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AN ASSESSMENT OF CAGE FLIGHT AS AN EXERCISE METHOD FOR RAPTORS

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ABSTRACT.—There are a number of methods used for exercising muscles during the rehabilitation of raptors, such as outdoor-creance flight, indoor-hall flight, outdoor-cage flight, and combinations of any of the above. Previous studies measured blood-lactate levels after cessation of exercise to assess muscle fitness and found that creance flight was an effective means of exercise. Physical fitness was inversely correlated with the time it took for postexercise blood-lactate levels to decrease. Using criterion for muscle fitness previously established for creance flight, we examined the effectiveness of caged flight to increase muscle fitness during rehabilitation of six species of raptors: Barn Owl (*Tyto alba*), Barred Owl (*Strix varia*), Broad-winged Hawk (*Buteo platypterus*), Eastern Screech-Owl (*Megascops asio*), Great Horned Owl (*Bubo virginianus*), and Red-tailed Hawk (*Buteo jamaicensis*). Examination of blood-lactate levels after exercise indicated that caged flight may be sufficient to increase muscle fitness in Great Horned Owls and Broad-winged Hawks and may be a useful method to increase muscle fitness in three of the remaining four raptor species examined. However, there was a difference in the recovery of lactate values related to the type of injury and species of raptor injured, suggesting the effectiveness of flight cages are species specific and that additional rehabilitation techniques, as well as longer rehabilitation durations may be needed for full recovery.

KEY WORDS: *Raptor rehabilitation; muscle fitness; cage-flight exercise; creance-flight exercise.*

UNA EVALUACIÓN DE LAS ENCIERROS DE VUELO COMO UN METODO DE EJERCICIO PARA AVES RAPACES

RESUMEN.—Hay un número de métodos usados para ejercitar los músculos durante la rehabilitación de rapaces, tales como el vuelo con fiador en exteriores, el vuelo en un salón interior, el vuelo en un encierro exterior, y combinaciones de algunos de los anteriores. Estudios previos han medido los niveles de lactato en la sangre luego de cesar el ejercicio para evaluar la aptitud del músculo y encontraron que el vuelo con fiador fue un medio efectivo de ejercicio. La aptitud física fue correlacionada inversamente con el tiempo invertido para que los niveles de lactato en la sangre decrecieran después del ejercicio. Usando un estándar para la aptitud del músculo establecida previamente para el vuelo con fiador, examinamos la efectividad del vuelo en jaula para aumentar la aptitud del músculo durante la rehabilitación de seis especies de rapaces: Lechuzas (*Tyto alba*), búhos barrados (*Strix varia*), gavilanes de ala ancha (*Buteo platypterus*), búhos chirreadores orientales (*Megascops asio*), el gran búho cornado (*Bubo virginianus*), y gavilanes de cola roja (*Buteo jamaicensis*). El examen de los niveles de lactato en la sangre después del ejercicio indicó que el vuelo en jaulas puede ser suficiente para incrementar la aptitud del músculo en búhos cornados y gavilanes de ala ancha y puede ser un método útil para incrementar la aptitud del músculo en tres de las restantes cuatro especies de aves rapaces examinadas. Sin embargo, no hubo diferencia en la recuperación de los valores de lactato relacionado con el tipo de lesión y la especie de ave rapaz herida, sugiriendo que la efectividad de las jaulas de vuelo es

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especifica a la especie y que las técnicas de rehabilitación adicionales, al igual que los tiempos de rehabilitación mas extensos pueden ser necesarios para una recuperación total.

[Traducción de César Márquez]

The goal of raptor rehabilitation is to treat, rehabilitate, and release injured birds of prey into the wild. During convalescence, the skeletal-muscle fitness of a raptor can significantly decline. To improve survival after release, muscle fitness should be restored to a degree that would allow a raptor to hunt successfully. However, there is little known about the effectiveness of various exercise methods used by rehabilitators.

Several main methods are used for exercising muscles during the rehabilitation of raptors (Chaplin et al. 1989). Hall flights are performed indoors with the bird flying unrestrained from one perch to another and usually these short flights are repeated several times. Creance flight is performed by attaching a tether to leather anklets placed on the bird's legs. The bird is then taken out into a large open field and allowed to fly the length of the tether a number of times as determined by the rehabilitator. Chaplin et al. (1989, 1993) established that creance flight increases the flight fitness of injured raptors. Hall flight and creance flight are often used together, starting first with hall flights and progressing to creance flight. Another method for rehabilitation is outdoor-cage flights. A raptor that has healed from its injury is placed in an outdoor-flight cage to build muscle strength initially by moving between low perches. Once the raptor is able to move easily between these perches without signs of stress (i.e., panting), it is then moved to a larger flight cage. Flight cages are usually long and narrow with high perches only at the ends in order to encourage full flights from one perch to the next. The cages are also built to species-specific dimensions (Read 1990). Unlike creance flight, there have been no studies examining the effectiveness of outdoor-cage flight.

