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Fitness Level as a Determining Factor in the Survival of Rehabilitated Peregrine Falcons (*Falco peregrinus*) and Brown Goshawks (*Accipiter fasciatus*) Released Back Into the Wild

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Abstract: This study examined the effect of 2 fitness programs on the postrelease survival and ability to maintain weight of 15 peregrine falcons (*Falco peregrinus*) and 12 brown goshawks (*Accipiter fasciatus*) held captive for treatment or because they had been orphaned. Each bird was treated or allowed to mature, then was either exercised by traditional falconry methods or by stimulating flight within its cage. Prior to release, resting blood lactate concentrations were measured before a short period of exercise and at 2 and 10 minutes after a standardized exercise test. Pre-exercise blood lactate concentrations were higher in cage-exercised peregrine falcons compared with those exercised by traditional methods, but there was no difference in pre-exercise lactate concentrations between the 2 treatment groups of goshawks. At 2 and 10 minutes following exercise, blood lactate concentrations were significantly higher for the cage-exercised group of both species. All birds were fitted with radiotransmitters, released, and monitored, then were trapped at varying times after release and weighed. Of the falconry-trained birds, 3 of 6 peregrine falcons and all 4 brown goshawks gained weight. In contrast, all 9 peregrine falcons and 6 of the 8 brown goshawks subjected to cage exercise lost weight postrelease. The results suggest that peregrine falcons and brown goshawks exercised with traditional falconry techniques were more fit than the same species of birds exercised in their cages and that the improved fitness achieved with the former method increases the probability that captive peregrine falcons and brown goshawks will survive after being released to the wild. The study also indicates that postexercise blood lactate concentrations are important predictors of fitness in raptors.

Key words: fitness, lactate, rehabilitation, avian, birds, peregrine falcon, *Falco peregrinus*, brown goshawk, *Accipiter fasciatus*

Introduction

Each year, wild raptors are injured, treated, rehabilitated, and released back into the wild. Time spent in captivity recovering from injuries decreases fitness levels. As raptors must actively hunt and kill prey, it is logical to assume that the fitness of these birds at the time of release may play a critical role in their ability to catch prey and survive after release.[1] In fact, the prerelease fitness training program to which raptors are subjected may have a significant impact on a raptor's chances for survival after release.

Controversy exists as to how to best prepare raptors for release. Some believe that stimulating flight back and forth within a flight cage or exercising a bird tethered to a line (cage exercise) will allow a bird to develop sufficient fitness for postrelease survival.[2] Others believe that birds in large flight cages will develop sufficient fitness in the absence of a specific exercise program.[3] It has also been suggested that birds in adequate nutritional condition can develop sufficient fitness after release to catch prey.[4] Still others advocate the use of intensive falconry-based techniques before a bird's release to improve the bird's fitness and increase its chances

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Table 1. Reasons for presentation and time in captivity prior to release for peregrine falcons included in this study.

Bird	Group[a]	Sex	Reason for presentation or major clinical sign(s)	Time in captivity (days)
PF01	1	female	healthy orphan	195
PF02	1	male	cranial trauma	55
PF03	1	male	sternal trauma	169
PF05	1	male	soft-tissue wing injury	469
PF06	1	male	healthy orphan	50
PF07	1	male	healthy orphan	50
PF04	2	male	luxated proximal humerus	330
PF08	2	female	fractured ulna	272
PF09	2	male	soft-tissue injury	636
PF10	2	female	no abnormalities found	28
PF11	2	male	healthy orphan	35
PF12	2	female	thin	68
PF13	2	male	soft-tissue wing injury	60
PF14	2	female	thin; soft-tissue trauma	150
PF15	2	male	healthy orphan	101
PF04[b]		male	luxated proximal humerus	56

[a] Group 1 birds were exercised using falconry techniques, and group 2 birds were exercised by stimulating flight in the aviary.
[b] Injury was detected following recapture.

for survival after release.[5–7] However, falconry and falconry-based techniques are discouraged by the Australasian Raptor Association[8] and are prohibited by the New South Wales National Parks and Wildlife Service.[3] Studies that have used prerelease conditioning did not provide survival data following release.[9,10] Long-term survival has been estimated through the use of band returns or by radiotracking individual birds.[11–17]

Blood lactate concentration following 10 minutes of exercise has been shown to be a good predictor of fitness in rehabilitated red-tailed hawks (*Buteo jamaicensis*), rough-legged hawks (*Buteo lagopus*), and great horned owls (*Bubo virginianus*).[18] In raptors sufficiently fit for release, blood lactate levels were ≤120 mg/dl 2 minutes after exercise and declined to pre-exercise concentrations within 10 minutes after exercise. In birds that were less fit, blood lactate concentrations were ≥200 mg/dl and did not decline as quickly. These findings suggest that blood lactate concentrations could also be used in other species of raptors to predict their prerelease fitness.[18]

