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Review article

Methodology and factors influencing the association of body weight, performance parameters with linear body measurements assessment in poultry

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The preceding review gives some insight on different methods and factors which influence the association of live weight, performance parameters with linear body measurements assessment in poultry. The relationship existing among linear body parameters provides useful information on the performance and carcass value of poultry. Linear body measurements variability in poultry arises due to genotypic and environmental effects, and the magnitude of variability may differs under different management practices and environmental conditions. The knowledge of the relationship existing between live weight, carcass traits and other performance traits in poultry is crucial because it enable us to predict the body weight and performance from linear body parts and vice versa. This is on the background that different methods have been employed to assess the association of live weight, performance parameters with linear body measurements in poultry. It is suffice to suggest that the understating of the relationship between linear body measurements and performance traits in poultry could be useful in designing appropriate management, selection and breeding programs for utilization of poultry genetic resources. Therefore, the conclusion that linear body measurements information for a particular poultry species or breed is important for breed or species identification and economic valuation in its utilization, might be valid.

1. Introduction

Practical difficulties to measure live weight at field level have led scientists to develop prediction models to estimate live weight using linear body measurements (Assan, 2013; Momoh and Kershima, 2008; Ige et al ., 2006). According to (FAO, 2012) quantitative traits are generally the dimensions of different body parts and live weight which are directly related to production parameters, therefore the strong correlation with meat yield, body weight is used as a proxy indicator of production. In poultry, these traits include measurements on chest circumference, wing length, back length, shank length and shank circumference, breast width, keel length and pelvis width and body weight, which may vary with the genotype, sex and influenced by the method of data analysis. Previous findings have indicated positive and significant correlations between live weight and body dimensions, that is, anybody dimension can be used to predict the body weight of an animal (Olawumi, 2013). Significant correlation between live body weight and carcass composition has been reported in different strains of chickens (Rance et al., 2002; Yang et al., 2006; Ojedapo et al., 2008; Yakubu, 2009). The coefficient of variation for linear body measurements suggest that there was an increased uniformity in body size measurements as the birds advance in age, especially among the female quails. Sexual dimorphism has previously been reported in favour of the male in duck (Raji et al. 2009), pigeon (Hassan and Adam, 1997), and pheasants (Kuzniaka and Adamski, 2010; Gorecki et al. 2012).The entails the characterization of animal genetic resources depends on the knowledge of the variation of morphological traits, which have played a very fundamental role in classification of livestock based on size and shape (Ferra et al., 2010; Agga et al., 2010; Leng et al., 2010). Based on body conformation, meat production can better be estimated than other production properties making body measurements important selection criteria (Bene et al., 2007).

Different methods have been employed to deduce the linear body components that best describe the relationship between body weight, performance traits and body measurements to come up with optimized regression models that could be used in predicting body weight in poultry (Adeleke, et al. 2011; Yakubu et al.,(2009; Pinto et al., 2006; Gueye et al 1998). The principal component based regression models, from their orthogonal shape characters which are preferable for selecting animals for optimal balance to predict body weight have been used in other animal species (Okpeku, et al. 2011). However, the biological relationships among the morphological traits may be different if these body measurements are treated as bivariates rather than multivariates. Principal components analysis has been applied to performance and carcass traits in the chicken (Pinto et al. 2006). Some of the parameters measured and used in the analyses include body weight, body length , heart girth , wing length , shank length and shank thickness (Egena et al. 2014; Yakubu et al. 2009; Peters, et al. 2006; El-labban, 1999). Musa et. al. (2006) reported positive phenotypic correlation between live weight and carcass weight, breast muscle weight, leg muscle weight, abdominal fat weight, heart weight and liver weight in broiler chickens. Elsewhere, Chambers (1990), Deeb and Lamont (2002), and Le Bihan-Duval et al., 1998) reported positive genetic correlations of body weight with abdominal fat weight and abdominal fat percentage. Chest circumference and wing length, generally having less variability in poultry are used to characterize different phenotypic groups (Momoh and Kershima, 2008). However, the traits that show less variability within breeds/types indicate homogeneity and identity of those categories. However, traits showing wider variation could be used for prediction purposes such as live weight prediction (Assan, 2013). This means correlations and driven equations of prediction are very specific to strain and age of bird and stage at which carcasses were processed for analysis (Musa et al., 2006, Ojedapo et al., 2008). In addition, most of the studies used single or mixed sex birds and the suitability of these equations for the prediction of body composition of different sexes is not fully clear. Ojo et al (2014) working with the Japanese quail the smallest farmed avian species reported estimates of coefficient of determination and predictive equations which showed that body weight in Japanese quail is linearly related to body measurements especially with body girth and body length. Then concluded that it is possible for breeders to use body girth and body length as criteria for assessment and early selection of Japanese quail Japanese quail the smallest farmed avian species for body weight. The proportions of major carcass parts such as breast, drumsticks and thigh are important parameters in determining broiler carcass quality when it comes to marketing and purchasing decisions for producers and consumers, respectively. A goal of poultry producers is to predict carcass characteristics that are determinants of carcass quality. The preceding review gives some insight on different methods and factors which influence the association of live weight, performance parameters with linear body measurements assessment in poultry.