Wildlife rehabilitation principles include limiting human contact to prevent habituating birds to humans to improve their success as independent predators in the wild, and to reduce stress from human contact (Patton and Crawford 1985). There are certain advantages and disadvantages associated with each of the exercise methods mentioned above. The advantages of cage flight are that a bird is handled much less than with creance flight, multiple birds can be exercised at one time and by one rehabilitator, and the exercise can be completed in a matter of minutes. This is beneficial to rehabilitation facilities dependent upon trained volunteers and a limited staff. However, an advantage of creance flight may be that it allows for longer continuous flight, up to 60 m or more, and construction of flight cages is not required.

Evaluating these exercise methods requires a means to assess exercise effectiveness. One assessment tool used to measure the physical fitness of raptors during their exercise regimen is based on physical fitness being inversely correlated with the time it takes for postexercise blood-lactate levels to decrease (Persson 1983). Lactate is a good indicator of overall skeletal-muscle fitness because it reflects how efficiently the animal is converting glucose into energy (Persson 1983). Lactate is increased during exercise when skeletal muscles are forced, by a lack of oxygen, to undergo anaerobic respiration.

The kinetics of the change in blood-lactate levels during and after exercise have been used to investigate the effectiveness of creance flight as a method for rehabilitation of Red-tailed Hawks (*Buteo jamaicensis*; Chaplin et al. 1989, Mueller and Chaplin 1990). Skeletal-muscle fitness was examined by quantifying the lactate concentration present in the blood at 2-min and 10-min postexercise. These workers found that over a 2–5 wk exercise regimen, Red-tailed Hawks had a decrease in the overall lactate concentration present in the blood postexercise, indicating that skeletal-muscle fitness was improving. A follow-up study using similar criteria found that creance flight was an effective means of rehabilitation for seven additional species of raptors: Northern Saw-whet Owl (*Aegolius acadicus*), Eastern Screech-Owl (*Megascops asio*), Long-eared Owl (*Asio otus*), Barred Owl (*Strix varia*), Great Horned Owl (*Bubo virginianus*), American Kestrel (*Falco sparverius*), and Northern Harrier (*Circus cyaneus*; Chaplin et al. 1993). As part of Chaplin's et al. (1993) research, the basal-lactate levels for these species of raptor were established for differing levels of exercise using creance flight.

Using the muscle-fitness-evaluation method described by Chaplin et al. (1989), we examined the effectiveness of cage flight to improve the fitness

Table 1. Injuries of raptors used in the study.

RAPTOR SPECIES	INJURY TYPE
Broad-winged Hawks ($N = 4$)	2 broken talons
	Old keel fracture, dehydration, bruising
	Left eye trauma, bruised left wing
	Orphaned, no injuries
Red-tailed Hawks ($N = 7$)	Fractured right wing (radius)
	Fractured right wing (humerus), emaciation
	Fractured left wing (ulna)
	Right eye trauma, fractured left tibiotarsus, emaciation
	Tissue damage left leg, emaciation
	Fractured right humerus
	Tissue damage right leg, emaciation
Barn Owls ($N = 4$)	Fractured left metacarpals
	Wound on right wrist
	Fractured left metacarpals, emaciation
	Orphaned, no injuries
Eastern Screech-Owls ($N = 4$)	Concussion
	Eye trauma (both eyes)
	Right eye trauma, concussion
	Unknown
Barred Owls ($N = 2$)	Fractured right ulna, right eye removed, left eye trauma
	Healed fracture left metatarsus, left eye trauma
Great Horned Owls ($N = 4$)	Orphaned, no injuries
	Orphaned, no injuries
	Emaciation, right leg wound, toe injuries
	Orphaned, no injuries

of injured Red-tailed Hawks, Broad-winged Hawks (*Buteo platypterus*), Eastern Screech-Owls, Barred Owls, Barn Owls (*Tyto alba*) and Great Horned Owls.