The first objective of the present study was to determine whether peregrine falcons (*Falco peregrinus*) and brown goshawks (*Accipiter fasciatus*) actively flown using traditional falconry techniques were more fit than cage-exercised birds. The second objective was to verify that blood lactate concentrations following exercise could be used to predict fitness, as has been shown in previous studies of other raptor species.[18]

Materials and Methods

Fifteen peregrine falcons and 12 brown goshawks were used in this study. Data from the first 9 brown goshawks (BG01–BG09) were included in a previously published preliminary report.[1] All individuals were wild birds presented to Healesville Sanctuary, Healesville, Victoria, Australia. Reasons for presentation and time spent in captivity before release are shown in Tables 1 and 2. Birds were individually assigned to 1 of 2 groups alternately based on order of presentation. No attempt was made to categorize birds with respect to gender, time in captivity, or reason for presentation. After recovery from their various conditions, birds were maintained in individual aviaries. Birds in group 1 were exercised by operant conditioning-based standard falconry techniques previously described (n = 6 peregrine falcons and 4 brown goshawks).[19] Birds were initially flown 50 m twice a day using a creance and food-based motivation. Birds were then free flown 50 m twice a day until judged by the handler to be ready for release. Group 2 birds (n = 9 peregrine falcons and 8 brown goshawks) were held in aviaries and fed; they were exercised once or twice a week by stimulating 10–18 flights back and forth in a 25-m flight cage.[2]

Birds were deemed ready for release when handlers determined normal flight ability had been attained. Prior to release, birds were forced to fly 18 repetitions of an 8-m horizontal flight during a period of approximately 5 minutes. A drop of blood

Table 2. Reasons for presentation and time in captivity prior to release for brown goshawks included in this study.

Bird	Group[a]	Sex	Reason for presentation or major clinical sign(s)	Time in captivity (days)
BG01	1	male	trapped in chicken pen	263
BG02	1	female	thin; head trauma	104
BG03	1	female	fractured humerus	1017
BG07	1	female	trapped in chicken pen	1[b]
BG04	2	female	thin	141
BG05	2	female	thin	78
BG06	2	female	healthy orphan	173
BG08	2	female	fractured coracoid	45
BG09	2	male	healthy orphan	90
BG10	2	female	thin; trichomoniasis	523
BG11	2	male	thin	30
BG12	2	female	fractured ulna	41
BG04[c]		female	thin	72
BG05[c]		female	thin	19
BG06[c]		female	healthy orphan	113
BG08[c]		female	fractured coracoid	10

[a] Group 1 birds were exercised using falconry techniques, and group 2 birds were exercised by stimulating flight in the aviary.
[b] This bird was assessed as having normal flight ability immediately.
[c] Injury was detected following recapture.

was collected from the basilic vein immediately before exercise (baseline) as well as at 2 and 10 minutes after exercise. Blood lactate concentrations were measured on a portable lactate meter (Accusport, Boehringer Mannheim, Castle Hill, Australia). Each bird was then weighed, an LF-3 radiotransmitter (L.L. Electronics, Mahomet, IL, USA) was glued to the central rectrices, and the bird was released. Release sites were assessed to have sufficient food availability for these species.

Birds were tracked then recaptured at variable times postrelease and reweighed. One peregrine falcon (PF04) and 4 brown goshawks (BG04, BG05, BG06, and BG08) from group 2 that had lost weight were taken back into captivity. These birds were then exercised using traditional falconry techniques and rereleased. In all instances of the body weight remaining steady or increasing subsequent to release, birds were returned to the wild without radiotransmitters.

Blood lactate concentrations for birds in groups 1 and 2 were compared at baseline, 2 minutes postexercise, and 10 minutes postexercise. Blood lactate concentrations at baseline and 10 minutes postexercise were also compared within groups to determine if concentrations had returned to baseline. Data was analyzed using commercially available software (Statistix 8, Analytical Software, Tallahassee, FL, USA). Because data were normally distributed, significance was measured using either a two-sample or a paired *t* test as deemed appropriate.

