Direct and maternal genetic effects of body weight traits in Japanese quail (Coturnix coturnix japonica)

DIREKTE UND MATERNALE GENETISCHE EFFEKTE FÜR KÖRPERGEWICHTSMERKMALER BEI DER JAPANISCHEN WACHTEL (COTURNIX COTURNIX JAPONICA)

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Introduction

Genetic parameters describe genetic and environmental variation and might vary among populations and environments and should thus be estimated in different populations and environments (Kawahara and Saito, 1976; Aggrey and Marks, 2002). In order to establish a breeding program, it is essential to know genetic variation and relationship among individuals. Breeders aim to exploit these forms of variation by taking additive, non additive, and environmental factors into account (Siegel and Dunnington, 1997; Schuler et al., 1998). Some traits are even influenced by maternal effects. The mother has an influence on the performance of her offspring over and above that of her direct additive genetic contribution. These maternal effects are strictly environmental for the offspring, but can have both genetic and environmental components. It has been shown that maternal effect has a considerable impact on accuracy of estimations. The maternal effect of a dam is a function of her genotype and environment, the additive genetic part being inherited from both her sire and dam. Therefore, genotypic differences among dams are expressed as phenotypic differences of their offspring when they become dams. The maternal genetic effect is expressed one generation later than the additive direct effect (Einarsson, 1981). In selection of animals and especially in dam lines, it is important to consider the maternal genetic effects. The direction of the bias on the heritability estimate depends partly on the size of the maternal genetic variance and the size and sign of the direct-maternal genetic covariance. A negative genetic correlation between the direct and maternal effect can lead to conflict in the improvement of a trait. Estimat of these effects also are required if selection for dam productivity traits is to be effective (Southwood and Kennedy, 1990).

Maternal effects in birds are different from those of other animals, because any maternal effect on chicks, incubated artificially, must be the residual effect of dam reflected in egg characteristics at laying. Estimation of genetic parameters for several traits in Japanese quail has been reported (Toelle et al., 1991; Minvielle et al., 1999, 2000; Arbas et al., 2004; Vali et al., 2005; Dionello et al., 2006; Milezen et al., 2006; Saatchi et al., 2006; Shokouhmand et al., 2007; Punya et al., 2009a; Khalbairi et al., 2010; Narine et al., 2010). In some investigations, it has been attempted to define maternal effects in poultry (Saatchi et al., 2006; Pardeel et al., 2002; Romero et al., 2009). The importance of the maternal genetic effect has not been clearly evaluated, especially for body weight in Japanese quail. The main purpose of present study was to estimate direct, maternal genetic and maternal permanent environmental effects for body weight at different ages in a pedigree Japanese quail population.

Materials and methods

Birds and traits

A Japanese quail population was reared in the poultry research station of Gorgan University of Agricultural Sciences and Natural Resources of Iran. In the first generation, 96 male and 192 female birds were randomly selected from the base population. One male with two females were assigned in each cage. Birds were fed with a diet containing 20% crude protein and 12.56 MJ/kg. The temperature of hen house was around 20°C and the light was given 15 hours per day (from 6:00 AM to 9:00 PM). Each collected egg was numbered, based on its sire and dam. Eggs of dam were identified by specific pattern of eggs surface. To avoid error in identification, dams with completely recognizable patterns of egg surface were assigned in each cage. Collected eggs were stored in a room with temperature of 13–16°C and humidity of 70%. Every 7 days, collected eggs were disinfected with formaldehyde, located in setter for 14 days and then transferred to hatchery for 3 days. Hatchery was equipped with separated boxes according to the number of parents to set quails’ pedigree. Eggs hatched from each sire and dam, were marked with same color and weighed before transferring to rearing house. The temperature of the house was 38°C and it was reduced weekly by 3°C until 20°C. Birds were weighed weekly from hatch to 42 days with a 0.01 g sensitive electronic scale. Feed, but not water, was removed 6 h prior to weighing. A diet containing 24% crude protein and 12.13 MJ/kg (based on NRC, 1999) was used ad libitum. Illumination was 24 h/d during rearing period. The same mating plan and rearing system was used to generate third generation.

