body matter of different densities. Two energy fields separate lean and adipose tissue, enabling the measurement of whole body and regional BC.²¹ Information is generated as raw values and indices indicating total and regional fat and lean mass distribution. Adiposity indices used as reference values were percentage body fat (%BF), truncal fat (TF) and visceral adipose tissue (VAT). BF is calculated from fat mass divided

by total mass and expressed as a percentage. TF in kg, representing abdominal fat, is presented in kilograms (kg) and VAT as area in cm². Lean mass is expressed as lean mass (LM), lean mass index (LMI) and appendicular lean mass index (ALMI). LM (kg) represents fat-free and bone-free mass, but includes muscle, skin, tendons and connective tissue. LMI is LM adjusted for height and is defined as total LM divided by height (H) in m². ALMI is calculated from the lean mass of the arms and legs in kg divided by H (m²). Appendicular lean mass refers to soft tissue found in arms and legs. A large percentage of whole-body skeletal muscle is found in the arms and legs while a large percentage of appendicular lean tissue is present as skeletal muscle. This represents about 75% of whole-body skeletal muscle.¹⁹

Anthropometric measurements

Dietitians conducted anthropometric measurements following refresher training by the principal investigator, as well as a post-training test to ensure standardisation of measurement techniques and to reduce inter-observer variability. Weight (WT), height (Ht), triceps skinfold thickness (TSF), mid upper arm circumference (MUAC), waist circumference (WC) and hip circumference (HC) were measured using protocols described in the National Health and Nutrition Examination Survey (NHANES).¹

Height in centimetres (cm) and WT (kg) was measured using equipment already present at various outpatient and dialysis centres. Observers were asked to calibrate scales using a standard one-kilogram weight. WT was measured post dialysis while circumference measurements (cm) and TSF in millimetres (mm) were taken using standardised callipers (Slim Guide; Creative Health Products, Ann Arbor, MI, USA) and measuring tape (SECA 201; Seca, Hamburg Germany) on the non-access arm for HD patients. The mean of three readings was recorded to one decimal place. BMI was calculated as WT divided by Ht squared (kg/m²) and classified according to the World Health Organization categories: underweight (< 18.5), normal WT (18.5 ≥ 24.9), overweight (25.0 ≥ 29.9), obese class I (30.0 ≥ 34.9), obese class II (35.0 ≥ 39.9) and obese class III (≥ 40).²² Waist-to-hip ratio (WHR) was calculated as WC divided by HC. Waist-to height ratio (WHtR) was calculated as WC divided by Ht. circumference MUAC were used to determine MAMC using the equation²³:

$$\text{MAMC(cm)} = \text{MUAC(cm)} - [3.1415 \times \text{TSF(cm)}]$$

Statistical analysis

Data was analysed using the Statistical Package for Social Sciences (SPSS®) version 25.0. (IBM Corp, Armonk, NY, USA) Means and standard deviations were calculated for continuous variables and frequencies and percentages for categorical variables. An independent samples t-test was used to determine differences between transplant candidates and recipients' clinical and nutritional variables. Pearson's coefficient was used for correlation analysis between anthropometric values and corresponding DEXA measurements. A *p*-value of < 0.05 was taken as statistically significant.

Results

Participant characteristics

Of the 34 participants, 18 were transplant awaiting candidates undergoing haemodialysis, while 16 were recipients of a kidney donated from an HIV-positive individual. Participant

