Manscript type: Original Research Article

**Relationship between Body Weight and Linear Body Measurements in Pakistani Quail (*Coturnix japonica* PK)**

Running title: Relationship of body measurements inPakistani quail

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**Novelty statement:**

The main objective of this study is to find the relationship between body weight and linear body measurements for the first time in Quail breed in Pakistan (*Coturnix japonica* PK) phenotypically. AM found strong correlation between body weight and body length of birds.

**Abstract**

In this study total 150 Pakistani quail (*Coturnix japonica* PK) locally evolved in Pakistan were used at the age of 30 days to reveal the relationship between body weight and linear body measurements. Body measurements included body weight (BW), body length (BL), wing spread (WS), shank length (SL), shank circumference (SC), drumstick length (DL), drumstick circumference (DC), breast width (BD) and keel length (KL). The overall association between BW and other body measurements found highly significant (p value is 0.000). Multiple linear regression model for both male and female birds was found to be highly significant (p value 0.000). In male birds there was strong positive correlation between BW and BL (p value is 0.000) and moderate negative correlation between BW and DC (p value is 0.000). Other body measurements were observed as weakly correlated with BW (p values is above 0.05). In female birds there was strong positive correlation between BW and BL (p value is 0.000). The interdependence between BW and SL has been observed to be a moderate negative correlation (p value < 0.01). The body measurement DC was moderately negatively correlated with body weight BW (p value < 0.011). Two variables SC and DL were also found to be moderately positively correlated with BW (p values < 0.001 and < 0.004 respectively). Rest of the variables were weakly correlated with BW.

**Keywords:** Pakistani quail, body weight, body measurements and multiple linear regression.

**Introduction**

In Pakistan and other developing countries there is a gap between requirement and supply of protein from animal source due to continuously increasing population (Anonymous 2013). The need of the hour is not only to increase the existing production resources but also to explore alternate resources (e.g quail, ducks, turkeys, goose etc). Alternate sources should be economical, efficient and comparably suitable to the existing animal protein resources. At commercial level quail farming is the alternative source. It has the potential to decrease the pressure on existing resources (Akram et al. 2008). Due to unique flavor of meat Japanese quail are of great importance (Padgett and Ivey 1959).

*Coturnix japonica* is the smallest avian specie farmed for the production of meat and eggs (Minvielle 1998). *Coturnix japonica* has the potential to serve as outstanding and inexpensive source of alternate animal protein (Raji et al. 2008). Several characters that recommend this bird for poultry as a pilot animal are robustness, short generation turnover, short (16-days) period of development, easy access to embryo, short life span, comparable physiology to humans, excellent resistance towards diseases, small sized body, unique taste of meat, high rate of egg production, ease of maintenance, least requirement of equipment, least requirement of space, prolific and efficiency of converting feed to meat (Cain and Cawley 2000; Minvielle 2004; Dhaliwal et al. 2004).

Body weight perform the key role in determining multiple other farm animals economic characters (Pesmen and Yardimci 2008). In meat industry body weight is considered as an economically important trait. There is a complex relationship between phenotypic traits and body weight. Some phenotypic traits have been reported by Yakubu (2010) to estimate body weight in animals (Yakubu 2010). Selection of trait for breeding purpose is of utmost important as some traits affect the breeding directly while some affect indirectly (Keskin *et al* 2005). and the best birds are selected for further breeding (Dekhili and Aggoun 2013).

The objective of the present study is to determine the relationship of body weight with the phenotypic traits in *Coturnix japonica* PK locally evolved in Pakistan environmental conditions and association of body weight with linear body measurements. This study provides easy, economical, accurate and fast method to screen heavy weight birds on the basis of linear body measurements.

**Materials and Methods**

**Linear body measurements**

All the birds were collected at the age of 30 days. Total one hundred and fifty birds of both the sexes were included in this study. On the basis of weight five categories (higher outliers > 250g; higher 211 to 250g; medium 171 to 210g; small 130 to 170g and lower outliers <130g) of birds were made. After random selection body parameters of birds were taken. Body parameters included BW, BL, WS, SL, SC, DL, DC, BD and KL.

**Statistical analysis**

Male and female birds data were statistically analysed for analysis of variance (ANOVA) to observe the significance of association between dependent and independent variables. Data obtained from male and female birds were normalized separately and partial correlation was found by taking body weight as a dependent variable and other variables were considered as an independent variables. A multiple linear regression model was established to determine the relationship between dependent variable (body weight of *Coturnix japonica* PK) and other variables (body measurements). Along with this model, the contribution of independent variables upon dependent variable in terms of percentage was also obtained by coefficient of determination $\left(R^{2}\right)$.