Genetic Analyses

The SAS (SAS Institute, 2000) statistical package was used for preliminary data analyses. A general linear model (GLM) was applied to examine the importance of fixed effects.
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influencing body weight. Univariate procedure of SAS was also used to test the normality of body weight traits. Each trait was analyzed with bird as a random factor to fit the additive direct effect, birds being the individual that the trait was recorded on. An additive maternal effect fitted as a second random effect for each bird with the same covari-ance structure as the additive direct effect and a covariance different from zero were considered between direct and maternal genetic effects. Maternal permanent environment effect was also included as an additional random effect uncorrelated with all other effects in the model. Therefore, data were analyzed using 3 animal models consisting direct genetic effect (model1), direct and maternal genetic effects (model2) and direct, maternal genetic and maternal permanent environment effects (model3) as following:

\[
Y_{ijk} = \mu + s_i + g_{hj} + a_k + e_{ijk} \quad \text{(Model1)}
\]

\[
Y_{ijkm} = \mu + s_i + g_{h1} + a_k + d_m + e_{ijkm} \quad \text{(Model2)}
\]

\[
Y_{ijkmn} = \mu + s_i + g_{h1} + a_k + d_m + c_n + e_{ijkmn} \quad \text{(Model3)}
\]

Where \( Y_{ijk(mn)} \) = performance of birds, \( s_i \) = fixed effect of sex, \( i = 1, \) female and 2, male, \( g_{hj} \) = combination of generation and hatch effects (\( j = 1,2, \ldots, 54 \) including 3 generations and 18 hatches), \( a_k \) = random direct genetic effect, \( d_m \) = random maternal genetic effect, \( c_n \) = random maternal permanent environmental effect and \( e_{ijk(mn)} \) = random residual effect. To test the significance of maternal genetic and maternal permanent environment effects, a likelihood ratio test was used.

\[
\chi^2 = 2\log L \text{ (full model)} - 2\log L \text{ (reduced model)}
\]

A bivariate analysis was used to estimate genetic correlations among BW at different ages. All bivariate analyses included additive direct effect for both traits and the covariance between the additive direct effects. (Co) variance components and genetic parameters were estimated using ASREML software (Gilmour et al., 2000).

Results and Discussion

Description of Traits

In poultry breeding, traits like growth rate and body weight are of great interest, as these traits have a major economic effect. Therefore, poultry breeders aim to select birds with higher body weight. In present study, maternal genetic and maternal permanent environmental effects were evaluated in addition to direct additive genetic effects for body weight traits in Japanese quail. Descriptive statistics including significance of fitted effects and test of normality for body weight at different ages are shown in Table 1. Body weight traits were normally distributed and effect of sex and gh were significant for all body weight traits. Mean values of body weight traits were higher than those reported by Saatci et al. (2006), Shokohmand et al. (2007) and Vali et al. (2005). Mean and coefficient of variation of weekly body weight at 0, 7, 14 and 21 d were similar to other studies (Toelle et al., 1991; Saatci et al. 2003; Punya et al., 2009b and Narine et al., 2010). Higher body weight could be due to genetic of birds, environmental effects and management. In this experiment, birds were transferred to cages (\( 30 \times 25 \times 30 \) cm) at 28 days and fed with a diet containing 24% crude protein and 12.13 MJ/kg. Rearing birds in cage will reduce their flying and moving. Therefore, waste of energy is reduced and available energy could be used for increasing body weight.

There were significant differences in body weight traits between sexes. The averages of body weight traits in females were higher than males. Same findings were reported by many researchers in Japanese quail (Kawahara and Saito, 1976; Caron et al., 1990; Toelle et al., 1991; Baumgartner, 1994; Minville et al., 2000; Saatci et al., 2006; Vali et al., 2005; Shokohmand et al., 2007; Narine et al., 2010). Differences in values between sexes could be attributed to large reproductive organs in females such as ovary and oviduct (Marks, 1993). Combination of generation and hatch (gh) had a significant effect on body weight traits. Mean value of body weight traits in birds with older mothers were higher than those with younger mothers. Peeples et al. (1999) described that older hens lay larger eggs that hatch into larger chickens, and egg weight and hatching weight are correlated with market age weight.

