Received: 2 March 2023 | Revised: 11 November 2023 | Accepted: 15 December 2023

DOI: 10.1002/vetr.3828

VetRecord

ORIGINAL RESEARCH

Neurological examination of clinically healthy pigeons (*Columba livia domestica*), mute swans (*Cygnus olor*), common buzzards (*Buteo buteo*), common kestrels (*Falco tinnunculus*) and northern goshawks (*Accipiter gentilis*)

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Abstract

Background: A neurological examination is essential for determining the localisation of neurological lesions. However, in avian species, quantitative data regarding the practicability and feasibility of neurological tests are very limited. Therefore, the aim of this study was to establish normative data for the neurological examination of clinically healthy birds of different species.

Methods: Forty-two domestic and feral pigeons (*Columba livia domestica*), 42 mute swans (*Cygnus olor*), 12 common buzzards (*Buteo buteo*), 24 common kestrels (*Falco tinnunculus*) and six northern goshawks (*Accipiter gentilis*) were examined. All birds underwent a predefined neurological examination. Interobserver variations between three examiners were investigated in 11 pigeons and 11 mute swans.

Results: All postural reaction tests, except for the drop and flap reaction in mute swans, provoked a consistent response in pigeons and mute swans, whereas postural reaction tests of the legs in raptors were often not performable. Cranial nerve tests and most of the spinal reflexes revealed variable responses in all birds. The gastrocnemius reflex was not provokable in any bird. Interobserver agreement was almost perfect (Gwet's AC1 coefficient $\geq$0.81) for 16 of 21 parameters in the examination in pigeons and for 14 of 21 in mute swans.

Limitations: The inclusion of free-ranging birds, which were not used to handling and for which limited information regarding age, history of previous diseases, etc. was available, may have influenced the results.

Conclusion: The normative neurological examination data provided in this study will help improve clinicians' interpretation of neurological examination results in the respective bird species.

KEYWORDS
avian neurological examination, feral pigeons, mute swans, neurology, raptors

INTRODUCTION

Avian patients with neurological disorders are frequently presented to veterinary practices; however, examination of these patients can be challenging. The aim of a neurological examination is to identify the neuroanatomical localisation of the causative lesion(s) within the nervous system.[1] The neurological examination of small and large domestic animals has been described by several authors,[1–3] with de Lahunta et al.[1] suggesting that the examination protocol used in a cooperative dog can be adapted to any other animal species.

In the recent literature, studies tested the applicability of modified neurological examinations in healthy exotic small mammals[4–6] and reptile species.[7,8] In these studies, certain neurological tests, such as the gag reflex in chinchillas[5] and hedgehogs,[4] were not performable due to anatomical reasons or handling challenges. Additionally, some responses or reflexes, such as the menace response or the perineal/cloacal reflex, were not provokable at all[4–7] or only in a few individuals.[8]

Techniques for the neurological examination of birds described by several authors.[9–13] However, normative data from healthy individuals, like they were obtained from the aforementioned small mammal[4–6] and reptile[7,8] species, are limited to neuro-ophthalmic tests in various avian species[14–20] and cranial nerve reflexes in different states of consciousness in turkeys and layer hens.[21]

Given the differences in anatomy and physiology between birds and mammals, as well as the huge variety of avian species, it is likely that not all tests are equally useful for every species. Distinct reaction patterns between predator and prey species, as suggested for small mammals like rabbits,[6] can also be assumed.

The purpose of this study was to evaluate the feasibility, applicability and interobserver agreement of neurological examinations in clinically neurologically unremarkable individuals of different avian species.

MATERIALS AND METHODS

Study design

To test the applicability of the neurological examination tests for a species, sample size calculation was performed using PASS (version 14.0.7). The power analysis using a one-sided exact test to detect a non-inferiority proportion of 0.75 (significance level of 0.05, power of 80%) resulted in a required sample size of 42 individuals per examination group.

For the interobserver agreement, birds were repeatedly examined by three different examiners. Due to animal welfare reasons, the group sizes were limited to 11 animals per species.

Birds

The study was registered and authorised by the Regional Office for Health and Social Affairs Berlin (LAGeSo) (no. A 0176/18).

To compare the data between different avian species, three examination groups were planned, representing prey and predator species. Individuals were mainly recruited from free-ranging birds presented to the Small Animal Clinic, Freie Universität Berlin, between 2018 and 2020. Species were chosen by frequency of presentation during the study period.