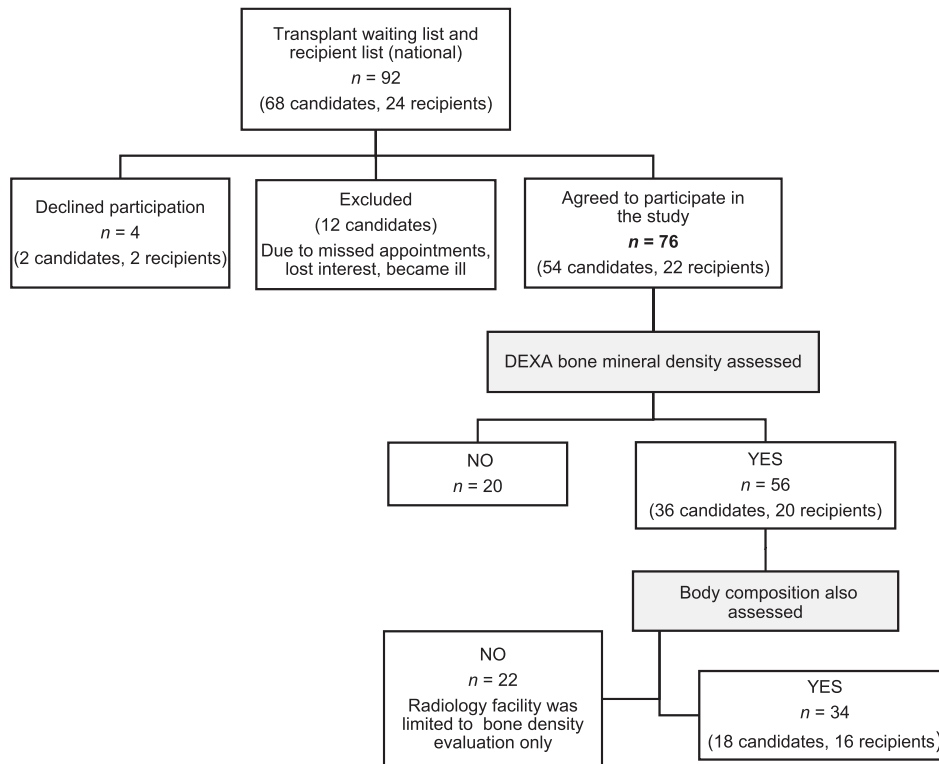


Figure 1: Patient participation flow chart.

characteristics are summarised in Table 1. The majority were male (61.8%), black (91.2%) with an average age of 43.9 ± 7.9 years. Most were hypertensive (88.2%), while two (5.9%) had hypercholesterolaemia, and five (14.7%) were diabetic. Transplant recipients had a non-significantly higher mean CD4 (417.69 ± 280.56 cells/ μl versus 334.53 ± 120.85 cells/ μl), when compared with transplant candidates. All transplant recipients had viral load (VL) levels that were lower than detectable limits (LDL), while 87.5% of transplant candidates had viral loads at LDL. The majority of transplant recipients were a normal WT (87.5%), and two (12.5%) were categorised as obese class I. In the transplant candidate group, 27.8% were classified as having a normal WT. The majority were either overweight (33.3%) or obese (38.9%).

Body composition

Table 2 depicts DEXA and anthropometric indices for the respective groups. There was a significant difference between transplant candidates and recipients, for BMI and WT, with higher values in those undergoing dialysis compared with transplant recipients. The BMI amongst transplant candidates versus transplant recipients was 27.9 ± 4.2 kg/ m^2 and 23.4 ± 4.6 kg/ m^2 respectively. WC and WHtR were also higher in the candidate (93.5 ± 13.6 and 0.6 ± 0.1) compared with the recipient group (86.8 ± 11.4 and 0.5 ± 0.1). Transplant candidates were also more muscular with a mean MAMC of 27.3 ± 4.4 cm compared with 24.5 ± 4.4 cm amongst transplant recipients.

Similarly, all DEXA measurements of adiposity were higher amongst transplant candidates compared with recipients with %BF being $29.5 \pm 11.4\%$ versus $24.0 \pm 11.8\%$. Mean TF among transplant candidates was 8.4 ± 5.9 kg and 8.1 ± 5.1 kg among recipients. VAT was 122.18 ± 57.38 cm 2 versus 104.01 ± 55.22 cm 2 . LM and LM indices were also higher. LMI was 17.99 ± 1.53 kg/ m^2 and 16.84 ± 1.94 kg/ m^2 amongst transplant-awaiting candidates and transplant recipients respectively.

Correlation coefficients between BC derived from anthropometry and DEXA were determined for the whole group (Table 3). Strong correlations were observed between BMI ($r = 0.773$, $p < 0.001$) and TSF ($r = 0.803$, $p < 0.001$) with %BF. TF correlated strongly with WHtR ($r = 0.778$, $p = 0.000$), but even more so with WC ($r = 0.799$, $p < 0.001$). WC strongly correlated with the reference VAT ($r = 0.885$, $p \leq 0.001$), as did WHtR ($r = 0.802$, $p \leq 0.001$), and BMI ($r = 0.716$, $p \leq 0.001$). No significant association was observed between WHR and TF or VAT. The strength of association between MAMC and lean mass was moderate ($r = 0.403$, $p = 0.041$), but was stronger with ALMI ($r = 0.511$, $p = 0.011$).

Discussion

Accurate measurements of BC are essential for the assessment of nutritional status. DEXA accurately quantifies adipose tissue and muscle mass. It was for this reason that it was used as a reference standard for BC determined by anthropometric indices.