2. Possible analysis in assessing the relationship between body weight, performance parameters and linear body measurements

The major purpose of assessing the interrelationship between performance parameters and body weight and its associated traits like body dimensions, is predicting body weight in indigenous chickens where scientific scales are not available. While this interrelationship has been found useful in predicting body weight in poultry it has not been able to point out the actual causal of growth (Monsi 1992; Gueye 1998). Gelalcha and Hanchinal (2013) used path analysis measuring the relative importance of causal factors which provides information leading to effective selection during improvement programmes. Regression equations that could be used to predict body weight from some linear body measurements have been developed (Bhakat et al., 2008; Bassano et al., 2001) Typically body weight is regressed on linear body measurements to determine a weight prediction equation. The correlation matrix of each of the linear body measurements could be used in predicting body weight or carcass parameters in poultry species (Ogah, 2011; Ojedapo et al 2007; Ige et al., 2006). Momoh and Kershima (2008) developed both linear and multiple regression as predictors of body weight in Nigerian local chickens , and found out that in both sexes the multiple regression equations when compared with the simple linear regression equations, multiple regression technique was better in predicting body weight from linear body measurements than simple linear regression technique. Multiple regression analysis has been used to interpret the complex relationship among body weight and some linear body measurements (Yakubu et al., 2012). However, its interpretation may be misleading where there exists multicollinearity among the predictor variables. Tabachnik and Fidell (2001) attempting to address the existence of multicollinearity among predictors variables used multivariate factor analysis which reduces a complex system of correlations into one of smaller dimensions through the extraction of few unobservable latent variables called factors. Factor scores can be derived from multivariate analysis which could be nearly uncorrelated or orthogonal hence such factors could be used for prediction , thereby giving a solution to the problem of collinearity. The use of interdependent explanatory variables to predict body weight should be treated with caution, since multicollinearity has been shown to be associated with unstable estimates of regression coefficients (Keskin et al., 2007; Yakubu et al., 2009) rendering the estimation effects of these predictors impossible. This justifies the use of factor scores for prediction (Yakubu et al 2012). Predictive equations with fewer variables are simple and easy to interpret are suggested (Baffour-Awuah et al., 2000). Both linear and non linear models have been applied in estimation of body weight using linear body measurements, however their effectiveness depends on the linear body measurements under consideration. In vivo prediction of carcass components based on single trait are usually discouraged as not reliable (Ogah, 2011). Another parameter to consider in predictive equations is the Variance Inflation Factor (VIF)v values for interrelationship between traits which should be shown along stepwise multiple regression. It represents the increase in variance due to high correlation between predictors (Pimentel et al., 2007) or gives the indication of existence of severe collinearity. Most models were developed by multiple regression procedure where collinearity among the independent variables was no evaluated (Ogah, 2011). However, collinearity problem among the independent variables should be expected as there are both genetically and phenotypically correlated (Simm and Dingwall, 1989) and it is known that models based on multicollinearity variables can limit inference and the accuracy of prediction (Chatterjee et al., 2000). In fact the use of collinear variables as independent variables does not improve the model precision and create instability in the regression coefficients estimation (Shahin and Hassan, 2000). Mosteller and Turkey, (1987) suggested that prediction accuracy of predictive models should be assessed using a simple cross validation approach. Possible models to use in estimating body weight and carcass parameters include allometric, quadratic and linear models, however they should be tested for best fit. The allometric model seemed to produce a better goodness of fit followed by the quadratic and linear models, respectively in goats (Yakubu et al., 2011). According to Gill (1986) VIF greater than 10 indicate severe collinearity rendering the reliability of the predictive equation not effective. Yakubu et al., (2012) used factor scores for predicting body weight body weight from some linear body measurements of two fish species in Nigeria by adopting a multivariate principal component factor analysis statistical technique. The respective factor scores fitted separately in a linear and multiple regression model as explanatory variables accounting for 76.6% and 84.5% of the variation in the body weight of fish species, respectively. Species or breed difference influencing type of prediction model. Regression models allow as fast evaluation of the body weight of an animal and are also used for the optimization of feeding, determination of optimum slaughtering age and selection criteria (Yakubu et al., 2011), however such measurements are not across breed on the choice of model that gives the best fit (Islam et al., 1991; Benyl, 1997). It is reasonable to suggest that there is need to develop different predictive models for different species or breeds of the same species.

