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Artificial rearing may result in changes in the physiology and anatomy of gallinaceous birds. This may partially explain the poor survival of released birds. To study the effects of hand-rearing on grey partridges *Perdix perdix*, we measured the anatomical and physiological characteristics of 14 wild and 15 hand-reared partridges. Captive partridges were heavier, had relatively larger breast muscles but relatively lighter hearts and livers than wild birds. Wild birds had longer small intestines, longer caeca and relatively heavier gizzards than hand-reared birds. They also had higher glycogen content and cytochrome-c oxidase activity in the pectoral muscles, indicating their better flying endurance compared to hand-reared birds. The results suggest that captivity results in altered anatomical and physiological characteristics, and hand-reared partridges may therefore be poorly predisposed for an abrupt release into the wild.

Key words: Grey partridge, Perdix perdix, hand-rearing, captivity, physiology, anatomy.

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Rearing birds for release is a traditional gamebird management technique. Hundreds of thousands of grey partridges are annually released in Europe, and rearing for release accounts for a large proportion of the expenses used in partridge management (Potts 1986). However, evidence of a sustained contribution to the wild stock by released birds has remained limited. Predators are usually considered to be the main reason for the poor survival and breeding success of released partridges (Birkan 1971, Panek 1988). Abnormal behaviour has been suggested to make released birds vulnerable to predation (Paludan 1963, Panek 1988, Dowell 1990, Putaala & Hissa 1993). In addition, hand-reared birds may differ both physiologically and anatomically from wild birds, and may thus be less suited for optimal foraging and escaping from predators in the wild. Large numbers of healthy-looking partridges can be raised in captivity, but it is probably difficult to produce birds that are physiologically adapted to living in the wild. Artificial rearing of birds in captivity has earlier been demonstrated to affect intestinal tract morphology both in some *Phasianidae* (Majewska et al. 1979, Paganin & Meneguz 1992) and *Tetraonidae* species (Moss 1972, Pendergast & Boag 1973, Hanssen 1979a). Evidence that reared gallinaceous birds may also differ from wild birds in regard to the relative weight of muscles and organs has been given (Hissa et al. 1990, Fehlberg et al. 1992).

The objective of this study was to determine the effects of hand-rearing on grey partridge physiology and anatomy and compare similar results obtained from wild birds.

Methods

Fifteen hand-reared, juvenile (9 months old), male partridges (7 birds in 1992 and 8 birds in 1993) were collected in early April from the University Zoo in Oulu, Finland. The birds were derived from wild stock in Tyrnävä (64°50'N, 25°37'E), near the city of Oulu, Finland, and had been reared for 1-2 generations in captivity. The birds were housed in 20 m² outdoor pens (12-15 birds per pen) and fed a commercial chicken food mixture (17% protein, 7.5% fat, 5.5% fibre), grain seeds ad libitum and provid-

ed with water or snow. Fourteen wild male partridges (11 juvenile and 3 adult) were collected in Tyrnävä between 27 March and 1 April 1992 (6 birds) and between 21 and 30 March 1993 (8 birds). The birds were caught with walk-in traps using hand-reared females as decoys. Before being used in our study, the captured birds were weighed and transported to the Zoo and kept for 0-12 days in pens similar to those of the hand-reared birds. During captivity the wild birds were maintained on a diet similar to that of hand-reared partridges. Food was removed one day before the dissection.

We weighed each bird to the nearest gram and killed them by decapitation. Tissue samples for biochemical analyses were collected immediately after decapitation. We dissected muscle samples from pectoral muscles (*musculus pectoralis major* and *musculus supracoracoideus*) and the leg muscle (*musculus iliotibialis*) from the left side of the body. We also took samples from the heart and the liver. All tissue samples were rapidly frozen in liquid nitrogen after removal, weighed to the nearest 0.001 g, and stored at -40°C until further processing. The heart was severed from its major veins, split to clean out the blood and weighed. The liver was also dissected and weighed.

Pectoral and leg muscles were dissected from the right side of the body and non-muscle tissues were carefully removed. These muscles were weighed to the nearest 0.01 g. The length of the small intestines and caeca was measured to the nearest 0.5 cm after cutting the mesenteries and straightening the gut. The emptied gizzards were weighed without the inner cuticle.

Tissue water, neutral fat and ash contents were measured using the method described by Hissa et al. (1990). Glycogen content of muscles and livers was assayed using the method described by Lo et al. (1970). Activity of cytochrome-c oxidase, the terminal enzyme in the mitochondrial respiratory chain, was chosen to represent the oxidative tissue capacity. Cytochrome-c oxidase activity was determined in mitochondrial fractions using the method of Rafael et al. (1970), as modified by Saarela et al. (1989). Mitochondria were separated, and mitochondrial protein content was analysed using the method described by Rafael et al. (1970).

