Comparison of Skinfold Thicknesses and Bioimpedance Spectroscopy to Dual-Energy X-Ray Absorptiometry for the Body Fat Measurement in Patients With Chronic Kidney Disease

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Abstract

Background/Objectives: The aim of the study was to compare the amount of body fat measured by skinfold thickness (SFT) and bioimpedance spectroscopy (BIS) with dual-energy x-ray absorptiometry (DXA) as a reference method. *Methods:* Forty-eight patients undergoing hemodialysis treatment thrice-weekly for at least 3 months (HD group) with a mean age of 59.8 ± 15.5 years, 61 patients with chronic kidney disease (CKD) with an estimated glomerular filtration rate (eGFR) <30 mL/min/1.73 m^2 and a mean age of 60.1 ± 17.7 years (predialysis group, PreD), and 33 individuals without kidney disease with an eGFR >60 mL/min/1.73 m^2 and a mean age of 58.7 ± 17.0 years (control group) were included. *Results:* Mean percentages of body fat measured by SFT did not significantly differ from those measured by DXA in the HD group ($P = .249$) and the PreD group ($P = .355$). In the control group, mean percentage of fat mass measured by SFT was significantly higher than measured by DXA ($P = .004$). Mean difference was $1.99\% \pm 3.65\%$. The measurements of body fat performed by BIS were significantly higher than those performed by DXA in all studied groups ($P < .001$). Age was statistically significant and the strongest factor that influenced the variability of measurements obtained by BIS and DXA in all studied groups ($R^2 = 0.302$, 0.153, and 0.250, respectively, for HD, PreD, and control groups). *Conclusions:* SFT as a method of fat mass assessment in daily routine practice seems to be more reliable then BIS in patients treated with hemodialysis and in patients with stage IV/V CKD. However, methods based on bioimpedance techniques can potentially offer more data such as overhydration or an amount of lean tissue mass, but further investigations are needed to establish method the most suitable for patients with CKD. (*Nutr Clin Pract.* 2017;32:533-538)

Protein energy wasting (PEW) is one of the late complications of chronic kidney disease (CKD) and is associated with increased morbidity and mortality in patients with CKD.[1-3] Regular nutrition status assessment is recommended to enable proper prevention and early recognition of this complication.[4] Diagnostic criteria of PEW established by the International Society of Renal Nutrition and Metabolism (ISRNM) include reduced body mass index (BMI) and/or amount of body fat (<10%), reduced muscle mass, and lower serum albumin, prealbumin, or cholesterol level.[5] In many studies, a positive influence of higher BMI on survival of patients treated with dialysis was proved.[6,7] However, BMI is not a precise parameter because it does not differentiate fat mass from muscle mass, the main component of lean tissue. Therefore, the body composition measurements can enable a more accurate evaluation of nutrition status. There are many methods of body composition assessment. The simplest are anthropometric measurements. The assessment of skinfold thicknesses provides information about the percentage of fat mass. This method is considered simple and nonexpensive but is related to an investigator's experience. Hydration status can influence accuracy of the measurements; therefore, this method should be used after a dialysis session. Other simple methods used for body composition assessment are based on the bioimpedance phenomenon. Bioimpedance spectroscopy (BIS), in contrast to bioimpedance analysis, uses many measurements at different frequencies of electric current and determines body composition in a 3-compartment model.[8]

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Body fat, lean tissue mass, and overhydration are obtained from BIS measurements. Fluid overload compartment provides important information since the decrease of lean body mass or body fat can be masked by an excessive amount of fluid, often invisible in a physical examination in hemodialysis patients. BIS can be performed at the bedside and is inexpensive, but it is contraindicated in the individuals with metal parts in the body. Dual-energy x-ray absorptiometry (DXA) is considered a reference method in body composition assessment. However, in patients with significant hydration disorders, this method has some limitations. If the degree of lean tissue hydration is in the range of 68.2%–78.2%, it has no impact on the results.[9,10] DXA is a method requiring special equipment and an installation place. The impossibility of use at the bedside limits its application as a screening method.

The aim of the study was to compare the amount of body fat measured by skinfold thicknesses and BIS with DXA as a reference method.