Group 1 consisted of feral and domestic pigeons (*Columba livia domestica*) and group 2 of mute swans (*Cygnus olor*). During the study period, common buzzards (*Buteo buteo*), common kestrels (*Falco tinnunculus*) and northern goshawks (*Accipiter gentilis*) were presented multiple times to the clinic. However, the number of individuals per species was less than the calculated group size of 42. Therefore, group 3 had to be excluded from the statistical analysis. The results of these examinations are included in the 'Results' section to illustrate trends of the examination in these species. Table 1 summarises group compositions including parameters such as number, species, age and weight.

The free-ranging birds were brought to the Small Animal Clinic by members of the public due to health concerns and were included in the study only after their full recovery. Additionally, 18 healthy domestic pigeons kept for research purposes were provided for examination by the Institute of Poultry Diseases, Freie Universität Berlin. A total of 126 birds were examined.

Prior to inclusion in the study, free-ranging individuals underwent further diagnostics (e.g., radiological examination) and case-dependent further treatment. Birds were included in the study when a full physical examination revealed no abnormal findings, thus considering them suitable for release. The bodyweight and age (adult or juvenile) of each bird were also recorded. The age was determined based on the plumage and colour of the bill, cere and iris, depending on the respective species.[22–24] No nestlings were included. Due to the lack of pronounced sexual dimorphism in most of the examined species (with the exception of goshawks and adult kestrels), sex was not assessed in this study.

The free-ranging birds were hospitalised in single cages and the pigeons from the Institute of Poultry Diseases were kept as a group in an outdoor aviary.

Neurological examination

All birds underwent the same neurological examination by the first author (S.F.), who was previously trained by a board-certified veterinary neurologist (S.L.). The results of the examination were recorded on an examination form immediately afterwards. The feasibility of the test, as well as the observed responses (not performable; 2 = normal, 1 = decreased, 0 = absent), were noted.

To assess interobserver agreement, 11 animals from each of groups 1 and 2 were, in addition to the examination by the first author, examined by an exotic pet veterinarian and by a final-year veterinary student, both of whom had no prior training by a neurologist. The order of raters was randomised. They were provided with the same examination protocol form and a description of the tests (performance and expected response). Examinations were repeated three times in total by each examiner, with a maximum of two examinations per day for each bird.

The neurological tests and examinations were performed and modified where required (S.L.), based on the described information for birds[9,10,12,13,25,26] and companion animals.[1] The neurological examination included mental status, gait, posture, cranial nerve tests, postural reactions and segmental spinal nerve assessment.

TABLE 1 Composition (number of examined birds [*N*], species, weight and age [juvenile or adult]) of the three examination groups used for evaluation of a neurological examination protocol

Group	*N*	Species	Weight	Juvenile	Adult
1	42	Feral and domestic pigeon (*Columba livia domestica*)	0.23–0.99 kg (median 0.35 kg)	8	34
2	42	Mute swan (*Cygnus olor*)	5–12.8 kg (median 7.6 kg)	13	29
3	12	Common buzzard (*Buteo buteo*)	0.56–1 kg (median 0.76 kg)	3	9
	24	Common kestrel (*Falco tinnunculus*)	0.16–0.24 kg (median 0.22 kg)	22	2
	6	Northern goshawk (*Accipiter gentilis*)	0.7–1.39 kg (median 0.93 kg)	3	3

The birds were observed in their enclosures to evaluate their mental status, gait and posture. The mental status was evaluated as normal when the birds were bright and alert. Gait was assessed for any paresis, ataxia or lameness. Posture was considered normal in the raptor and pigeon groups when the birds were perched in an erect posture and in swans when the birds were standing straight with both legs bearing weight equally and the head in an upright position.

Birds were carefully restrained by an experienced assistant for testing the cranial nerves and the spinal reflexes. For postural reaction tests, birds were restrained by the examiner. Cranial nerve testing was performed first and comprised of the response to an auditory stimulus, menace response, palpebral and direct pupillary light reflex, assessment of facial symmetry, facial sensation, the oculocephalic reflex, gag reflex and closure and tone of the beak.

Finger snapping next to each ear without fixating the head was used to assess any reaction (head or body movement) to an auditory stimulus. The menace response was tested by moving the examiner's hand towards each eye and the palpebral reflex by touching the medial and lateral canthus of each eye using a cotton tip applicator. The expected response was a subsequent blink (closure of the eyelid or nictitating membrane). The direct pupillary light reflex was assessed by using a pen torch. The facial symmetry of the head, including its anatomical structures (feathers, eye position within the orbit, palpebral fissures), was also assessed.