METHODS

Exercise Regimen. The injured and orphaned birds used in this study were admitted to the Carolina Raptor Center and confined to indoor cages for 3–30 wk during injury treatment (Table 1). Raptors were then placed in small outdoor cages (3 m × 5 m × 3 m) containing multiple perches of varying heights (0.3–1.6 m tall). Birds were fed a diet of either rats (*Rattus norvegicus*) or mice (*Mus musculus*) 6 d/wk. They were moved to a flight cage after they were able to move among the low perches without difficulty, and based upon inspection of respiration and feather condition. Only raptors of the same species were housed together in flight cages, with 6–8 birds per cage. The flight cages were species specific (Table 2), and large enough to accommodate flight during the entire period of rehabilitation. The flight cages at the Car-

Table 2. Approximate cage and perch measurements for selected rehabilitation cages. Each species of raptor studied were housed in outdoor flight cages for the 3 wk of study. Dimensions within each cage are variable because ground slopes in most cases, leaving one end of the cage taller than the other. Perches represent the tallest available to birds and the ones they select most of the time while exercising.

RAPTOR HOUSED	CAGE DIMENSIONS	GROUND-TO-PERCH	PERCH-TO-CEILING
Broad-winged Hawks	14 m L × 3 m W × 3.5 m H	2.5 m	1 m
Barn Owls	17 m L × 3 m W × 3.5 m H	2.5 m	1 m
Barred Owls	17 m L × 3 m W × 3.5 m H	2.5 m	1 m
Eastern Screech-Owls	10.5 m L × 3 m W × 3 m H	2.5 m	0.5 m
Red-tailed Hawks	27.5 m L × 4.5 m W × 4.5 m H	3 m–3.5 m	1 m–1.5 m
Great Horned Owls	14 m L × 3 m W × 3.5 m H	2.5 m–3 m	1 m–1.5 m

Table 3. Slopes of lactate concentrations for six species of raptors with and without inclusion of orphans over a 3–5 wk exercise period. Raptor samples with no orphans are indicated with N/A.

	DATA WITH ALL BIRDS		DATA WITHOUT ORPHANS	
RAPTOR SPECIES	2-min	10-min	2-min	10-min
Red-tailed Hawks ($N = 7$)	−1.87	−6.79	N/A	N/A
Great Horned Owls ($N = 4$), no orphans ($N = 1$)	−12.02*	−15.28*	−16.18[a]	−39.08[a]
Barred Owls ($N = 2$)	10.25	12.63	N/A	N/A
Barn Owls ($N = 4$), no orphans ($N = 3$)	0.58	7.96	−5.48	5.74
Broad-winged Hawks ($N = 4$), no orphans ($N = 3$)	−22.04	3.44	−36.66*	0.24
Eastern Screech-Owls ($N = 4$)	−9.45	−4.12	N/A	N/A

* Indicates a significant decrease in lactate concentrations ($P \leq 0.05$).
[a] Indicates no analysis was possible because there was only one Great Horned Owl in this group.

olina Raptor Center were built based upon the experience of the rehabilitators, and built as large as possible based on the birds' needs and available funding. The perches were situated high at opposite ends to encourage full flights the length of the cage (Table 2).

Once the birds acclimated to their surroundings (2–5 d), they were exercised daily by a rehabilitator walking from one end of the cage to the other end, encouraging the birds to fly. The numbers of flights were gradually increased by 2–5 flights per wk, depending on the species of raptor and the rehabilitator's opinion of the individual fitness of each bird at the beginning of the regimen. Respiratory rate, feather condition, and flight form were used as indices of physical fitness. Red-tailed Hawks were initially exercised by flying 8–10 laps/d (one lap is equivalent to flight from one end of the cage and back to the starting point) and increased to 20 laps/d by the end of their recovery (3–5 wk) before release. Rest time was kept to a minimum (less than 15 sec) between laps. Broad-winged Hawks began with 5–8 laps, which was increased to 15 laps. Barn Owls, Barred Owls and Great Horned Owls began with 4–6 laps, which were increased to 10 laps. The criteria used for increasing a bird's exercise regimen (increasing laps) was determined by the number of laps each bird could fly without rapid respirations (panting) and if the bird was able to make full flights between perches.