Results

Results of the survival studies are presented in Tables 3 and 4. Three group 1 peregrine falcons gained weight after release, 2 lost weight, and 1 could not be recaptured (Table 3). All group 2 peregrine falcons lost weight (range of weight loss = 4%–32% of body weight at release). Four of the group 2 falcons were found dead; one had been struck by a car, but there were no significant findings, apart from emaciation, during necropsy of the other birds. All 4 group 1 brown goshawks gained weight after release (Table 4). Three of these birds (BG01, BG02, and BG03) were incidentally recaptured a second time at 15 months, 6 months, and 2 months after initial recapture, respectively, indicating their relatively long-term survival. All 3 birds were in good condition on recapture. Six group 2 goshawks lost weight (range of weight loss = 9%–37% of body weight at release), and 1 group 2 goshawk died with no significant findings at necropsy apart from emaciation. One group 2 goshawk gained weight, and 1 could not be recaptured but was seen alive 16 days postrelease.

Four goshawks (BG04, BG05, BG06, and BG08) and 1 falcon (PF04) in group 2 that had lost weight after initial release were taken back into captivity, exercised in the same manner as group 1 birds, and rereleased. All 4 goshawks gained weight after the second release. The falcon lost 8% of its body weight after the second release but substantially less than after its first release (18% of body weight).

Table 3. Body-weight fluctuations between release and recapture in peregrine falcons exercised prior to release using traditional falconry methods (group 1) or cage exercise (group 2).

Bird	Group	Release weight (g)	Recapture weight (g)	Difference (g)	Difference (% of release weight)	Time from release to recapture (days)
PF01	1	956	893	−63	−6.6	25
PF02[a]	1	603	—[a]			
PF03	1	635	624	−11	−1.7	12
PF05	1	560	590	+30	+5.4	35
PF06	1	605	615	+10	+1.7	48
PF07	1	590	600	+10	+1.7	71
PF04	2	620	509	−111	−17.9	15
PF08	2	880	841	−39	−4.4	11
PF09	2	605	437 (dead)	−168	−27.8	11
PF10	2	645	450	−195	−30.2	35
PF11	2	540	emaciated (dead)[b]			5
PF12	2	878	emaciated (dead)[b]			
PF13	2	590	400 (dead)[c]	−190	−32.2	10
PF14	2	1045	815	−230	−22.0	21
PF15	2	596	545	−51	−8.6	16
PF04[d]		670	615	−55	−8.2	17

[a] Unable to trap; observed alive 11 months postrelease.
[b] Substantial postmortem predation precluded meaningful estimation of weight.
[c] Hit by car.
[d] Following recapture.

Table 4. Body-weight fluctuations between release and recapture in brown goshawks exercised prior to release using traditional falconry methods (group 1) or cage exercise (group 2).

Bird	Group	Release weight (g)	Recapture weight (g)	Difference (g)	Difference (% of release weight)	Time from release to recapture (days)
BG01	1	304	357	+53	+17.4	6
BG02	1	535	580	+45	+8.4	20
BG03	1	580	616	+36	+6.2	9
BG07	1	550	560	+10	+1.8	10
BG04	2	538	490	−48	−8.9	5
BG05	2	580	474	−106	−18.3	6
BG06	2	538	476	−62	−11.5	5
BG08	2	545	490	−55	−10.1	34
BG09	2	301	360	+59	+19.6	27
BG10	2	490	390	−100	−20.4	12
BG11	2	331	210 (dead)	−121	−36.6	17
BG12	2	630	—[a]			
BG04[b]		538	540	+2	+0.4	20
BG05[b]		570	580	+10	+1.8	11
BG06[b]		582	590	+8	+1.4	17
BG08[b]		550	568	+18	+3.3	6

[a] Unable to trap; observed alive 16 days after release.
[b] Following recapture.

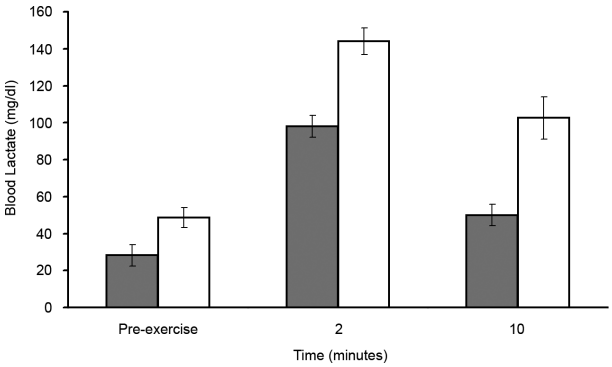

Figure 1. Prerelease blood lactate concentrations before and after approximately 5 minutes of controlled exercise in peregrine falcons exercised during captivity using either a program of falconry techniques (group 1, filled bars; n = 6) or cage exercise (group 2, open bars; n = 9 birds).