Genetic Parameters

Genetic parameters including direct (\( h^2_a \)) and maternal heritability (\( h^2_m \)) and ratio of maternal permanent environment to phenotypic variance (\( c^2 \)) are shown in Table 2. Estimated heritabilities in model1 (0.34–0.90) were higher than model2 (0.15–0.42) for most of body weight traits. Large increases in direct heritability were found for traits with a significant maternal genetic effect when it was neglected (Model1). Clement et al. (2001) demonstrated that if maternal genetic effects exist but are neglected in the model, the

Table 1. Descriptive statistics of body weight (g) at different ages

<table>
<thead>
<tr>
<th>Trait</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Sex1</th>
<th>Gh2</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW0</td>
<td>1907</td>
<td>8.91</td>
<td>1.12</td>
<td>5.65</td>
<td>12.5</td>
<td>0.110* ***</td>
<td>0.071</td>
<td>-0.471</td>
<td></td>
</tr>
<tr>
<td>BW7</td>
<td>1838</td>
<td>32.2</td>
<td>7.93</td>
<td>11.0</td>
<td>60.4</td>
<td>1.42*** ***</td>
<td>0.163</td>
<td>-0.334</td>
<td></td>
</tr>
<tr>
<td>BW14</td>
<td>1559</td>
<td>72.6</td>
<td>15.7</td>
<td>25.7</td>
<td>153</td>
<td>3.51*** ***</td>
<td>0.124</td>
<td>0.502</td>
<td></td>
</tr>
<tr>
<td>BW21</td>
<td>1622</td>
<td>124</td>
<td>20.7</td>
<td>45.1</td>
<td>185</td>
<td>5.23*** ***</td>
<td>-0.192</td>
<td>0.083</td>
<td></td>
</tr>
<tr>
<td>BW28</td>
<td>1754</td>
<td>171</td>
<td>29.1</td>
<td>70.4</td>
<td>258</td>
<td>7.02*** ***</td>
<td>-0.502</td>
<td>0.482</td>
<td></td>
</tr>
<tr>
<td>BW35</td>
<td>1550</td>
<td>203</td>
<td>23.3</td>
<td>150</td>
<td>290</td>
<td>8.87*** ***</td>
<td>-0.160</td>
<td>-0.704</td>
<td></td>
</tr>
<tr>
<td>BW42</td>
<td>1589</td>
<td>232</td>
<td>28.5</td>
<td>166</td>
<td>321</td>
<td>21.6*** ***</td>
<td>0.261</td>
<td>-0.421</td>
<td></td>
</tr>
</tbody>
</table>

1 Difference of male and female was shown as effect of sex
2 Gh is the combination of generation and hatch effects
* P ≤ 0.05.
** P ≤ 0.01.
*** P ≤ 0.001

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direct heritability is overestimated. Based on the result of likelihood ratio test, significant differences between model1 and model2 for all traits and only a significant difference between model2 and model3 for BW0 were found (p < 0.05). It means, maternal genetic effects in model2 improved estimated genetic parameters for body weight traits compared to model1. Estimated genetic parameters for BW0 in model3 were even more accurate than model2. The results illustrated that the importance of maternal permanent environmental effects is higher than direct and maternal genetic effects for BW0. It implies that rearing of dams, healthcare and feeding are very important determinants of BW0. Therefore, in terms of hatching weight, the genes of the dam are important but management and environmental conditions are very crucial. Similar results were found by PRADO-GONZALEZ et al. (2003) in Creole chickens of Southeastern Mexico. SAATCI et al. (2006) estimated maternal heritability (0.74) and maternal permanent environmental effect (0.24) for BW0 in Japanese quail.