Blood-Lactate Level Determination. Once a wk the birds were caught using a large net. Capture was performed immediately after exercise in order to prevent additional flights and to ensure all birds in the same cage had the same number of flights. After capture, the birds were dorsally restrained in weight wrappers that enclosed their body and covered their heads so that the birds remained calm and immobile throughout the subsequent procedure (Engelmann and Marcum 1993, Miller 2000). For this assessment, it is imperative to keep stress levels to a minimum because lactic-acid values can increase due to stress. Blood samples were drawn from the brachial veins at 2-min postexercise and then at 10-min postexercise. In the time between blood sampling, stress levels were reduced by keeping the birds covered and motionless in a quiet environment. Whole blood (0.02–0.10 ml) was stored on ice for up to 1 hr prior to extracting proteins using twice the volume of 8% perchloric acid. Samples were then centrifuged for 10 min at 2700 × g. The supernatant (clear) was removed and kept at 4°C for up to 10 d until performing the lactate assay.

The lactate assay was performed per manufacturer's instructions using the Lactate Diagnostic Kit (Sigma Chemical Co., St. Louis, MO U.S.A.), using a Benchmark Microplate Reader (Bio-Rad Laboratories, Hercules, CA U.S.A.) and Microplate 5.2 data analysis software (Bio-Rad Laboratories, Hercules, CA U.S.A.).

Data Analysis. Data were analyzed by linear regression, and the means of the 2-min and 10-min lactate values were analyzed using a one way Analysis of Variance (ANOVA), followed by Tukey's studentized range test, when appropriate (SAS statistical software, version 5.0, Cary, NC U.S.A.).

RESULTS

The rate of the decrease in blood lactate over the 3–5 wk exercise period for six species of raptors is indicated by the slope of the regression line through each of the averaged lactate values for the 2-min and the 10-min postexercise times (Fig. 1). A negative slope of the regression trend line would suggest an increase in skeletal-muscle fitness.

Four (including orphans) or five (excluding orphans) of the six raptor species examined exhibited a decrease in overall blood-lactate concentrations at one of the time points over the 3–5 wk

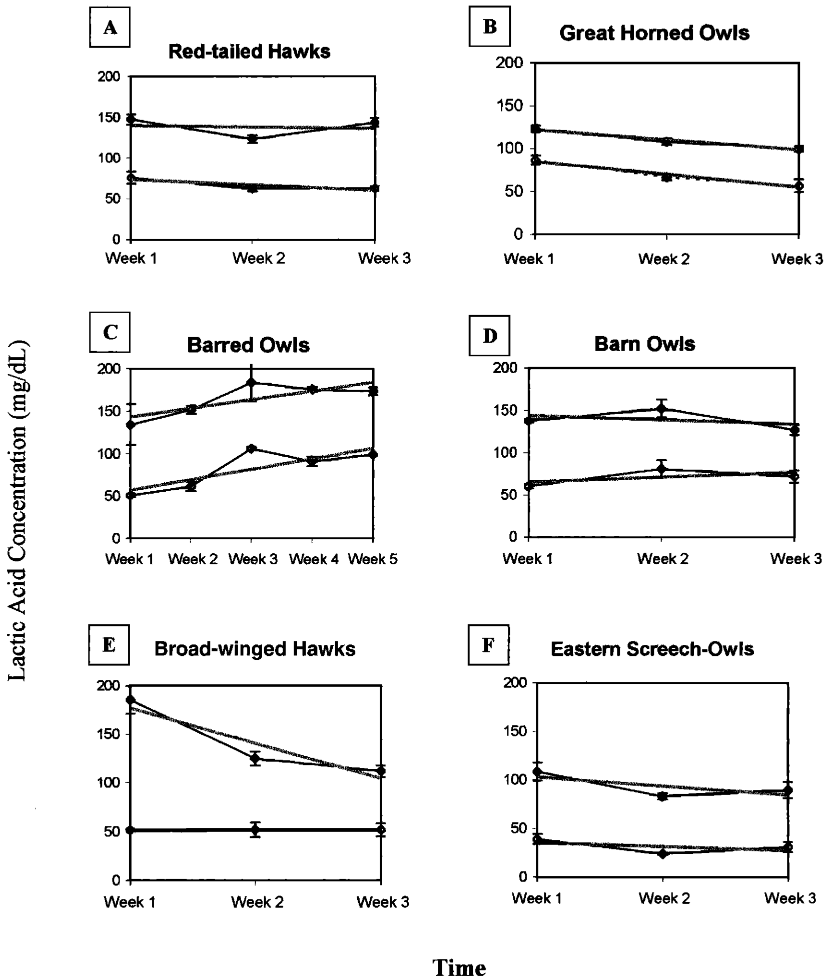

Figure 1. Change in lactate concentrations for six species of raptors over an exercise period (see Methods). Blood-lactate levels were measured postexercise at 2-min (♦) and 10-min (◊) intervals. Data are expressed as the overall blood-lactate levels at the end of each wk, and regression lines (gray solid lines) were calculated to represent the mean change in blood-lactate concentration over time. Panel A—Red-tailed Hawks ($N = 7$). Panel B—Great Horned Owls ($N = 4$). Panel C—Barred Owls ($N = 2$). Panel D—Barn Owls ($N = 3$) regression data exclude one orphan. Panel E—Broad-winged Hawks ($N = 3$) regression data exclude one orphan. Panel F—Eastern Screech-Owls.