Overall adiposity is widely assessed using BMI, based on the existing correlation between BMI and direct measures of body fat such as underwater weighing and DEXA.⁴ The current study confirms this relationship by showing a strong correlation between BMI and total body adiposity from DEXA-derived %BF. TSF also had a strong relationship with %BF, most likely due to the fact that skinfolds measure subcutaneous fat, which comprises 40% to 60% of whole-body fat, thereby being a predictor of overall body fat.¹⁸ In this regard, skinfold measurements are most often taken at the triceps site, due to ease of access and reproducibility. Nonetheless, BMI is generally used,⁴ as skinfolds require skill and equipment.¹⁸

Although the correlation between BMI and %BF was strong, similar correlations were documented with TF and VAT, possibly due to the fact that an increase in abdominal fat and total body

Table 1: Demographic, nutritional and clinical characteristics of the study group

Patient characteristics	Total group (n = 34) n (%)	Transplant candidates (n = 18) n (%)	Transplant recipients (n = 16) n (%)
Gender:			
Male	21 (61.8)	11 (61.1)	10 (62.5)
Female	13 (38.2)	7 (38.9)	6 (37.5)
Age (years)	43.9 ± 7.9	46.2 ± 7.6	41.2 ± 7.56
Ethnicity:			
Black	31 (91.2)	16 (88.9)	15 (93.8)
Coloured	3 (8.8)	2 (11.1)	1 (6.3)
Duration of current treatment (years)	3.7 ± 2.6		
Chronic illness:			
Diabetes	5 (14.7)	5 (27.8)	0 (0.0)
Hypertension	30 (88.2)	17 (94.4)	13 (81.3)
Hypercholesterolaemia	2 (5.9)	1 (5.6)	1 (6.3)
CD4 (cells/μl)*	374.85 ± 214.42	334.53 ± 120.85	417.69 ± 280.56
Viral load (copies/ml): [†]			
Lower than detectable limit (LDL)	29 (93.5)	14 (87.5)	15 (100.0)
≤ 10,000 copies/ml	2 (6.5)	2 (12.5)	(0.0)
BMI			
Normal (18.5–24.9)	19 (55.9)	5 (27.8)	14 (87.5)
Overweight (25.0–29.9)	6 (17.6)	6 (33.3)	-
Obese class I (30–34.0)	9 (26.5)	7 (38.9)	2 (12.5)

BMI: body mass index.

Data expressed as means and standard deviation or frequencies with percentages.

*CD4: n = 33 (dialysis: n = 17, transplant: n = 16), [†]viral load: n = 31 (dialysis: n = 16, transplant: n = 15).

fat occurs simultaneously. Despite the correlation with overall and central adiposity, BMI is not a stand-alone indicator of TF and VAT, as it is not a suitable predictor of morbidity.²⁴ Evidence shows that indicators of central obesity better reflect cardiovascular disease (CVD) risk and are less affected by muscle loss associated with ageing.²⁵

Central/truncal adiposity is abdominally located and incorporates both intra-abdominal visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT). Although both SAT and VAT are indicators of cardio-metabolic risk, VAT adversely affects the metabolic profile more so than SAT.¹² VAT is becoming an increasingly important research focus area since significant

Table 2: Anthropometry and DEXA-derived body compositional characteristics of transplant candidates and recipients

Body composition		Transplant candidates		Transplant recipients		p-values
		n		n		
Anthropometry	Weight (kg)	18	75.7 ± 11.5	16	64.9 ± 13.2	0.016*
	Height (cm)	18	164.7 ± 10.3	16	166.6 ± 9.3	0.591
	BMI (kg/m ²)	18	27.9 ± 4.2	16	23.4 ± 4.6	0.005*
	Waist circumference (cm)	13	93.5 ± 13.6	14	86.8 ± 11.4	0.178
	Waist to hip ratio	13	0.9 ± 0.1	14	0.9 ± 0.1	0.327
	Waist to height ratio	13	0.6 ± 0.1	14	0.5 ± 0.1	0.227
	Mid upper arm circumference (cm)	12	30.4 ± 4.6	14	27.3 ± 5.2	0.123
	Triceps skinfold thickness (mm)	12	10.8 ± 5.2	14	9.0 ± 4.8	0.386
	Mid arm muscle circumference (cm)	12	27.3 ± 4.4	14	24.5 ± 4.4	0.112
DEXA	Body fat (%)	18	29.5 ± 11.4	16	24.0 ± 11.8	0.182
	Fat mass (kg)	18	22.3 ± 10.8	16	16.3 ± 11.54	0.124
	Visceral adipose tissue (g)	13	589.31 ± 276.67	16	501.38 ± 266.28	0.392
	Visceral adipose tissue (cm ²)	13	122.18 ± 57.38	16	104.01 ± 55.22	0.394
	Truncal fat (kg)	18	8.4 ± 5.9	16	8.1 ± 5.1	0.873
	Lean mass (kg)	18	49.5 ± 7.8	16	46.4 ± 9.0	0.294
	Lean mass index (kg/ht ²)	18	17.99 ± 1.53	14	16.84 ± 1.94	0.070
	Appendicular lean mass index (kg/Ht ²)	18	7.72 ± 0.93	14	7.08 ± 0.94	0.063

Data expressed as means and standard deviation.