Statistical analysis of the data was carried out using SPSS statistical software. We used Student's t-test (two-tailed) or Mann-Whitney U-test, when appropriate, to compare data from the two years. Data from the different years were pooled when no differences existed between the years. We compared the pooled values of hand-reared and wild partridges with the Student's t-test (two-tailed). However, the four percentages of tissue composition (fat, protein, water and ash) were first transformed to three log ratios, log(fat/ash), log(protein/ash) and log(water/ash), and then tested with MANOVA to compare tissue composition between the years and between the wild and hand-reared birds (see Aitchison 1986).

Table 1. Morphological and anatomical parameters and relative composition of organs (% of body weight) for wild (n = 14) and captive, hand-reared (n = 15) male grey partridges.

		Wild mean	SE	Captive mean	SE	t	P
Body weight	(g)	353	6.3	383	7.0	3.13	0.004
Pectoral muscles							
Musculus pectoralis major	(g) [a]	32.8	0.99	37.5	0.99	3.31	0.003
	(%) [a]	9.3	0.15	9.8	0.24	1.82	0.079
Musculus supracoracoideus	(g) [a]	11.5	0.37	13.7	0.27	4.83	0.000
	(%) [a]	3.3	0.07	3.6	0.07	3.57	0.001
Leg muscles	(g) [a]	25.6	0.66	27.1	0.59	1.66	0.109
Leg muscles	(%) [a]	7.2	0.09	7.1	0.16	0.85	0.403
Heart	(g)	3.3	0.11	3.1	0.09	1.02	0.142
Heart	(%)	0.9	0.02	0.8	0.02	3.54	0.001
Liver	(g)	7.0	0.45	6.0	0.21	2.19	0.037
Liver	(%)	2.0	0.13	1.6	0.05	3.16	0.004
Gizzard	(g)	11.4	0.47	9.2	0.29	3.97	0.000
Gizzard	(%)	3.2	0.12	2.4	0.08	5.43	0.000
Small intestine length	(cm)	62.1	1.15	56.6	1.06	3.57	0.001
Combined caecal length	(cm)	30.0	1.15	26.2	0.59	3.05	0.005

[a]) Dexter muscle only

Table 2. Composition and glycogen content of tissues in wild (n = 14, except for glycogen n = 13) and captive (n = 15) male grey partridges. The values are expressed as means ± S.E. For statistical comparison the 4 percentages of composition were transformed to three log ratios, and differences between wild and captive birds were tested by MANOVA. Comparisons of glycogen content between wild and captive birds were performed with logaritmically transformed values by t-test; * P = 0.05, ** P = 0.01, *** P = 0.001.

Tissue Origin	Fat (%)	Protein (%)	Water (%)	Ash (%)		Glycogen (mg/g)	
Pectoral muscle (*musculus pectoralis major*)							
Wild	2.1 ± 0.34	24.5 ± 0.43	72.1 ± 0.47	1.3 ± 0.05	ns.	4.2 ± 1.47	***
Captive	2.1 ± 0.46	25.9 ± 0.51	70.7 ± 0.41	1.3 ± 0.04		07. ± 0.12	
Leg muscle (*musculus iliotibialis*)							
Wild	1.4 ± 0.38	23.2 ± 0.36	74.1 ± 0.50	1.3 ± 0.05	ns.	2.6 ± 1.01	**
Captive	1.7 ± 0.34	23.0 ± 0.32	74.0 ± 0.16	1.4 ± 0.02		0.8 ± 0.25	
Liver							
Wild	8.2 ± 1.50	20.1 ± 1.34	70.5 ± 2.29	1.3 ± 0.11	***	28.7 ± 7.65	***
Captive	6.2 ± 0.70	25.8 ± 0.55	66.4 ± 0.58	1.5 ± 0.05		3.2 ± 0.93	

Results

The tests performed to compare data between the different years did not reveal any significant differences and the data of the different years were pooled. Compared to wild partridges, captive birds were heavier (t=3.13, P=0.004) and had relatively heavier pectoral muscles (*pectoralis major*: t=1.82, P=0.079, *supracoracoideus*: t=3.57, P=0.001) (Table 1). Conversely, the wild partridges had relatively heavier hearts (t=3.54, P=0.001), livers (t=3.16, P=0.004) and gizzards (t=5.43, P<0.001) than the hand-reared birds. The relative weight of the leg muscles was almost the same in both groups (t=0.85, P=0.403). The wild birds had longer small intestines (t=3.57, P=0.001) and caeca (t=3.05, P=0.005) than the captive birds.