Following multiple linear regression models was used for the study:

$$Y=β\_{0}+β\_{1}X\_{1}+β\_{2}X\_{2}+β\_{3}X\_{3}+β\_{4}X\_{4}+β\_{5}X\_{5}+β\_{6}X\_{6}+β\_{7}X\_{7}+β\_{8}X\_{8}+ϵ$$

where,$ Y= body weight (dependent variable),$

$$β\_{0}= Intercept $$

$$β\_{\left(1-8\right)}= Partial regression coefficients$$

$$X\_{\left(1-8\right)}= various body measurements (independent variables)$$

$$ϵ=Error term$$

and

$$R^{2}=1-\frac{Unexplained variation}{Total variation}$$

Partial correlation coefficient had been used to observe the association between dependent variable and any of the other variables while taking rest of the variables as fixed i.e. to observe how strongly or weekly the body measurement variables were inter-linked with body weight. To validate the findings of the study, all necessary tests (tolerance and variance inflation factor to check the presence of multicollinearity in the model) was employed.

**Results**

**Descriptive statistics, confidence interval and R Square**

Descriptive statistics of male and female birds were presented in Table No. 1. The results showed that values of mean and standard deviation of almost every study variable of female birds were higher as compared to male birds. The 95% confidence interval estimates of true mean values of all respective variables have also been tabulated in Table No. 2 for both male and female birds. The values of R Square for male (female) birds indicated that around 72% (68.8%) respectively of the variation in BW was due to eight other variables (BL, WS, SL, SC, DL, DC, BD and KL) (see Table No. 3). The overall significance of the multiple linear regression model for both male and female birds was observed and found to be highly significant with p value 0.000 (see Table No. 4-5). The resultant multiple regression model for male birds obtained through Table No.6 is presented below:

$$BW=-483.976+22.882BL+1.059WS-16.653SL+30.819SC+10.953DL-20.521DC+0.397BD-2.825KL$$

Similarly the fitted multiple regression model for female birds formulated from Table No. 7 is stated below:

$$BW=-425.572+18.471BL+0.987WS-23.495SL+74.199SC+21.79DL-14.541DC-6.309BD-9.138KL$$

These models further can be utilized to predict the body weight of male and female birds having age of 30 days respectively.

**Partial correlation**

Partial correlation coefficients were computed for both male and female birds to see the behaviour of relationship between BW and any of the other body measurement while removing the effect of other body measurements. The results obtained for male birds have been presented in Table No. 8 show that there was strong positive correlation between BW and BL (highly significant with p value as 0.000). There was moderate negative correlation between BW and DC (highly significant with p value as 0.000) while comparing this value with zero correlation. Rest of the body measurements like WS, SL, SC, DL, BD and KL were observed as weakly correlated with BW (all results are insignificant with p values above 0.05).

Similarly the results compiled in Table No. 9 related to measurement of correlation between BW and other variables of female birds portray somehow a different picture. There was strong positive correlation between BW and BL (highly significant with p value as 0.000). The interdependence between BW and SL was observed to be a moderate negative correlation (significant with p value < 0.01) as compared to no correlation between these two variables. The body measurement DC is moderately negatively correlated with BW (significant with p value < 0.011). Two more variables SC and DL were also found to be moderately positively correlated with BW. In both cases, the correlation values significant with p values < 0.001 and < 0.004 respectively. Rest of the variables were weakly correlated with BW.

**Discussion**

In this study relationship between BW and linear body measurements such as BL, WS, SL, SC, DL, DC, BD and KL of 150 bird (Males = 77 and Females = 73) were recorded at 30 days of age. Ojo and his colleagues (2014) reported relationship between BW and linear body measurements (BL, wing length, SL, shank diameter, drum stick and body girth) of 108 birds (*Coturnix coturnix japonica*) at the age of two, four and eight weeks respectively (Ojo et al. 2014). There was another study in which body weight was predicted from linear body measurements (BL, wing length, SL and breast girth) of *Coturnix* quail after one, two, three, four, five and six weeks respectively. Number of birds included in this study was 169 (Gambo et al. 2014). In another study Japanese quail (598 birds) were studied (Emam et al. 2020). Tyasi and his colleages (2021b) predicted body weight from phenotypic traits. Phenotypic traits studied include BL, beak length, wingspan, wing length, SL, SC, body girth, back length, KL, chest circumference and toe length (Tyasi et al. 2021b).