Methods

Forty-eight patients undergoing hemodialysis treatment thrice-weekly for at least 3 months have been included in our study as the first study group (hemodialysis group, HD). The second group consisted of 61 patients with CKD with an estimated glomerular filtration rate (eGFR) <30 mL/min/1.73 m^2 (predialysis group, PreD). Thirty-three individuals without kidney disease, with an eGFR >60 mL/min/1.73 m^2, formed the third group (control group). The exclusion criteria were clinical signs of fluid overload, clinical signs of infection, chronic heart failure, chronic liver or pulmonary failure, current malignancy, metal parts in the body (heart pacemakers, stents, metal stitches), body weight above 120 kg, or an amputated arm or leg. All patients signed informed consent. The study protocol was accepted by the local ethical committee.

DXA was performed in the supine position using a Delphi W (S/N 70608) densitometer (Hologic, Marlborough, MA) with software version 11.1. Body composition, including total and segmental amount of fat, lean body mass, and bone mineral content, was obtained. In HD patients, DXA was done during the day after a midweek dialysis session. BIS was performed using a Body Composition Monitor (Fresenius Medical Care, Bad Homburg, Germany). Measurements were performed in the supine position after a 5-minute rest. Electrodes were placed in the tetrapolar configuration (on hand and on foot). In patients undergoing hemodialysis, electrodes were placed on the hand contralateral to the arm with arteriovenous fistula. In these patients, BIS was done before the midweek dialysis session. Total amount of fat, adipose tissue mass, lean tissue mass, overhydration, intracellular water, extracellular water, and total body water was obtained. Skinfold thickness (SFT) was performed at 4 different sites (biceps, triceps, subscapular, suprailiac) using the Harpenden (West Sussex, United Kingdom) skinfold caliper. The mean of 3 measurements for each skinfold was taken. The sum of skinfold thicknesses at 4

sites allowed obtaining the percentage of body fat using the table published by Durnin and Womersley.[11] In hemodialysis patients, SFT was performed after the dialysis session.

All data are presented as mean ± standard deviation (SD) for variables with normal distribution or median (interquartile range) for variables without normal distribution. For comparisons of continuous variables between groups, 1-way analysis of variance or Kruskal-Wallis test was used (respectively) with Bonferroni correction. For comparisons of categorical variables between groups, the χ^2 test was used. The hypotheses regarding differences in percentages of body fat assessment performed by different methods were verified using 1-sample Student t test (H_0:$\Delta = 0$). Lin's concordance correlation coefficient and Bland-Altman plot analysis were used to evaluate concordance and agreement between the studied methods. Univariate and multivariate linear regression analyses were used to evaluate strength of the association of selected parameters on the differences between percentages of body fat obtained by the tested methods. Statistical analysis was performed using SPSS version 23 (SPSS, Inc, an IBM Company, Chicago, IL) and STATA version 13 (concord command; StataCorp, College Station, TX); statistical significance was considered when $P < .05$.

Results

The study population consisted of 48 hemodialysis patients (HD group), 61 patients with CKD stage IV/V (PreD group), and 33 individuals without kidney disease (control group). Mean age was 59.8 ± 15.5, 60.1 ± 17.7, and 58.7 ± 17.0 years, respectively, for the HD, PreD, and control groups. The groups did not differ significantly in terms of age in comparison with the control group. The proportion of men was 66.7% for the HD group, 57.4% for the PreD group, and 54.5% for the control group. The number of men did not differ between the groups. Mean BMI was 25.2 ± 5.0 kg/m^2 for the HD group, 27.9 ± 5.61 kg/m^2 for the PreD group, and 27.6 ± 5.6 kg/m^2 for the control group. The demographic and clinical data are presented in Table 1.

The mean percentages of body fat measured by the 3 methods in 3 study groups are presented in Table 2. In the HD group, the mean percentage of body fat measured by SFT was significantly lower in comparison with the control group ($P = .004$) and PreD group ($P = .006$). Also, the mean percentage of body fat measured by DXA in the HD group was significantly lower in comparison with the PreD group. However, the percentages of body fat measured by BIS did not differ between the 3 groups.

Taking into account separately men and women, statistically significant differences in means of body fat measured by SFT were found in women between the HD and the control groups and in men between the HD and the PreD groups (at the border of significance). Differences in body fat measured by DXA and BIS between the groups were not found in men or women.