For BW at wk 1 to 7, genes of birds and genes of their dams were important factors but permanent environmental effects of dams were not considerable. Therefore, rearing and management condition of dams are not important factors in the performance of birds. CATTERALL and POLLOTT (1996) reported maternal heritability (0.55) in chicken. The significance of maternal genetic effect for body weight traits suggested that maternal effect plays an important role in body weight at different ages. There was an increasing trend for direct genetic effects and a declining trend for maternal genetic effects from BW0 to BW42, suggesting that maternal genetic effects are less important at older ages. CHAMBERS (1990) notified that direct heritabilities for body weight of broilers tend to increase with age. PRADO-GONZALEZ et al. (2003) and NORRIS and NGAMBI (2006) studied genetic parameters for BW from hatching to 21 weeks and observed that maternal genetic and maternal permanent environmental effects disappear as birds grow older.

Estimated direct heritability of body weight traits by correct models, were moderate to high (0.15–0.42). It would suggest that selection at any stage of growth will result in considerable genetic progress, especially at 42 days of age. Genetic correlations between direct genetic effects and maternal effects showed moderately negative values, but the high SD of the estimates indicated that this parameter could not be accurately estimated. The antagonism between the additive direct and maternal effects has been observed in other domestic species (Tosti and KEMP, 1994; DIOP and VAN VLECK, 1998; VAJ et al., 2010). Genetic and phenotypic correlations of body weight traits are presented in Table 3. Approximated SE of parameters

<table>
<thead>
<tr>
<th>Trait</th>
<th>h²a</th>
<th>h²m</th>
<th>rma</th>
<th>c²</th>
<th>M1–M2</th>
<th>M2–M3</th>
<th>Best model</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW0</td>
<td>0.90 ± 0.03</td>
<td>0.20 ± 0.11</td>
<td>-0.59 ± 0.24</td>
<td>0.60 ± 0.06</td>
<td>0.15 ± 0.11</td>
<td>0.20 ± 0.10</td>
<td>0.41 ± 0.12</td>
</tr>
<tr>
<td>BW7</td>
<td>0.50 ± 0.04</td>
<td>0.15 ± 0.09</td>
<td>-0.70 ± 0.29</td>
<td>0.29 ± 0.06</td>
<td>0.15 ± 0.11</td>
<td>0.20 ± 0.10</td>
<td>0.41 ± 0.12</td>
</tr>
<tr>
<td>BW14</td>
<td>0.34 ± 0.05</td>
<td>0.19 ± 0.08</td>
<td>-0.82 ± 0.22</td>
<td>0.24 ± 0.06</td>
<td>0.15 ± 0.11</td>
<td>0.20 ± 0.10</td>
<td>0.41 ± 0.12</td>
</tr>
<tr>
<td>BW21</td>
<td>0.43 ± 0.05</td>
<td>0.25 ± 0.09</td>
<td>-0.77 ± 0.19</td>
<td>0.27 ± 0.06</td>
<td>0.15 ± 0.11</td>
<td>0.20 ± 0.10</td>
<td>0.41 ± 0.12</td>
</tr>
<tr>
<td>BW28</td>
<td>0.45 ± 0.05</td>
<td>0.24 ± 0.08</td>
<td>-0.87 ± 0.18</td>
<td>0.30 ± 0.06</td>
<td>0.15 ± 0.11</td>
<td>0.20 ± 0.10</td>
<td>0.41 ± 0.12</td>
</tr>
<tr>
<td>BW35</td>
<td>0.41 ± 0.04</td>
<td>0.32 ± 0.05</td>
<td>-0.34 ± 0.19</td>
<td>0.16 ± 0.03</td>
<td>0.15 ± 0.11</td>
<td>0.20 ± 0.10</td>
<td>0.41 ± 0.12</td>
</tr>
<tr>
<td>BW42</td>
<td>0.43 ± 0.04</td>
<td>0.42 ± 0.05</td>
<td>-0.45 ± 0.15</td>
<td>0.14 ± 0.03</td>
<td>0.15 ± 0.11</td>
<td>0.20 ± 0.10</td>
<td>0.41 ± 0.12</td>
</tr>
</tbody>
</table>