In present study data was subjected to ANOVA, partial correlation and multiple linear regression model. The overall BW and BL showed significant values (p value as 0.000) in both male and female birds at the age of 30 days. The overall significance of the multiple linear regression model for birds was found to be highly significant (p value 0.000). In this study strongest positive correlation was found between BW and BL (p value as 0.000). Other variables were moderately and weekly correlated with BW.

Gambo and his colleagues (2014) reported an increase in linear body measurements with age of one to six weeks of birds (Gambo et al. 2014). In another study Ojo and his colleagues (2014) found a significantly positive correlations (*P*<0.01) at two, four and eight weeks of age between BW and body measurements. Highly significant correlation (p value as 0.000) was found between BW and body girth (two weeks age) (Ojo et al. 2014). A study was conducted on Ross and Anak of Titan chickens at age of one day to 9 weeks. Simple linear and non-linear regression analyses were carried out among body measurement and body weight. Highest significant positive relationship (P < 0.001) was found among body measurement and body weight. Relationship between body weight and body girth can predict body weight of bird better as compared to other body parameters (Ajayi et al. 2008). In both male and female birds strong correlation (P<0.01) was found in body weight and body measurements. Linear relationship was found among wing length and live body weight (Teguia et al. 2008). Tyasi et al (2017a) observed the direct and indirect effects among body measurements and body weight on both sexes of Chinese Dagu chicken. Path analysis of female birds results indicated that shank length has the highest direct effect on Chinese Dagu chicken body weight while male birds body slope length has the highest direct effect on Chinese Dagu chicken body weight (Tyasi et al. 2017a). The outcomes of this study are helpful for the breeders to plan breeding programs and genetic selection studies.

**Conclusion**

It had been revealed that all study variables of female birds are higher than male birds. Strong correlation between BW and BL of both male and female birds was also found.

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**Author contributions**

AM and ARA planned the experiments, HJ provided the samples, AM, HJ and WM interpreted the results, AM, FS and TM made the write up and AM statistically analyzed the data and made illustrations**.**

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**TABLES**

**Table No. 1. Descriptive statistics related to various variables.**

|  |  |  |
| --- | --- | --- |
| **Variables** | **Male** | **Female** |
| ***n*** | ***mean*** | ***sd*** | ***n*** | ***mean*** | ***Sd*** |
| BW | 77 | 185.7532 | 55.4608 | 73 | 192.5205 | 57.6076 |
| BL | 77 | 29.8753 | 2.3776 | 73 | 30.2411 | 2.4109 |
| WS | 77 | 16.9844 | 1.6860 | 73 | 17.7027 | 3.1546 |
| SL | 77 | 3.4091 | 0.5763 | 73 | 3.4781 | 0.6682 |
| SC | 77 | 1.6078 | 0.3094 | 73 | 1.6726 | 0.3276 |
| DL | 77 | 5.4701 | 1.0279 | 73 | 5.7205 | 1.0726 |
| DC | 77 | 3.4338 | 1.4087 | 73 | 3.6425 | 1.2745 |
| BD | 77 | 3.2857 | 1.0991 | 73 | 3.5055 | 1.2805 |
| KL | 77 | 5.4558 | 1.2164 | 73 | 5.4630 | 1.3452 |

**Table No. 2. 95% confidence interval estimates of measurement variables for male and female birds.**

|  |  |  |
| --- | --- | --- |
| **Variables** | **Male** | **Female** |
| **Lower** | **Higher** | **Lower** | **Higher** |
| BW | 173.1652 | 198.3413 | 179.0797 | 205.9614 |
| BL | 29.3357 | 30.4150 | 29.6786 | 30.8036 |
| WS | 16.6017 | 17.3671 | 16.9667 | 18.4388 |
| SL | 3.2783 | 3.5399 | 3.3222 | 3.6340 |
| SC | 1.5376 | 1.6780 | 1.5962 | 1.7490 |
| DL | 5.2368 | 5.7034 | 5.4703 | 5.9708 |
| DC | 3.1140 | 3.7535 | 3.3451 | 3.9398 |
| BD | 3.0362 | 3.5352 | 3.2067 | 3.8042 |
| KL | 5.1798 | 5.7319 | 5.1492 | 5.7769 |