Table 1. Demographic and Clinical Characteristics of the Patients.

Characteristic	HD (n = 48)	PreD (n = 61)	Control (n = 33)
Age, mean ± SD, y	59.8 ± 15.5	60.1 ± 17.7	58.7 ± 17.0
Men, %	66.7	57.4	54.5
eGFR, mean ± SD, mL/min/1.73 m^2		18.3 ± 7.0[a]	91.8 ± 24.8
Primary renal disease, %			
PGN	18.7	26.2	
Nephrosclerosis	12.5	14.7	
PKD	14.6	16.3	
Diabetic nephropathy	10.4	14.7	
Hypertensive nephropathy	4.1	9.8	
Unknown	18.7	11.5	
Urological causes	12.5	6.5	
Other[b]	8.3		
Duration of HD, median (IQR), mo	13.0 (6.0–37.3)		
Kt/V, mean ± SD	1.2 ± 0.2		
RRF, mean ± SD, L	0.9 ± 0.7		
BMI, mean ± SD, kg/m^2	25.2 ± 5.0	27.9 ± 4.8[c]	27.6 ± 5.6
OH, mean ± SD, L	1.3 ± 1.6[d]	0.75 ± 1.5[c]	0.30 ± 1.1
SCr, mean ± SD, mg/dL	8.5 ± 2.8[d]	3.8 ± 1.9[a,c]	0.8 ± 0.1

BMI, body mass index; eGFR, estimated glomerular filtration rate; HD, hemodialysis; IQR, interquartile range; Kt/V, a measure of dialysis adequacy (K, dialyser clearance of urea; t, dialysis time; V, volume of urea distribution); OH, overhydration measured by bioimpedance spectroscopy; PGN, primary glomerulonephritis; PKD, polycystic kidney disease; PreD, predialysis; RRF, residual renal function; SCr, serum creatinine level.
[a]Statistically significant difference between PreD vs control group.
[b]Alport syndrome, chronic urate nephropathy, lupus nephritis, and monoclonal gammopathy of undetermined significance.
[c]Statistically significant difference between PreD vs HD group.
[d]Statistically significant difference between HD vs control group.

Table 2. Body Fat Percent (Mean ± SD) Measured by SFT, BIS, and DXA in 3 Study Groups.

	Body Fat Percent, Mean ± SD			*P* Value			
Characteristic	HD (n = 48)	PreD (n = 61)	Control (n = 33)	Overall	HD vs Control	PreD vs Control	HD vs PreD
Total							
SFT	26.5 ± 9.1	31.8 ± 8.4	32.9 ± 8.6	.001	.004	1.000	.006
DXA	27.2 ± 9.0	31.2 ± 7.8	31.0 ± 8.3	.035	.146	1.000	.046
BIS	34.7 ± 11.6	37.3 ± 8.6	35.7 ± 9.0	.375			
Women							
SFT	32.6 ± 6.7	37.4 ± 6.6	38.8 ± 7.8	.036	.050	1.000	.103
DXA	31.4 ± 9.2	35.9 ± 7.1	37.6 ± 6.1	.110			
BIS	35.9 ± 9.5	41.8 ± 7.0	40.8 ± 6.8	.057			
Men							
SFT	23.4 ± 8.7	27.7 ± 7.2	27.8 ± 5.5	.046	.173	1.000	.072
DXA	25.1 ± 8.2	27.7 ± 6.4	25.5 ± 5.4	.300			
BIS	34.1 ± 12.6	34.0 ± 8.1	31.5 ± 8.5	.565			

BIS, bioimpedance spectroscopy; DXA, dual-energy x-ray absorptiometry; HD, hemodialysis group; PreD, predialysis group; SFT, skinfold thickness.

SFT-DXA

The results of body fat assessment performed by SFT were compared with those performed by DXA using 1-sample Student *t* test (Table 3). The mean differences in percentages of body fat measured by SFT and DXA did not significantly differ from zero in the HD (*P* = .249) and the PreD (*P* = .355) groups but were positive in the control group (*P* = .004). The mean difference between the measurements performed by these 2 methods was 1.99% ± 3.65%. Comparing mean percentages of body fat measured by SFT and DXA using Lin's concordance correlation coefficient, significant correlation was observed in

Table 3. Mean Differences Between Fat Mass Percentages Obtained by SFT and DXA in All Study Groups.