Facial sensation was evaluated for any reaction while touching the skin of the forehead, the nares and the rictus with the wooden end of a cotton tip applicator. The oculocephalic reflex was elicited by moving the head of the bird in a horizontal plane to induce a physiological nystagmus. The gag reflex was provoked by opening the beak and touching the oropharynx with a cotton tip applicator, in this regard closure and tone of the beak were also evaluated.

Postural reactions were tested on an examination table in pigeons and raptors and on the floor in mute swans. Hopping was performed by holding one leg up and pushing the bird to the side to evaluate the compensatory response of the weight-bearing leg. The process was then repeated on the opposite leg. The bird was subsequently lowered to the ground or a table with unrestrained pelvic limbs and then pushed backwards to elicit the extensor postural thrust reaction; here, the pelvic limbs should bear weight and move in a walking fashion.

Foot and wing replacement were assessed by placing the foot repeatedly on its dorsal surface and by pulling each wing away from the body to evaluate if the bird readjusts the extremity to its normal position. The drop and flap reaction was evaluated by moving the bird downwards with unfixed wings to provoke flapping with both wings equally. During this process, the birds' legs were restrained with both hands while simultaneously providing support to the body with the hands during the downward motion.

Spinal nerve tests included examination of thoracic and pelvic limb withdrawal, patellar, gastrocnemius and vent sphincter reflexes. To test the withdrawal reflexes, a gentle pinch stimulus to the skin of each foot and the skin of the major digit of each wing with a haemostat was performed to generate flexion of the leg/wing. The patellar and the gastrocnemius reflex were tested by striking the respective tendon with a reflex hammer in swans and with the handle of a mosquito haemostat in pigeons and raptors to generate extension of the stifle (patellar reflex) or the hock (gastrocnemius reflex). For assessment of the vent sphincter reflex, the cloaca was gently pricked by a cotton tip applicator and observed for a contraction of the external sphincter.

The pectoralis muscle and the muscles of the legs were palpated for symmetry and tone in the latter. The head and neck were rotated to check for any pain or resistance.

Data analysis

Statistical analysis was performed using R (version 4.0.5). The 95% confidence interval for each test of the neurological examination was computed according to the Wilson score interval using the Hmisc package in R.

The interobserver agreement metrics were calculated using the irrCAC v.1.0 package in R. The percentage agreement between raters was determined for each test. The reliability of the observed agreements was also assessed using the kappa statistic. Since the Fleiss kappa calculation resulted in paradox results due to a skewed frequency distribution of given ratings,[27] the Gwet's AC1 coefficient, a more paradox-resistant beyond chance agreement coefficient,[28] was computed to evaluate interobserver agreement. According to Landis and Koch[29] Gwet's AC1 values were interpreted as the following: 0.20 or less = poor agreement, 0.21–0.40 = fair agreement,