1 h²a = direct heritability, h²m = maternal heritability, c² = ratio of maternal permanent environment effect to phenotypic variance
2 likelihood ratio test between M1 (model1), M2 (model2) and M3 (model3)
3 Best models was determined based on likelihood ratio test
* P ≤ 0.05
** P ≤ 0.001
were rather low. Genetic correlations among body weight traits were generally high. In most investigations, high genetic correlations among weights at different ages were found (Akbas et al., 2004; Váli et al., 2005; Shokooehmand et al. 2007; Narine et al., 2010). The highest genetic and phenotypic correlations were found between BW28 and BW35 (0.99 and 0.83, respectively), which is similar to report of Akbas et al. (2004) and Resende et al. (2005). Akbas et al. (2004) reported that genetic correlations between BW28 and BW35 were 0.87.

Genetic correlations between adjacent weeks were higher than distant weeks. Moreover, genetic correlations of BW0 with other body weight traits were lower than others. It shows although, genes controlling BW7 to BW42 are more or less the same, BW0 is also controlled by some different genes.

In conclusion, present results revealed the importance of permanent maternal environment effects for body weight at hatching day and maternal genetic effects for body weight at 7–42 days of age. Present results suggested that body weight at hatch couldn’t be used as a selection criterion to improve body weight at slaughter age (BW35 or 42) and it is better to select birds based on BW7, instead.

Summary

The objective was to estimate direct and maternal genetic effects for body weight at different ages of Japanese quail. Genetic and phenotypic correlations were also estimated among body weight traits. In the first generation, 96 male and 192 female birds were randomly selected and one among body weight traits was generally high. In most investigations, high genetic correlations among weights at different ages were found (Akbas et al., 2004; Vali et al., 2005; Shokooehmand et al. 2007; Narine et al., 2010). The highest genetic and phenotypic correlations were found between BW28 and BW35 (0.99 and 0.83, respectively), which is similar to report of Akbas et al. (2004) and Resende et al. (2005). Akbas et al. (2004) reported that genetic correlations between BW28 and BW35 were 0.87.

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Zusammenfassung

Direkte und maternale genetische Effekte für Körpergewichtsmerkmale bei der Japanischen Wachtel (Coturnix coturnix japonica)


Das Modell 2 erwies sich als am besten geeignet für die Körpergewichtsmerkmale, außer für das Schlupfgewicht (BW0). Für BW0 war das Modell 3 am besten geeignet. Für das Schlupfgewicht (BW0) wurde eine Heritabilität von 0.15 geschätzt, für das Lebendgewicht am 7., 14., 21., 28., 35. und 42. Lebenstag (LT) Heritabilitäten von 0,15, 0,19, 0,25, 0,24, 0,32 bzw. 0,42. Die entsprechenden Schätzwerte für die materiale Heritabilität waren 0,60, 0,29, 0,24, 0,27, 0,30, 0,16 und 0,14. Die direkten genetischen Effekte nahmen mit dem Alter zu und die maternalen, genetischen Effekte nahmen mit dem Alter ab. Hierauf wurde der Schluss gezogen, dass die Bedeutung der maternalen, genetischen Effekte mit dem Alter der Nachkommen abnimmt. Die höchsten und die geringsten genetischen Korrelationen zwischen den direkten und den maternalen, direkten Effekten wurden am 35. (–0,49) und am 28. (–0,87) Lebenstag ermittelt. Die höchsten phänotypischen und genetischen Korrelationen wurden für BW28 und BW35 geschätzt (0,83 und 0,99). Die vorliegenden Ergebnisse deuten darauf hin, dass das Schlupfgewicht nicht als Selektionskriterium zur Selektion auf Lebendgewicht bei der Schlachtung (LT 35 oder 42) geeignet ist, sondern dass eine Selektion auf das Körpergewicht am 7. Lebensstag (BW7) Erfolg versprechender ist.

Stichworte

Wachtel, genetische Effekte, maternal, Umwelt, Körpergewicht

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Key words

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