	HD (n = 48)		Control (n = 33)		PreD (n = 61)	
Characteristic	Mean ± SD	P Value, SFT vs DXA	Mean ± SD	P Value, SFT vs DXA	Mean ± SD	P Value, SFT vs DXA
Total	−0.78 ± 4.61	.249	1.99 ± 3.65	.004	0.62 ± 5.17	.355
Women	1.16 ± 5.40	.402	1.21 ± 4.05	.268	1.47 ± 5.74	.203
Men	−1.75 ± 3.91	.017	2.69 ± 3.22	.003	−0.01 ± 4.70	.986

DXA, dual-energy x-ray absorptiometry; HD, hemodialysis group; PreD, predialysis group; SFT, skinfold thickness.
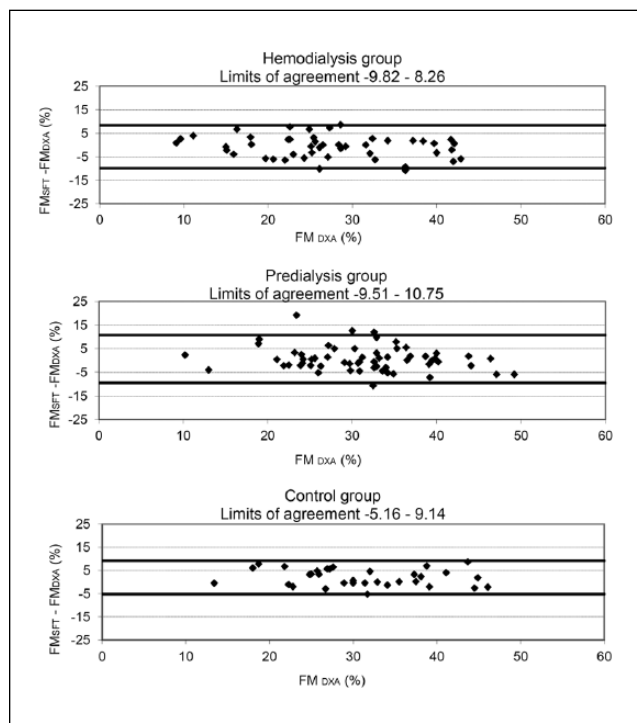

Figure 1. Bland-Altman plot analysis to evaluate agreement between SFT and DXA for assessment of body fat in studied groups. DXA, dual-energy x-ray absorptiometry; FM, fat mass; SFT, skinfold thickness.

all groups. Correlation coefficients were 0.868 ($P < .001$), 0.796 ($P < .001$), and 0.884 ($P < .001$), respectively, for the HD, PreD, and control groups.

For further analysis, the compatibility of both methods was analyzed using the Bland-Altman test. The narrowest limits of agreement were observed in the control group. Bland-Altman plots are presented in Figure 1.

BIS-DXA

To compare the mean differences in percentages of body fat measured by BIS and DXA, a 1-sample Student *t* test was performed. Significant, positive differences were revealed between measurements done by BIS and DXA in all study groups (Table 4), irrespective on sex. The measurements

performed by BIS were higher than those by DXA by 7.44% ± 6.46% in the HD group, 6.12% ± 4.07% in the PreD group, and 4.70% ± 4.09% in the control group.

At the same time, a positive, significant correlation between measurements performed by these 2 methods was observed in all study groups. Lin's concordance correlation coefficients for the HD, PreD, and control groups were, respectively, 0.642 ($P < .001$), 0.685 ($P < .001$), and 0.771 ($P < .001$).

In Bland-Altman plot analysis, the narrowest limits of agreement were observed in the PreD and control groups. Bland-Altman plots are presented in Figure 2.

Three parameters—age, sex, and BMI—have been distinguished to evaluate their influence on differences between the body fat measurements obtained by BIS and DXA. The strength of association was assessed by univariate and multivariate linear regression. After controlling for sex and BMI, age made the strongest influence on the differences between the measurements in all groups ($R^2 = 0.302$, 0.153, and 0.250, respectively, for HD, PreD, and control groups). In the control group, the differences were also influenced by sex.