Ukwu et al (2014) through statistical modeling of body weight and linear body measurements in Nigerian indigenous chicken, the resultant predictive equations showed that there were significant relationships between body weight and linear body measurements. High R2 values observed showed that the predictive equations could be used to predict body weight accurately, with the multiple regression model being more efficient than the simple regression models. The correlations between body weight and linear body measurements were determined using Pearson's product moment correlation coefficient. Using simple correlation coefficients between body weight and body measurements have been reported in indigenous chickens of Senegal (Gueye et al 1998), Jinghai yellow chicken (Yang et al 2006) and in Gaga chicken of Indonesia (Sri Rachma et al 2013). Wolanski et al (2006) suggested that due to the positive and strong nature of the correlation between body weight and linear body measurement traits in males of eight selected pure or commercial broiler breeder strains means that body weight could be estimated from body measurements. This is because growth in animals could be evaluated from the component parts of the animal. This implied that an improvement in the body measurements will invariable lead to a corresponding improvement in the body weight of the indigenous Nigerian chickens especially if the correlation is positive (Egena et al. 2014). Shafey et al. (2013) using regression equations identified differences between sexes in predicting weights of wings and neck in the carcass of Ross broiler chickens. It can be concluded that prediction equations developed from live body weight can be useful to estimate carcass composition. Sex of bird significantly influenced the R2 when predicting neck and wings weights. It was further noted that prediction equations for carcass weight and carcass composition of breast, drumsticks, thighs, back and wings of female birds were slightly more variable in precision (R2=98.3 to 21.2%) than those developed in male birds (R2=96.9 to 63.4%). Liyanage et al. (2015) using performing a regression analysis showed significant relationships of body weight with every linear trait while chest circumference and shank length were the best predictors of live weight in village chickens in Sri Lanka. This implied that the performance gap between village chicken and exotic breeds showed the potential for village chicken to be developed and sustainably utilized. Oga (2011) discouraged prediction of carcass components based on single linear body measurements as unreliable. The interpretation of several morphometric characteristics body weight prediction is difficult due to the high degree of correlation among them (Yakubu et al., 2012). A crucial step in constructing a multiple regression model for predictive purposes is to determine those variables that contribute much to the response variable (body weight) with elimination of non significant variables. Using all possible selection approach will maximize the number of independent variables and their contribution in regression equation for predicting the dependent variable (body weight). Raji et al., (2009) and Wawro (1990) proposed that more accurate results in predicting body weight in turkey can be obtained when several parameters are used as independent variables in predicting and improving carcass performance, this was substantiated when multiple traits where used in a regression model. In a stepwise multiple regression of body weight, carcass weight and breast weight in guinea fowl on linear body measurements revealed that when chest circumference alone was used it accounted for 55% of the total variation in body weight, inclusion of keel length in the model increased the proportion of the explained variance to 74.3%. The accuracy of the model was further improved (R2=80.9) when thigh length, body length and wing length were added to the equation. Their result indicate that body weight can be predicted with fair degree of accuracy from chest circumference, keel length and thigh length. Peter et al., (2006) and Yakubu et al., (2009) observed similar findings in Nigerian indigenous chicken genotypes. In Senegal Gueye et al.,(1998) in chicken and Teguia et al., (2007) in Muscovy duck reported that the relationship between live body measurements of carcass component in vivo depends on the correlation between body weight and chest circumference, keel length and thigh length. Wright (1934) proposed the path analysis to understand the causes of trait association which is helpful in partitioning correlation into direct and indirect effect. Path analysis is a standardized partial regression coefficient measuring the direct influence of one variable upon the other and permits separation of correlation coefficient into component of direct and indirect effects. Thus, a crucial evaluation can be made of the specific factor producing correlation (Mohammad et al. 1999). Different explanatory variables may have different contribution to a trait, those with a larger effect on the trait may be the most important to the breeder (Isci, et al. 2004), explanatory variables may have direct or indirect effect on the trait, usually the direct effect are measured using correlation coefficient. However, the indirect effect may confound the correlation coefficient. This may be because another variable may be contributing to the correlation coefficient (Sirali and Kayaalp, 1995).