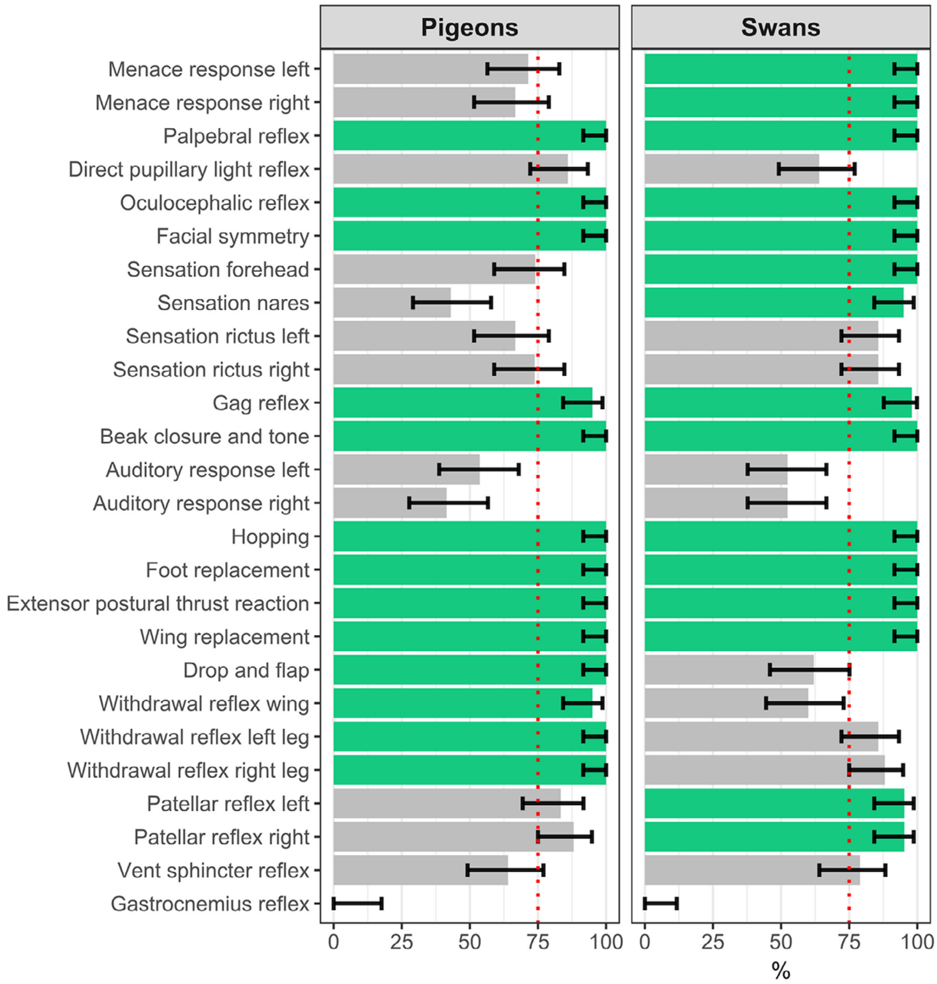

FIGURE 1 Proportion of healthy pigeons ($n = 42$) and mute swans ($n = 42$) in which a response to each neurological test could be evaluated. Bars are coloured in green if the lower confidence interval is above 75% (red dotted line), and hence the test can be considered useful for the concerned species

0.41–0.60 = moderate agreement, 0.61–0.80 = substantial agreement and 0.81–1 = almost perfect agreement.

RESULTS

In this study, a neurological test was considered useful for the total population of the species when a response was provokable and could be evaluated in 38 or more (>90%) of the 42 individuals of each group (Figure 1). The results for each species are summarised in Tables 2–4.

Physical examination was normal in all birds and every individual tolerated a full neurological examination. Mentation, gait, posture, symmetry and tone of muscles, as well as head and neck movement, were determined to be normal in all animals.

Cranial nerve tests

Facial symmetry and the closure and tone of the beak were normal in all subjects of all groups. The oculocephalic and palpebral reflex could be induced in all birds, and the gag reflex was consistently provokable in swans (41/42, 98%) and pigeons (40/42, 95%).

A menace response was present in all swans, but only in 30 (71%) of the pigeons. In two pigeons, there was a positive result in only one eye. In all three raptor species, the menace response was regularly absent. Notably, when testing the menace response and palpebral reflex, closure of the nictitating membrane rather than the eyelid appeared in all swans. This finding was also observed in all three raptor species, except for single kestrels that closed their eyelids. In contrast, most pigeons blinked with their eyelid (menace response 27/30, 90%; palpebral reflex 41/42, 98%).

Facial sensation testing was most successful in swans, when touching the forehead (42/42, 100%) or nares (40/42, 95%). In the other groups, responses were seen irregularly.

Direct pupillary light reflex and auditory response testing revealed inconsistent results in all groups.

Postural reactions

Most postural reaction tests (hopping, foot and wing replacement, extensor postural thrust reaction) were

TABLE 2 Results of the neurological examination of 42 clinically healthy feral and domestic pigeons (*Columba livia domestica*)

Neurological parameter	Positive response/successfully tested birds Left	Right	Positive response Left	Right	95% confidence interval (%) Left	Right
Cranial nerves						
Menace response	30/42	28/42	71%	67%	56.43–82.83	51.55–78.99
Palpebral reflex	42/42		100%		91.62–100	
Direct pupillary light reflex	36/42		86%		72.16–93.28	
Oculocephalic reflex	42/42		100%		91.62–100	
Facial symmetry	42/42		100%		91.62–100	
Sensation forehead	31/42		74%		58.93–84.70	
Sensation nares	18/42		43%		29.12–57.79	
Sensation rictus	28/42	31/42	67%	74%	51.55–78.99	58.93–84.70
Gag reflex	40/42		95%		84.21–98.68	
Beak closure and tone	42/42		100%		91.62–100	
Auditory response	22/41	17/41	54%	41%	38.75–67.94	27.76–56.63
Postural reactions						
Hopping	42/42		100%		91.62–100	
Foot replacement	42/42		100%		91.62–100	
Extensor postural thrust reaction	42/42		100%		91.62–100	
Wing replacement	42/42		100%		91.62–100	
Drop and flap	42/42		100%		91.62–100	
Spinal reflexes						
Withdrawal reflex wing	40/42		95%		84.21–98.68	
Withdrawal reflex leg	42/42		100%		91.62–100	
Patellar reflex	35/42	37/42	83%	88%	69.40–91.68	75.00–94.81
Vent sphincter reflex	27/42		64%		49.17–77.01	
Gastrocnemius reflex	0/18		0%		0–17.59	

successfully completed and assessed in all 42 (100%) pigeons and swans.