Discussion

Body composition measurements are an important part of the nutrition status assessment. Determination of body compartments, classically divided into fat and fat-free mass, is much more useful than BMI for the assessment of mortality risk and choosing proper treatment.[12] Diagnostic criteria of PEW, defined by the ISRNM, include BMI as well as an amount of fat and fat-free mass.[5] However, the recommendation does not state which method should be used in its measurements. That is why we decided to compare the 3 main methods assessing fat mass: SFT, BIS, and DXA. SFT measurement is an anthropometric method of body fat assessment. It is not expensive and easy to perform, but it is operator dependent. In our study, the results obtained by SFT did not significantly differ from those obtained by DXA in the HD and PreD groups (Table 3). A similar trend was observed by Kamimura et al[13] in HD patients. However, in the control group of our study, the results obtained by SFT were significantly higher than those obtained by DXA. The mean difference was 1.99%. Bross et al[14] observed a similar trend, with a mean difference of 2.1%. In the present study, Lin's concordance correlation coefficient analysis

Table 4. Mean Differences Between Fat Mass Percentages Obtained by BIS and DXA in All Study Groups.

	HD (n = 48)		Control (n = 33)		PreD (n = 61)	
Characteristic	Mean ± SD	P Value, BIS vs DXA	Mean ± SD	P Value, BIS vs DXA	Mean ± SD	P Value, BIS vs DXA
Total	7.44 ± 6.46	<.001	4.70 ± 4.09	<.001	6.12 ± 4.07	<.001
Women	4.47 ± 6.10	.010	3.19 ± 3.19	.002	5.90 ± 3.54	<.001
Men	8.93 ± 6.19	<.001	5.96 ± 4.40	<.001	6.29 ± 4.46	<.001

BIS, bioimpedance spectroscopy; DXA, dual-energy x-ray absorptiometry; HD, hemodialysis group; PreD, predialysis group.
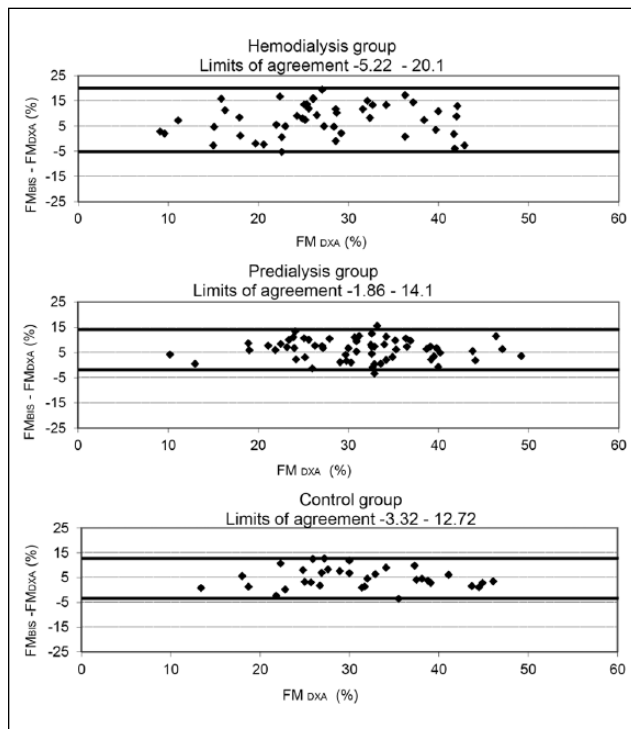

Figure 2. Bland-Altman plot analysis to evaluate agreement between BIS and DXA for assessment of body fat in study groups. BIS, bioimpedance spectroscopy; DXA, dual-energy x-ray absorptiometry; FM, fat mass.

revealed a positive, significant correlation between both methods (r = 0.868, 0.796, and 0.884, respectively, for the HD, PreD, and control groups). However, we should emphasize the fact that the study population presents relatively undisturbed fluid status. As the European Best Practice Guidelines recommend,[4] SFT was performed after the dialysis session in HD patients, at the moment of the smallest overhydration. In the PreD group, patients without visible signs of fluid overload were included. This criterion can be treated as a limitation because large number of patients with CKD present fluid disturbances. However, chronic nutrition disorders should be diagnosed in stable patients, which excludes significant overhydration.