exercise period (Table 3). Great Horned Owls had a significant decrease in their lactate values ($P = 0.03$, $F_{23,5} = 4.18$, $N = 4$; Fig. 1B). Eastern Screech-Owls had a decrease in both their lactate values; however, the decrease did not reach significance ($P = 0.17$, $F_{23,5} = 1.91$, $N = 4$; Fig. 1F). Red-tailed Hawks had a decrease in both the 2-min and 10-min values, but again this pattern was not significant ($P = 0.40$, $F_{41,5} = 0.95$, $N = 7$; Fig. 1A). Broad-winged Hawks showed a decrease in their 2-min values, but not in their 10-min values; the decrease was not significant ($P = 0.25$, $F_{23,5} = 1.50$, $N = 4$; Fig. 1E). However, when the orphaned raptor in this group was removed, the decrease in lactate at 2-min was significant ($P = 0.05$, $F_{17,5} = 3.86$, $N = 3$). There was also a significant interaction between the 2-min and 10-min lactate values ($P = 0.05$, $F_{17,5} = 3.98$, $N = 3$); analysis of the treatment weeks showed that wk 1 and wk 3 were significantly different from each other for the 2-min lactate values ($P < 0.05$), but not for the 10-min lactate values ($P > 0.05$) (Fig. 1E, Table 3). Barn Owls did not

Table 4. Effectiveness of cage flight is influenced by injury type. Linear regression slopes were calculated based on injury type for each species group. One injury or mild injuries include broken talons, tissue damage, mild concussion, or non-blinding eye traumas. Multiple injuries or severe injuries include fractures that are accompanied with other injuries such as emaciation, tissue damage, and eye trauma or eye removal. N/A denotes no birds qualified for this sample group.

RAPTOR SPECIES	ONE INJURY OR MILD INJURIES		MULTIPLE INJURIES OR SEVERE INJURIES		ORPHANED WITH NO INJURIES	
	2-min	10-min	2-min	10-min	2-min	10-min
Red-tailed Hawks	−17.64	−8.28	32.55	7.98	N/A	N/A
N	5	5	2	2		
Great Horned Owls	−12.02	−15.28	N/A	N/A	−1.48	−2.63
N	1	1			3	3
Barred Owls	N/A	N/A	10.25	12.63	N/A	N/A
N			4	4		
Barn Owls	−5.47	−5.74	N/A	N/A	18.75	14.63
N	3	3			1	1
Broad-winged Hawks	−36.66	0.24	N/A	N/A	21.80	13.05
N	3	3			1	1
Eastern Screech-Owls	−9.45	−4.12	N/A	N/A	N/A	N/A
N	4	4				

show a decrease in lactate values over time (P = 0.46, $F_{23,5}$ = 0.82, N = 4). When the orphan in this group was removed, the 2-min lactate value decreased, giving a negative regression slope, but this trend was not significant (P = 0.58, $F_{17,5}$ = 0.55, N = 3; Fig. 1D, Table 3). Barred Owls showed a slight nonsignificant increase in lactate values (P = 0.05, $F_{15,7}$ = 4.01, N = 2; Fig. 1C).

DISCUSSION

Our results indicated that the use of flight cages as a form of rehabilitation exercise may be an adequate method for increasing skeletal-muscle fitness and improving aerobic conditioning of certain species of injured raptors. Of the six raptor species studied, five exhibited a negative linear-regression slope in at least one of the two time points studied (Table 3). The Great Horned Owls showed a statistically significant improvement in lactate recovery with cage flight, indicating that cage flight was sufficient to improve muscle fitness in this species. Red-tailed Hawks and Eastern Screech-Owls showed decreases in both 2-min and 10-min lactate values; however, these trends were not significant. Broad-winged Hawks and Barn Owls (excluding orphans) showed a decrease in the 2-min time lactate values, but these trends were not significant. Further analysis of the Broad-winged Hawks that involved exclusion of the orphaned raptor resulted in a significant decrease in the lactate values, suggesting that cage flight is useful for the adult injured raptors of this species. These data indicated that use of cage flight may be a valuable method to improve muscle fitness in certain species, such as the Great Horned Owls and Broad-winged Hawks, but may need to be combined with other rehabilitation methods in other species.