In raptors, the postural reaction tests of the pelvic limbs could often not be carried out because individuals (especially goshawks and kestrels) did not tolerate testing and reacted with pronounced defensive behaviour. Furthermore, examiners were required to release their hold on the pelvic limbs of the raptors, which led to inadequate restraint and an increased potential for injuries caused by the raptors' talons. The drop and flap reaction could be elicited in all pigeons and raptors, but the expected wing flapping was absent in 15 of 39 (38%) swans. In three swans, this test could not be performed due to difficulties in lifting these birds.

Spinal reflexes

All pigeons and raptors exhibited a withdrawal reflex of the legs. Meanwhile, in swans, it was not provokable in five of 42 (12%) animals and was was only present in one leg in another. In the swan and raptor groups, the patellar reflex was positive in all birds except one kestrel and two swans. The patellar reflex could also be elicited in 37 of 42 (88%) pigeons, but in two pigeons it was only positive in one leg.

The vent sphincter reflex testing resulted in variable responses (33/42 [79%] swans; 27/42 [64%] pigeons; 7/12 [58%] buzzards; 5/6 [83%] goshawks; 21/24 [88%] kestrels). The gastrocnemius reflex was absent in all animals of all groups.

Interobserver agreement

Interobserver agreement was assessed for pigeons and mute swans (Table 5).

The three examiners agreed almost perfectly (Gwet's AC1 0.81–1) in most of the cranial nerve tests. Substantial agreement (Gwet's AC1 0.61–0.8) was noted for the pupillary light reflex in both groups, the sensation of the nares in pigeons and the auditory response in swans, while moderate agreement (Gwet's AC1 0.41–0.6) was noted for the auditory response in pigeons.

Interobserver agreement was almost perfect in all postural reaction tests in both species except the drop and flap reaction in mute swan, where only moderate agreement was observed.

TABLE 3 Results of the neurological examination of 42 clinically healthy mute swans (*Cygnus olor*)

Neurological parameter	Positive response/ successfully tested birds		Positive response		95% confidence interval (%)	
	Left	Right	Left	Right	Left	Right
Cranial nerves						
Menace response	42/42		100%		91.62–100	
Palpebral reflex	42/42		100%		91.62–100	
Direct pupillary light reflex	27/42		64%		49.17–77.01	
Oculocephalic reflex	42/42		100%		91.62–100	
Facial symmetry	42/42		100%		91.62–100	
Sensation forehead	42/42		100%		91.62–100	
Sensation nares	40/42		95%		84.21–98.68	
Sensation rictus	36/42		86%		72.16–93.28	
Gag reflex	41/42		98%		87.68–99.88	
Beak closure and tone	42/42		100%		91.62–100	
Auditory response	22/42		52%		37.72–66.64	
Postural reactions						
Hopping	42/42		100%		91.62–100	
Foot replacement	42/42		100%		91.62–100	
Extensor postural thrust reaction	42/42		100%		91.62–100	
Wing replacement	42/42		100%		91.62–100	
Drop and flap	24/39		62%		45.90–75.11	
Spinal reflexes						
Withdrawal reflex wing	25/42		60%		44.49–72.96	
Withdrawal reflex leg	36/42	37/42	86%	88%	72.16–93.28	75.00–94.81
Patellar reflex	40/42		95%		84.21–98.68	
Vent sphincter reflex	33/42		79%		64.06–88.29	
Gastrocnemius reflex	0/29		0%		0–11.70	

Since the gastrocnemius reflex could not be provoked in any bird by any examiner, perfect agreement was achieved in both groups. Regarding the withdrawal of the pelvic limbs, perfect agreement in pigeons and substantial agreement in swans was determined. Examiners agreed perfectly when assessing the withdrawal of the wings in pigeons, but only moderately when assessing swans. Agreement was substantial for the patellar and vent sphincter reflex in both groups.

In all tests of the examination that resulted in a positive response in more than 90% of individuals (and were therefore considered useful for the species population), almost perfect agreement was achieved.

DISCUSSION

Different authors have described bird-specific adaptations of the neurological examination[10–13,30] without providing data on whether the tests are applicable to different bird species and individuals. The present study provides normative quantitative data for the tests of a standardised neurological examination protocol in clinically healthy birds from different species.