Some authors report a good agreement between SFT and DXA, even better than techniques based on bioimpedance.

Ravindranath et al[15] observed this trend in the predialysis patients with CKD using bioimpedance analysis and Kamimura et al[13] in hemodialysis patients. In our study, differences between the measurements of fat mass performed by SFT and DXA were definitely smaller than performed by BIS and DXA. Rodrigues et al[16] report better agreement of SFT with air displacement plethysmography (ADP) than bioimpedance analysis with ADP.

BIS is a relatively new method based on the phenomenon of electrical bioimpedance used in patients with CKD. In addition, this method provides information about classic compartments like fat and lean tissue mass, as well as the amount of overhydration. In patients with CKD, hydration disturbances can be substantial, and clinically invisible fluid overload can mask changes in body composition. BIS, similarly to SFT, is easily applicable at a patient's bedside. Therefore, it is widely used for nutrition status assessment and for calculation of fluid overload. The studies comparing results obtained by bioimpedance techniques and by DXA in a group of patients with CKD are limited. Most compare bioimpedance analysis, rather than BIS, with DXA. In our study, overestimation of fat percentage by BIS in comparison with DXA was observed. Mean differences between body fat percentage measured by BIS and DXA were 7.44%, 6.12%, and 4.7%, respectively, for the HD, PreD, and control groups. Bross et al[14] also observed higher percentages of fat mass obtained by bioimpedance techniques than by DXA. However, they used bioimpedance analysis based on the Kushner, Lukaski, and Segal equation. In HD patients, BIA-Segal overestimated body fat percentage by 6.2% and BIA-Lukaski by 3.9%. Pellé et al[17] also observed a higher amount of fat mass measured by BIS in comparison with DXA in patients after renal transplantation.

In the presented study, we observed a tendency for a larger error in estimating body fat by BIS in men than in women, demonstrated by greater differences between measurements (Table 4). After taking into account, in the linear regression analysis, age, sex, and BMI as factors associated with the differences between measurements performed by the 2 methods, only age significantly influenced the differences between the measurements in the HD and PreD groups and age and sex in the control group. Age had the strongest influence in the HD (R^2 = 0.302) and control (R^2 = 0.250) groups. In other studies, sex was also the factor that affected the variability of the results.[13]

In the presented study, linear regression analysis did not reveal overhydration as a variable that can influence the differences between the results obtained by BIS and DXA (data not shown). However, this parameter should be taken into account. In our study, BIS measurements were performed before the dialysis session as the manufacturer recommends. In contrast to SFT, which was performed at the lowest overhydration, BIS measurements were obtained at the moment of maximal fluid overload. Although patients without signs of overhydration were included, we observed significantly greater overhydration in the HD patients than in the control group (1.3 ± 1.6 L vs 0.3 ± 1.1 L; reference range, –1 to 1 L). Following this observation, we should remark that in the control group, the limit of agreement was the narrowest. Tangvoraphonkchai et al[18] report that the moment of BIS measurement (before or after the dialysis session) associated with different fluid status influences the results of fat and fat-free mass assessment. These authors suggest performing BIS after the dialysis session. Supporting this trend, Fürstenberg et al[19] performed multifrequency bioimpedance analysis 20–30 minutes after hemodialysis and observed high accordance with this method with DXA.

All methods using bioimpedance techniques are easily applicable and inexpensive, but they are all based on estimations. They apply various equations and assumptions. Furthermore, the moment of performance associated with fluid disturbances can also influence the accuracy of the results. Patients with CKD present a wide spectrum of these abnormalities whereby proper use of these techniques can be problematic. However, establishing the best bioimpedance method for patients with CKD with the usage recommendations seems to be worth further investigations.

Conclusions

SFT as a method of fat mass assessment in daily routine practice seems to be reliable in patients treated with hemodialysis and in patients with stage IV/V CKD. However, BIS based on a 3-compartment model of body composition offers more important data such as overhydration or an amount of lean tissue mass.

Statement of Authorship

A. Rymarz and S. Niemczyk equally contributed to the conception of the research; A. Rymarz contributed to the design of the research and the acquisition and analysis of the data; K. Szamotulska contributed to the analysis and interpretation of the data. All authors drafted the manuscript, critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

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