DEXA: dual-energy X-ray absorptiometry.

*Significant difference between transplant candidates and recipients (independent samples t-test: p < 0.05).

Table 3: Pearson's correlation of anthropometric measurements with DEXA measurements for the whole group

	%BF		TF (kg)			VAT (cm ²)			LM (kg)			LMI (kg/Ht ²)			ALMI (kg/Ht ²)				
	n	r	n	r	p	n	r	p	n	r	p	n	r	p	n	r	p		
BMI	34	0.773**	< 0.001	33	0.884**	0.000	29	0.716**	< 0.001										
TSF	26	0.803**	< 0.001																
WHR				27	0.131	0.515	23	0.238	0.275										
WHtR				27	0.0778**	0.000	23	0.802**	< 0.001										
WC				27	0.799**	0.000	23	0.885**	< 0.001										
MAMC							26	0.403*	0.041				24	0.475*	0.019		24	0.511*	0.011

BMI: body mass index, TSF: triceps skinfold thickness, WHR: waist to hip ratio, WC: waist circumference, MAMC: mid arm muscle circumference, %BF: percentage body fat, VAT: visceral adipose tissue, LM: lean mass, LMI: lean mass index, ALMI: appendicular lean mass index.

**Correlation is significant at the 0.01 level, *correlation is significant at the 0.05 level.

associations between VAT, plasma glucose, diabetes, selected lipids, high blood pressure and the metabolic syndrome have been documented despite adjustment for BMI.²⁶

In the current study, the performance of WC, WHR and WHtR as proxy measures of central adiposity was assessed using their associations with TF and VAT. Of these indicators, WC demonstrated the strongest correlation with both TF and VAT. WHtR also showed strong associations, although to a lesser extent. A correlation between WHR and TF or VAT was not documented. This may be due to the fact that WHR not only reflects adipose distribution in the truncal area, but also the hip area, with the latter comprising the pelvic bone structure, gluteal muscle and fat. Given the individual variations in these body compartments, hip measurements are likely to affect WHR.²⁷ The superior performance of WC in this study is an encouraging finding and supported by a recent meta-analysis, which documented that despite not always being significant the associations between WC and nearly all CVD risk factors were the most significant for both genders.²⁸

Apart from adiposity, quantification of musculature is essential,¹⁹ due to its relationship with strength, physical function, mobility, balance and longevity.²⁹ In the current study, MAMC was associated with LM, thereby being in agreement with studies conducted among those suffering from chronic renal failure and HIV-positive populations.^{17,30} The strength of association was greater for LM adjusted for height (LMI), with the strongest association documented for ALMI. This is not surprising, as whole-body LM includes muscle, skin, tendons and connective tissues, whereas appendicular LM (in arms and legs) is largely skeletal muscle and represents approximately 75% of whole-body skeletal muscle mass.¹⁹ Therefore a stronger relationship would exist between ALMI and whole-body skeletal muscle.³¹

BC measured by anthropometry and DEXA in the normal setting is reasonably well documented, but less so in disease states. This study therefore adds value to the pool of the current knowledge. The small sample size is limiting, especially for subgroup analysis according to gender or age. While significance was reached for certain parameters, a larger sample size could have resulted in significant relationships reached in others. The geographical distribution of participants relative to DEXA centres created difficulties in coordinating DEXA and anthropometric measurements on the same day, or immediately following dialysis. Therefore, most candidates did not have DEXA done post dialysis. This is an important consideration as muscle tissue is influenced by the hydration status of dialysed patients and estimates should ideally be done on dry WT.³² This also limited statistical analysis to correlational analysis, determining the strength of association between two continuous variables. Future studies should aim to measure DEXA and anthropometry in closer time proximity to validate the results using agreement analysis. Nevertheless, as pointed out by Ranasinghe *et al.*, the results were not unlike those reported in more controlled studies.³³ A possible explanation for this was the recruitment of dietitians as anthropometric examiners. Previous research showed good intra-observer precision, even among newly trained dietitians with limited experience.³⁴

Conclusion

Based on the correlations of BMI, WC and MAMC with DEXA-derived %BF, VAT and ALMI respectively, these anthropometric measures suitably reflect overall and regional adiposity as well as musculature, and can confidently be used for BC assessment in this patient group.

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