This study revealed that most tests were feasible in the examined bird species, but certain differences were determined regarding practicability and observed responses between groups. Prioritising tests with the most consistent response is recommended for each respective species (Figure 1). The gastrocnemius reflex could not be elicited in any bird in this study and should, therefore, be excluded from the examination protocol.

The palpebral reflex was always present in all groups in our study. This finding is consistent with the existing literature, where a positive reflex was observed in all examined birds (pigeons [*C. livia domestica*; n = 10],[18] American flamingos [*Phoenicopterus ruber ruber*; n = 17],[16] cinereous vultures [*Aegypius monachus*; n = 16],[31] screech owls [*Megascops asio*; n = 23],[15] turkeys [n = 10] and layer hens [n = 12][21]).

The menace response was inconsistently provokable in raptors and pigeons and positive in all mute swans. Our findings reflect the varying results of this test in the literature. Studies aiming to establish normative ophthalmological data found inconsistent, equivocal or consistently absent menace responses in great grey owls (*Strix nebulosa*) and snowy owls (*Bubo scandiacus*),[19] brown pelicans (*Pelecanus*

TABLE 4 Results of the neurological examination of clinically healthy common buzzards (*Buteo buteo*), common kestrels (*Falco tinnunculus*) and northern goshawks (*Accipiter gentilis*)

	Positive response/successfully tested birds (% positive)		
Neurological parameter	**Common buzzards (*N* = 12)**	**Northern goshawks (*N* = 6)**	**Common kestrels (*N* = 24)**
Cranial nerves			
Menace response	6/12 (50%)	4/6 (67%)	15/24 (63%)
Palpebral reflex	12/12 (100%)	6/6 (100%)	24/24 (100%)
Direct pupillary light reflex	6/12 (50%)	6/6 (100%)[a]	14/24 (58%)
Oculocephalic reflex	12/12 (100%)	6/6 (100%)	24/24 (100%)
Facial symmetry	12/12 (100%)	6/6 (100%)	24/24 (100%)
Sensation forehead	7/12 (58%)	2/6 (33%)	19/24 (79%)
Sensation nares	5/12 (42%)	1/6 (17%)	12/24 (50%)
Sensation rictus	3/12 (25%)	1/6 (17%)	14/24 (58%)
Gag reflex	6/12 (50%)	4/6 (67%)	22/24 (92%)
Beak closure and tone	12/12 (100%)	6/6 (100%)	24/24 (100%)
Auditory response	1/12 (8%)	0/6 (0%)	12/24 (50%)
Postural reactions			
Hopping	1/10 (10%)	0/2 (0%)	0/1 (0%)
Foot replacement	3/10 (30%)	1/3 (33%)	1/2 (50%)
Extensor postural thrust reaction	7/12 (58%)	3/3 (100%)	14/15 (93%)
Wing replacement	11/12 (92%)[b]	6/6 (100%)[c]	23/24 (96%)
Drop and flap	12/12 (100%)	6/6 (100%)	24/24 (100%)
Spinal reflexes			
Withdrawal reflex wing	6/12 (50%)	5/6 (83%)[d]	23/24 (96%)
Withdrawal reflex leg	12/12 (100%)[e]	6/6 (100%)	24/24 (100%)
Patellar reflex	12/12 (100%)[f]	6/6 (100%)[g]	23/24 (96%)
Vent sphincter reflex	7/12 (58%)	5/6 (83%)	21/24 (88%)
Gastrocnemius reflex	0/11 (0%)	0/6 (0%)	0/23 (0%)

[a]Slow and incomplete constriction in four birds (both eyes).
[b]Slow response in three birds.
[c]Slow response in three birds.
[d]Reduced response in three birds.
[e]Reduced response in five birds.
[f]Reduced response in six birds.
[g]Reduced response in four birds.

occidentalis),[17] American flamingos (*P. ruber ruber*),[16] bald eagles (*Haliaeetus leucocephalus*),[20] cinereous vultures (*A. monachus*)[31] and screech owls (*M. asio*).[15] Other studies revealed a positive menace response in all individuals of the examined species: pigeons (n = 10),[18] ducks (n = 48), geese (n = 52),[14] turkeys (n = 10) and layer hens (n = 12).[21] Potential causes for the varying results for the menace response in different avian species (and individuals) may include stress, temperament and unobserved pathologies.[10,11] Since this test is used to evaluate vision,[1] it should be interpreted with care in birds, especially when triaging free-ranging avian patients. Interestingly, differences in response characteristics between species were observed when the menace response and palpebral reflex were tested: raptors and swans blinked with their nictitating membrane rather than with their eyelid, which was in contrast to most of the pigeons. In accordance with other authors,[19,31] we considered both reactions as normal.