Pinto et al., (2006) used principal component analysis (PCA) to analyze performance and carcass traits measured in a population of Gallus gallus. The authors observed that the five first principal components explained 93.30% of the total variation and the first component explained 66.00%. The first component was generalized weight because the largest eigen vectors were associated with bodyweight at 35 and 42 days of age, liver, breast, wing and thigh weights.

Udeh and Ogbu (2011) studying three strains of broilers chickens used the principal components analysis which is a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables known as principal components which are ordered so that the first few retain most of the variation present in the original variables. In a related study Pinto et al. (2006) suggested that from the view point of animal genetics and improvement, principal components simultaneously consider a group of attributes which may be used for selection purpose Principal component analysis has been used to describe the relationship between body measurements and body size in chicken (Ibe, 1989; (Jolliffe, 2002; Yakubu et al., 2009), duck (Ogah et al., 2009) and turkey (Ogah et al., 2011). The positive relationship between bodyweight and most of the body measurements showed that bodyweight can be predicted from body measurements. A similar observation was reported by Ajayi et al., (2008). The values of communalities computed for the three strains of chickens confirm that principal component analysis was appropriate for the data sets used in the study. Yakubu et al., (2009) reported that the first principal component accounted for the largest variance in the morphological traits of three Nigerian chicken genotypes. Principal component analysis is a multivariate technique which could be used with success when morphological variables are interdependent. Principal components are a weighted linear combination of correlated variables, explaining a maximal amount of variance of the variables (Truxillo, 2003). This aids in data reduction, and breaks multicollinearity which may lead to wrong inferences. Many researchers have used the independent factor scores derived from multivariate technique of principal component factor analysis to estimate body weight (Yakubu and Ayoade, 2009), functional traits (Karacaoren and Kardamideen, 2008), and as a selection criterion for the improvement of body size (Pinto et al., 2006). This technique has also been used to reduce the number of independent variables in the prediction of genomic breeding values (Macciotta and Gaspa, 2009).

3. Genotype influencing linear body measurements in poultry

Fayeye et al (2014) showed that the two genotypes could be adequately characterized using morphometric indices. Their study further revealed that morphometric indices like body length and comb length can be adequately used to predict body weight of birds in the two genotypes. However, the negative correlation obtained between body weight and wing length in Ilorin ecotype chicken requires further investigation to determine its basis for chicken adaptation.