The composition of the muscles was not significantly different (*pectoralis major*: F=1.81, P=0.172, *musculus iliotibialis*: F=1.79, P=0.176), but the composition of the liver differed significantly between the wild and the hand-reared birds (F=12.54, P<0.001, Table 2). The wild birds had more glycogen in all the examined tissues. Activity of cytochrome-c oxidase enzyme was higher (t=2.88, P=0.008) in the pectoral muscle of the wild birds than in the pectoral muscle of the hand-reared individuals. The cytochrome-c oxidase activity in the liver did not differ between the wild and the hand-reared birds (t=0.89, P=0.381, Table 3).

Table 3. Cytochrome-c oxidase activity of mitochondrial fraction (COXmito, U/mg mitochondrial protein) and the mitochondrial protein content (mg/g) in the pectoral muscle and liver of wild (n = 13) and captive (n = 15) grey partridges.

	Wild birds		Captive birds			
Tissue	mean	SE	mean	SE	t	P
Pectoral muscle, major						
COXmito	1.5	0.20	0.8	0.14	2.88	0.008
proteins	4.9	0.59	4.1	0.59	0.86	0.399
Liver						
COXmito	0.9	0.08	1.0	0.05	0.89	0.381
proteins	28.1	2.67	30.2	2.13	0.64	0.529

Discussion

Dahlgren (1987) gives evidence which shows that the vigilance behaviour, not the size of the male, is the predominant selection criterion of females in the grey partridge. As we captured the wild birds at the normal pairing time of the grey partridge, the method used is not expected to bias the data by selecting birds in a poor fit. The greater body weight of the captive birds compared with the wild birds is probably a consequence of higher-quality food and less exercise in captivity. Robertson et al. (1991) also suggested that hand-rearing increases the body weight of pheasants *Phasianus colchicus*. However, Fehlberg et al. (1992) showed that hand-reared pheasants had lighter breast muscles than wild birds. Conversely, the leg muscles of the hand-reared pheasants were much heavier. However, we did not find any evidence of atrophy in the breast muscles or hypertrophy in the leg muscles of the hand-reared partridges, when compared with the wild partridges. Our results are in accordance with the results of Majewska et al. (1979) on pheasants. Hissa et al. (1990) did not find any atrophy of breast muscles in captive capercaillie *Tetrao urogallus* either. However, as demonstrated by Fehlberg et al. (1992), the growing of muscles

in hand-reared birds may vary widely depending on the density of the individuals and their opportunity to exercise in captivity.

The higher cytochrome-c oxidase activity in the breast muscles of wild partridges may indicate that their flying endurance is better than that of hand-reared birds. Furthermore, higher glycogen reserves in the muscles and livers of the wild birds, as also shown in pheasants (Majewska et al. 1979), might be beneficial when escaping from predators, as glycogen is the primary energy source during take-off and the initial phase of flight (Parker & George 1975). Thus, low glycogen reserves together with the low oxidative capacity of the pectoral muscles and high body mass could seriously threaten the survival of released birds. Our unpublished results concerning the flying ability of wild and hand-reared partridges support the view that wild partridges indeed are better fliers than hand-reared birds.

Artificial feeding has been documented to shorten the intestinal tract in red grouse *Lagopus lagopus scoticus* (Moss 1972), spruce grouse *Dendragapus obscurus* (Pendergast & Boag 1973), willow grouse *Lagopus lagopus lagopus* (Hanssen 1979a) and rock partridge *Alectoris graeca* (Paganin & Meneguz 1992). The differences in the size of the gizzard and the length of the small intestine and caeca between wild and hand-reared birds suggest differences in food digestion efficiency and assimilation. The gizzard plays an important role in grinding food items with the help of abrasive grits. A larger gizzard may indicate a more effective grinding process in wild partridges compared to hand-reared birds. It appears that the gastrointestinal tract of a wild partridge is adapted to process harder food, in larger amounts, than the gut of a hand-reared partridge. Wild birds need high food consumption capacity when foraging on a diet which is more fibrous and less digestible than the food offered in captivity. The observed differences in the weight and composition of the liver between wild and hand-reared partridges are probably also attributable to different diets.

The microfauna of the gut may also differ between wild and hand-reared birds (see Hanssen 1979b). The adaptation of the morphology and microorganisms of the gastrointestinal tract to a new diet may take up to 3-4 months (Redig 1989). Therefore it appears to be most important that birds reared for release have been accustomed to natural food during captivity. The capability of efficient foraging behaviour and survival ability of a released bird is dependent on the utilisation efficiency of wild diet. This, in turn, presupposes that the gastrointestinal tract is well adapted to utilise a natural diet (Thomas 1987).

Our results suggest that after release, hand-reared partridges may have difficulties in utilising natural food and escaping from predators. We suggest that partridges should be properly trained for release by feeding them natural food items and keeping them in large pens for at least 1-2 months before release. By these means it may be possible to improve their ability to escape from predators and to use a natural diet. For future work, more research is needed on refinements in rearing techniques that would improve both behavioural and physiological performances of released birds. The validity of the refinements should be tested in the field.

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