The direct pupillary light reflex was absent in 14% of pigeons and 36% of swans, with variable results in the raptors (present in 6/12 [50%] of buzzards, 6/6 [100%] of goshawks and 14/24 [58%] of kestrels). Since the musculus dilatator and sphincter pupillae consist mainly of striated muscle fibres in birds,[32] this finding was not unexpected. However, our results are contrary to most studies in the existing literature, where the direct pupillary light reflex was present in all examined birds.[14,16–18,20,21,31] One study on different captive owl species reported this reflex to be absent in five of 23 great grey owls (*S. nebulosa*)[19] and in three of 23 screech owls (*M. asio*),[15] where eye pathologies have been held accountable in these birds. Since these studies were solely conducted on captive individuals, the birds' accustomisation to humans and handling might have been beneficial. This assumption is supported by the fact that all 18 captive individuals of the pigeon group of our study had a positive direct pupillary light reflex.

TABLE 5 Interobserver agreement (percent agreement and Gwet's AC1) between the neurological examinations of three raters examining 11 clinically healthy pigeons (*Columba livia domestica*) and 11 clinically healthy mute swans (*Cygnus olor*)

Neurological parameter	Pigeons		Swans	
	Percent agreement	Gwet's AC1 (95% CI)	Percent agreement	Gwet's AC1 (95% CI)
Cranial nerves				
Menace response	81.8%	0.81 (0.69–0.93)	100%	1 (1–1)
Palpebral reflex	96.0%	0.96 (0.9–1)	100%	1 (1–1)
Direct pupillary light reflex left eye	69.7%	0.67 (0.54–0.81)	77.8%	0.77 (0.64–0.89)
Direct pupillary light reflex right eye			79.8%	0.79 (0.69–0.91)
Oculocephalic reflex	100%	1 (1–1)	100%	1 (1–1)
Facial symmetry	100%	1 (1–1)	100%	1 (1–1)
Sensation forehead	85.9%	0.85 (0.75–0.96)	100%	1 (1–1)
Sensation nares	77.8%	0.76 (0.64–0.89)	100%	1 (1–1)
Sensation rictus	91.9%	0.92 (0.84–0.99)	100%	1 (1–1)
Gag reflex	98%	0.98 (0.94–1)	100%	1 (1–1)
Beak closure and tone	100%	1 (1–1)	100%	1 (1–1)
Auditory response	59.6%	0.55 (0.41–0.69)	69.7%	0.67 (0.53–0.81)
Postural reactions				
Hopping left leg	92.9%	0.93 (0.84–1)	96%	0.96 (0.90–1)
Hopping right leg			93.9%	0.94 (0.87–1)
Foot replacement left leg	100%	1 (1–1)	98%	0.98 (0.94–1)
Foot replacement right leg			100%	1 (1–1)
Extensor postural thrust reaction	91.9%	0.92 (0.82–1)	98%	0.98 (0.94–1)
Wing replacement	100%	1 (1–1)	100%	1 (1–1)
Drop and flap	100%	1 (1–1)	61.6%	0.57 (0.38–0.76)
Spinal reflexes				
Withdrawal reflex left wing	98.0%	0.98 (0.94–1)	58.6%	0.53 (0.39–0.68)
Withdrawal reflex right wing			60.6%	0.56 (0.41–0.70)
Withdrawal reflex left leg	98.0%	0.98 (0.94–1)	68.7%	0.66 (0.49–0.81)
Withdrawal reflex right leg			75.8%	0.74 (0.59–0.88)
Patellar reflex left leg	73.7%	0.72 (0.45–1)	75.8%	0.74 (0.62–0.87)
Patellar reflex right leg	71.7%	0.69 (0.56–0.83)	81.8%	0.81 (0.69–0.93)
Vent sphincter reflex	77.8%	0.76 (0.63–0.89)	79.8%	0.79 (0.67–0.91)
Gastrocnemius reflex	100%	1 (1–1)	100%	1 (1–1)

CI, confidence interval

Facial sensation was often not assessable. This was not an unexpected finding since birds lack mimic musculature, and therefore reactions to a touching stimulus of the face are limited. To allow the bird any reaction in this context, we recommend as little fixation of the head as safely possible in the respective species.