The differences between Isa Brown and Ilorin ecotype chicken in morphometric trait measurements were similar to the results of morphometric measurements in birds of different genotypes (Islam and Dutta, 2010; Ogah, 2013). Alabi, et al.(2012) on a comparative study of three South African indigenous chicken breeds on the interrelationship between body weight and linear body measurements taken at maturity (22 weeks of age) observed that males of the three breeds were statistically heavier had longer body, better body girth, wing length, shank thickness and shank length than the females. The study also revealed that Potchefstroom koekoek chicken was better than the Naked neck and Venda chickens for the traits evaluated with the exception of shank length where no significant differences were observed between the three breeds. The study concluded that breed differences do exist between the three indigenous South African chicken breeds studied and these differences are in favour of the males and the Potchefstroom koekoek chickens. Analysis of variance procedure followed by Duncan's new Multiple Range test showed significant differences in linear measurements and body weight among groups, where Giri raj village chicken (exotic genotype of Indian origin) reporting to be the largest and frizzle feathered the smallest (Liyanage et al. 2015). Furthermore the occurrence of different morphological features varied significantly between study sites, sexes and among phenotypic groups as shown by chi square analysis. In local fowls, Ige et al. (2007) reported positive phenotypic correlation between body weight and linear measurements, while Razuki et al. (2011) reported significant strain differences in body weight at different ages among breeds of broiler chickens. The morphometric parameters of different phenotypic categories suggested that the predominant categories such as normal village chicken and naked neck exhibit the linear body measurements related to medium level of production performances (Liyanage, et al. 2015). Furthermore the phenotypic categories which are exotic or crosses of exotic genotypes showed the linear body measurements related to comparatively high level of production performances, where body circumference was identified as a suitable predictor trait of live weight. The traits that show less variability within breeds/types indicate homogeneity and identity of those categories. However, traits showing wider variation could be used for prediction purposes such as live weight prediction (Assan, 2013). Adeleke et al (2011) reported that the phenotypic correlation among the linear body measurements increased as the birds advanced in age. The phenotypic correlation coefficients obtained among body weight and linear body measurements were all positive in pure and crossbred progenies of Nigerian indigenous chickens. The study also showed that at 1 day-old, the phenotypic correlations were very low with the highest value being 0.15 between body weight and breast girth. In subsequent weeks, phenotypic correlation increased till week 20 when body weight –breast girth relationship had correlation coefficient of 0.92. Regression models allow as fast evaluation of the body weight of an animal and are also used for the optimization of feeding, determination of optimum slaughtering age and selection criteria (Yakubu et al., 2011), however such measurements are not across breed on the choice of model that gives the best fit as in other animal species (Islam et al., 1991; Benyl, 1997). It is reasonable to suggest that there is need to develop different predictive models for different poultry species or breeds of the same species.

4. Sex variability in linear body measurements in poultry

Momoh and Kershima (2008) working with local chickens in Nigeria showed that males had higher values for body weight and body measurements. This was attributed to the fact that males were heavier than females. In females body weight was only positively and significantly correlated to body length, chest circumference, with femur, crus and tarso-metatarsus demonstrating non significant. Studying morphometric traits and correlation between body weight and body size traits in Isa Brown and Ilorin ecotype chickens, Fayeye et al (2014) observed that linear body measurements measured on male birds were more highly correlated with body weight (0.68-0.95) than in female chickens, except for breast breadth. The relationship between zoometrical measurements and live body weight was determined in indigenous chicken of the Lake Victoria Crescent Agro-ecological Zone in Uganda, in males all measurements were strongly correlated to the body weight of chicken, while in females all measurements were significant except body length and femur length in 6 - 8 months old chickens (Semakula et al. 2011). Assessing gender influence, Liyanage, et al. (2015) reported that males always had a larger values for body circumference, wing length and breast width than females in all the chicken types, though the differences were not statistically significant due to large variation within groups and fewer observations in certain groups. On the other hand, frizzled feathered group showed the lowest mean body circumference values for both males and females. This implies that categorization of data according to sex is necessary to improve prediction power of equations. In a different study, Taguia et al., (2008) working with African Muscovy ducks, reported highest correlation coefficients of body weight with wing length and thoracic perimeter in both males and females. The moderate to high correlation between body weight with linear body measurements are expected given that the body conformation traits reflects element of size of animals (Berry et al., 2005). The results of least squares mean analysis indicated that sex had significant effect on body weight and other linear body measurements (Getu, 2014). Gender was the main source of variation in all traits than females except keel length. Therefore, the fixed effect of sex was the main cause of variations of the measurable traits from the population mean. This might be attributable to the stronger foraging behavior and over computation nature of males than females (Tadelle et al., 2003). This was in good agreement with the report of (Halima et al., 2007; Aberra and Tegene, 2011; Nigussie, 2011) who stated that male chickens had better performance than females. Body weight is also regarded as a function of frame work or size of the animal and its condition. Similar observation had been reported in indigenous chickens by Missohou et al., (1997) and Ngou Ngou-Payou (19900. Elsewhere, Hassan and Adam (1997) also reported higher values for body weight and morphometric measurements in indigenous male pigeons when compared with the females. Ages on which dimorphism is expressed in predicting body weight in broilers differed according to the strain of broilers. Therefore it is reasonable to suggest that different equations should be developed for males and females in species considered. The differences in linear body measurements between sexes in different studies was attributed to sex dimorphism (Gatford et al., 1998; Egena et al., 2010). Sexual dimorphism was observed in predicting body weight of two broiler strains (Adedibu and Ayorinde, 2002). The relationship between live weight and morphometric characteristics as well as predictability of both live weight and linear body measurements were influenced by sex in broilers. However sexual dimorphism existed in relationships between live weights and linear body measurements on different ages. The existing sexual dimorphism is explained by the differences in levels of male sex hormone which is responsible for greater muscle development in males than in females.