Chaplin et al. (1989) proposed guidelines for 2-min and 10-min lactate values postexercise for creance rehabilitation of certain species (e.g., screech-owls, Great Horned Owls, Red-tailed Hawks). The lactate values of the cage-exercised raptors were comparable to the guidelines set by Chaplin (1989); however, the decreases were not as dramatic as seen in this earlier work. There are several reasons that may account for this difference. In flight cages, there was a possibility the raptors did not obtain enough sustained wing flaps, probably coasting to the other perch involving less muscle exertion. Coasting was not observed by the rehabilitators during this study; however, there was a short rest period between flights, which was kept to a minimum (the time for a rehabilitator to walk from one end of the cage to the other; <15 sec). This rest period may account for the decreased effectiveness of the flight cages for these raptors. Future studies should be performed that reduce or eliminate this rest time.

The difference in response of raptors of different species may also be due to differing wing mechanics and hunting behaviors. Great Horned Owls are a perch-and-watch predator and once prey are detected, they pursue their prey by descent or a short-sprint flight. Cage flight may duplicate these hunting flights and could be the reason that the Great Horned Owls responded well to this method of rehabilitation. Other species that are more endurance fliers when hunting, such as Barn Owls, may need longer sustained flights for skeletal-muscle improvement. In this case, cage flight may be a good preliminary exercise method for these species, if it is then followed by other methods such as creance flight.

One confounding factor in this study was the extent of injuries sustained by the raptors (Table 1). The greater number and more complex the injuries sustained, the raptors were less responsive to exercise (Table 4). Raptors with multiple and severe injuries tended to have a positive linear-regression slope for the lactate concentrations over time, as compared to those with one injury or mild injuries, which had negative slopes (Table 4). The differences in injury types may contribute to the variation of responses in the other raptor species, as well as the lack of response to treatment in the Barred Owls, which had severe injuries. In cases of severe injuries, cage flight may be suitable as a preliminary form of exercise. However, it may be necessary to exercise the birds for a longer duration than used in this experiment and use other exercise methods, such as creance flight.

A third, perhaps related, factor was whether the raptor was an orphan. Orphaned raptors did not show an increase in muscle fitness. This may be due to a lack of injuries, and an absence of prior flight experience. The raptor orphans in this study tended to have shallower negative linear lactate regression slopes, or positive slopes as compared to the adult raptors rehabilitated for mild injuries (Table 4). The Broad-winged Hawks demonstrate this pattern. The adult Broad-winged Hawks showed a significant decrease in lactate values, but the orphaned hawk of this species did not show improvement with cage flight. These results are similar to previous research that compared lactate dehydrogenase kinetics between untrained and previously flight-trained Rock Pigeons (*Columba livia*) that were either cage confined, or wing restrained for several wk before retraining (Chaplin et al. 1997). The untrained Rock Pigeons had slower clearance of lactate than did the trained birds, which was similar to what we observed with the orphaned raptors (Table 4). Our results indicated that raptor orphans may need special flight training and for a longer duration than injured adults.

We note that the sizes of the flight cages are important when replicating these findings. The sizes of the flight cages used in this study were determined by the rehabilitation staff at the Carolina Raptor Center based upon previous experience with these raptor species, as well as the amount of available funds. Most of the flight cages were built larger than many current guidelines set forth by the National Wildlife Rehabilitation Association and International Wildlife Rehabilitation Council for unlimited activities (Eastern Screech-Owl, 2.4 m × 2.4 m × 2.4 m; Barn Owl, 3 m × 9 m × 3.6 m; Barred Owl 3 m × 15.2 m × 3.6 m; Great Horned Owl 3 m × 15.2 m × 3.6 m; Broad-winged Hawk, 3 m × 9 m × 3.6 m; and Red-tailed Hawk, 3 m × 15.2 m × 3.6 m; Miller 2000). The fitness criteria used in this study are proposed by Chaplin et al. (1989, 1993) and represent a standard determined using falconry-trained Red-tailed Hawks. This standard may differ for other types of raptors, especially those with very different wing mechanics and flight habits.

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