Postural reaction tests have not been studied systematically in birds prior to this study.[12,30] All postural reaction tests produced a consistent response in pigeons in our study. In mute swans, the drop and flap reaction could not be elicited regularly. Due to the higher weight of these birds (median weight 7.6 kg, weight range 5–12.8 kg), performing this test was more difficult. In the raptor species, postural reaction tests of the limbs were often impracticable due to the risk of injury for the examiner. As part of normal defensive behaviour,[24] some individuals, especially juvenile kestrels and goshawks, reacted by throwing themselves on their backs and defending themselves with their talons. Other individuals reacted 'stoic' without responding to changes in the position of their feet. This highlights that knowledge of the normal behaviour of a bird species is crucial to evaluate responses to neurological tests. Postural reactions of the wings were easy to perform in the examined raptors, but might be more difficult in larger species such as, for example, white-tailed eagles (*Haliaeetus albicilla*).

The spinal reflexes resulted in variable responses in all species, with the withdrawal reflex of the pelvic limbs being the most consistent in raptors and pigeons. The vent sphincter reflex was absent regularly, but no bird had any indication for cloacal dysfunction during examination or prior hospitalisation. There is very little information available in the veterinary literature regarding the vent sphincter reflex in birds in clinical settings. In an anaesthetic study that tested the sedative effect of medetomidine in domestic pigeons, the cloacal reflex was tested in sedated birds and resulted in massive defensive behaviour rather than contraction of the sphincter,[33] probably due to a stronger stimulus. Our results are consistent with the findings in other species: in healthy juvenile bearded dragons (*Pogona vitticeps*) and adult leopard geckos (*Eublepharis macularius*), the cloacal reflex was also not provokable[7] and the authors suggested that a stronger stimulus needed to be applied. In clinically healthy chinchillas (*Chinchilla lanigera*), the perineal reflex was also consistently absent,[5] but the reason for this finding was unclear.

The gastrocnemius reflex was absent in every bird in our study. This is consistent with the suggestions of other authors regarding this reflex in birds[10] and small animals.[1]

Our data should be critically discussed regarding the origin of the animals and age distribution within the groups. Adult birds and juveniles (but no nestlings) were included, so age-related differences in behaviour patterns could have influenced the results of the examination. Furthermore, since most of the birds examined were free-ranging individuals, no or only very limited information about the age, sex, history of previous diseases, etc., was available. Additionally, most of the examined birds in our study were not used to handling. Hence, stress is possibly the main factor for absent responses in the free-ranging birds. Nevertheless, even though we examined predominantly wild birds, most of the tests were feasible and only slight differences between the captive pigeons and the free-ranging individuals were observed (e.g., the pupillary light reflex was present in all captive pigeons but not in the free-ranging birds).

In conclusion, this study provides normative data for the neurological examination of pigeons and mute swans. Furthermore, trends in physiological responses to the neurological tests in three raptor species were reported. We noticed interspecies variations regarding the test feasibility and response consistency. Therefore, test outcomes should be evaluated considering the normal neurological findings in the respective species to avoid misinterpretations. To minimise stress, we recommend prioritising the most reliable tests for the relevant species when examining a bird.

AUTHOR CONTRIBUTIONS

Conceptualisation, data curation, investigation, formal analysis, visualisation, methodology and writing—original draft preparation, review and editing: Sina Feyer. *Conceptualisation, methodology, supervision and writing—review and editing*: Shenja Loderstedt. *Investigation and writing—review and editing*: Lesley Halter-Gölkel. *Formal analysis, methodology and writing—review and editing*: Roswitha Merle. *Investigation and writing—review and editing*: Stephanie Zein. *Conceptualisation, methodology, project administration, supervision and writing—review and editing*: Kerstin Müller.

ACKNOWLEDGEMENTS

We thank Tobias Gräßle for the excellent support with statistical analysis. We also thank Dörte Lüschow and Anne Kleine for providing the pigeons from the Institute of Poultry Diseases. This work is part of the doctoral thesis of Sina Feyer.

Open access funding enabled and organized by Projekt DEAL.

CONFLICT OF INTEREST STATEMENT

The authors declare they have no conflicts of interest.

FUNDING INFORMATION

The authors received no specific funding for this work.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to cite this article: Feyer S, Loderstedt S, Halter-Gölkel L, Merle R, Zein S, Müller K. Neurological examination of clinically healthy pigeons (*Columba livia domestica*), mute swans (*Cygnus olor*), common buzzards (*Buteo buteo*), common kestrels (*Falco tinnunculus*) and northern goshawks (*Accipiter gentilis*). Vet Rec. 2024;e3828. https://doi.org/10.1002/vetr.3828