5. Linear body measurements and carcass parameters in poultry

Ago (2011) reported wing chest, chest circumference having lowest variability in guinea fowls and suggested that could have been a result of breed identity and specificity indicating homogeneity of the population. The breast and the thigh had higher muscle deposition in the body of birds hence their relationship with body weight was high. Their findings were congruous to the submission of Hassan and Adam (1997) who observed a strong and significant correlation of body length and chest width to body weight in indigenous pigeons. Ojedapo et al.(2008) working with Anak broiler strain, reported a significant positive phenotypic correlations between live weight and carcass weight (0.95), shank weight (0.93) and breast muscle weight (0.97) but observed significant negative phenotypic correlation (-0.78) between live weight and carcass weight in Wadi Ross strain. Olawumi (2013) showed that all the carcass traits measured were good indicators of live weight, and that anyone of them could be used to predict its value and concluded that there was a gene linkage effect. As regards relationship between body weight and carcass traits, Musa et al. (2006) reported significant positive phenotypic correlation between live weight and carcass weight, breast muscle weight and abdominal fat weight, but significant negative phenotypic correlation between live weight and abdominal fat percentage in Anka breed. However, El-Labban (1999) suggested that in the event that there was a very high and positive phenotypic correlation between body weight and carcass traits, it is highly likely that the influence is a result of pleiotrophic effects of genes and linkage effects which operate on the measures traits. Therefore, any attempt to perform phenotypic selection on one trait will consequently result in improvement of the other. Ige et al. (2006) and Momoh and Kershima (2008) showed higher muscle deposition in breast and thigh that creates a strong relationship between chest circumference or shank length with live weight. When all breed groups were combined (overall), every linear parameter had a significantly positive association with body weight and the following formula was found to be the best predictor of body weight with coefficient of determination value of 65 percent: Predicted body weight = -1690.4 + 5.53*Chest circ. + 10.11*Shank length (Liyanage et al. 2015). Musa et al. (2006) reported significant positive correlations between live body weight and carcass weight (0.968) and breast weight (0.840) in Anka strain and between live weight and carcass weight (0.759) in Ruago strain.

6. Implications

From the preceding review, can deduce that there is consensus among researchers working with different poultry species that linear body measurements could serve as predictors of body weight and carcass parameters. Body weight is an important attribute in poultry production as it forms the basis for not only assessing growth and feed efficiency but also in making economic and management decisions. The correlation and regression analyses made in several studies point to the fact that linear body measurements can be a good indication for predicting body weight, carcass weight and carcass components in chickens. A number of linear body are known to be good indicators of body growth and market value of poultry apart from body weight. In certain cases poultry breeders have tried to establish the relationship that exist between body weight and linear body parameters such as shank length, breast width, keel length, neck length, back length and thigh length. The knowledge of the relationship existing between live weight, carcass traits and other performance traits in poultry is crucial because it enable us to predict the body weight and performance from linear body parts and vice versa. Therefore, in a situation whereby the live weights in poultry is not measured before slaughter, the weight of linear body measurements be used to determine the live weight and carcass parameters, especially were there is a strong association between linear body measurements and, live weight and carcass traits. However, it is important to ascertain phenotypic correlations and regression coefficient between live weight and performance traits in poultry raised under different management practices. It can be concluded that linear body measurements information for a particular poultry species or breed is important for breed or species identification and economic valuation in its utilization.

Furthermore, the relationships between body weight and linear body measurements are important for predicting body weight and can also be applied speedily in selection and breeding program, especially in indigenous chickens.

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