**Table No. 3. Coefficient of Determination (**$R^{2}$**) and** $R\_{adj}^{2}$**.**

|  |  |
| --- | --- |
| **Male** | **Female** |
| **Model** | **R** | **R Square** | **Adjusted R Square** | **R** | **R Square** | **Adjusted R Square** |
| 1 | .848a | .720 | .687 | .829a | .688 | .649 |

(a). Predictors: (Constant), KL, DC, WS, DL, SL, SC, BL, BD (b). Dependent Variable: BW

**Table No. 4. Overall Significance of Regression Model using ANOVAa (Male).**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Model** | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Regression | 168296.938 | 8 | 21037.117 | 21.850 | .000b |
| Residual | 65471.373 | 68 | 962.814 |
| Total | 233768.312 | 76 |  |

(a). Dependent Variable: BW (b). Predictors: (Constant), KL, DC, WS, DL, SL, SC, BL, BD

**Table No. 5. Overall Significance of Regression Model using ANOVA a(Female).**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Model** | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Regression | 164305.585 | 8 | 20538.198 | 17.611 | .000b |
| Residual | 74636.634 | 64 | 1166.197 |
| Total | 238942.219 | 72 |  |

(a). Dependent Variable: BW (b). Predictors: (Constant), KL, DC, WS, DL, SL, SC, BL, BD

**Table No. 6. Coefficientsa (Male).**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Model** | **Unstandardized Coefficients** | **Standardized Coefficients** | **t** | **Sig.** | **Collinearity Statistics** |
| **B** | **Std. Error** | **Beta** | **Tolerance** | **VIF** |
| (Constant) | -483.976 | 59.397 | -8.148 | .000 |
| BL | 22.882 | 2.833 | .981 | 8.077 | .000 | .279 | 3.581 |
| WS | 1.059 | 3.817 | .032 | .278 | .782 | .306 | 3.269 |
| SL | -16.653 | 10.351 | -.173 | -1.609 | .112 | .356 | 2.809 |
| SC | 30.819 | 19.734 | .172 | 1.562 | .123 | .340 | 2.943 |
| DL | 10.953 | 6.704 | .203 | 1.634 | .107 | .267 | 3.748 |
| DC | -20.521 | 5.180 | -.521 | -3.961 | .000 | .238 | 4.204 |
| BD | 0.397 | 6.142 | .008 | .065 | .949 | .278 | 3.597 |
| KL | -2.825 | 4.577 | -.062 | -.617 | .539 | .409 | 2.447 |

**Table No. 7. Coefficientsa (Female).**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Model** | **Unstandardized Coefficients** | **Standardized Coefficients** | **t** | **Sig.** | **Collinearity Statistics** |
| **B** | **Std. Error** | **Beta** | **Tolerance** | **VIF** |
| (Constant) | -425.572 | 67.885 | -6.269 | .000 |
| BL | 18.471 | 2.323 | .773 | 7.952 | .000 | .516 | 1.936 |
| WS | .987 | 1.338 | .054 | .737 | .464 | .909 | 1.100 |
| SL | -23.495 | 8.862 | -.273 | -2.651 | .010 | .462 | 2.164 |
| SC | 74.199 | 20.969 | .422 | 3.538 | .001 | .343 | 2.913 |
| DL | 21.790 | 7.198 | .406 | 3.027 | .004 | .272 | 3.681 |
| DC | -14.541 | 5.561 | -.322 | -2.615 | .011 | .322 | 3.101 |
| BD | -6.309 | 8.584 | -.140 | -.735 | .465 | .134 | 7.460 |
| KL | -9.138 | 6.465 | -.213 | -1.413 | .162 | .214 | 4.670 |

**Table No. 8. Partial correlation coefficient (Male).**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **BL** | **WS** | **SL** | **SC** | **DL** | **DC** | **BD** | **KL** |
| **BW (Correlation)** | .700 | .034 | -.191 | .186 | .194 | -.433 | .008 | -.075 |
| **p value** | .000 | .782 | .112 | .123 | .107 | .000 | .949 | .539 |

**Table No. 9. Partial correlation coefficient (Female).**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **BL** | **WS** | **SL** | **SC** | **DL** | **DC** | **BD** | **KL** |
| **BW (Correlation)** | .705 | .092 | -.315 | .405 | .354 | -.311 | -.091 | -.174 |
| **p value** | .000 | .464 | .010 | .001 | .004 | .011 | .465 | .162 |