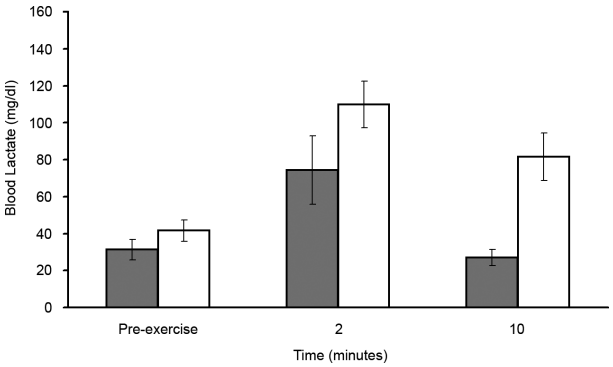

Figure 2. Prerelease blood lactate concentrations before and after approximately 5 minutes of controlled exercise in brown goshawks exercised during captivity using either a program of falconry techniques (group 1, filled bars; n = 4 birds) or cage exercise (group 2, open bars; n = 8).

Blood lactate concentrations are shown in Figures 1 and 2. Mean blood lactate concentrations for group 1 peregrine falcons were significantly lower than those for group 2 falcons at all time points (Fig 1). At 10 minutes postexercise, mean blood lactate concentrations for group 1 peregrine falcons were still significantly elevated above mean resting concentrations. Differences in mean blood lactate concentrations between group 1 and group 2 brown goshawks were not significant at either baseline or 2 minutes postexercise (Fig 2), but concentrations in group 1 birds were significantly lower than those in group 2 birds at 10 minutes postexercise. For the group 1 goshawks, the mean blood lactate concentration for the 10-minute sampling could not be distinguished statistically from the pre-exercise concentration.

Discussion

The purpose of this study was twofold: to determine the effect of 2 fitness programs for peregrine falcons and brown goshawks on postrelease outcomes and to verify the usefulness of postexercise blood lactate concentrations as a measure of fitness. It has been argued that prerelease training using traditional falconry techniques improves the fitness of raptors and can be expected to increase their ability to catch prey and ultimately survive in the wild. The results presented in this study support this assertion. Both peregrine falcons and brown goshawks in group 1 fared much better after release than did the birds in group 2. None of the group 1 birds died, and the majority of them were able to maintain or gain weight. In contrast, weight loss was common in the group 2 birds, and all mortality was confined to these birds. Additionally, all but 1 of the group 2 birds brought back into captivity because of weight loss maintained or gained weight when released following exercise training using the group 1 protocol.

Differences in success were noted between the brown goshawks and peregrine falcons trained with the group 1 protocol. None of the recaptured brown goshawks (n = 4) lost weight; however, 2 of 5 recaptured peregrine falcons did. These data suggest that peregrine falcons need a more intensive training regime than brown goshawks before release. This is not surprising, as peregrine falcons have a higher wing loading and aspect ratio than goshawks; therefore, it is more energetically expensive for them to become airborne and chase and catch prey.[20] Also, peregrine falcons spend more time searching for prey while flying as compared with goshawks, which do some searching while perched. These data suggest that prerelease fitness programs should be tailored specifically for each species of raptor, depending on their hunting techniques.

A single peregrine falcon in group 2 that was recaptured and retrained using the group 1 exercise protocol failed to gain weight after the second release. Whether this was fitness related is not known. It is possible that this bird had other medical conditions that were not recognized or may have had less developed hunting skills than the other released birds.

Previously, it has been shown in 2 species of buteo and a species of owl that postexercise blood lactate concentration is a useful indicator of a raptor's fitness.[18] The results of the present study show that blood lactate concentration is also a good measure of postrelease fitness and survivability in accipiters and falcons. Group 1 birds that were more

intensively exercised had lower blood lactate concentrations following exercise compared with the less intensively exercised birds in group 2, and the blood lactate concentrations in group 2 birds also returned to normal faster after exercise. Retrospectively, blood lactate concentrations were found to be inversely predictive of weight maintenance and survival after release. The fact that blood lactate concentrations in group 1 peregrine falcons were still significantly above baseline at 10 minutes post-exercise suggests that an exercise program that is longer or more intensive than the one provided in this study may be necessary for this species.

Pre-exercise blood lactate concentrations were higher in group 2 than group 1 birds. This may reflect conditioning, or it is possible that birds in group 2 were less habituated to handling than those in group 1. If the second explanation is correct, group 2 birds may have been more likely to resist capture, and struggle during capture may have resulted in increased blood lactate concentrations.

In conclusion, this study presents compelling data demonstrating that falconry-based exercise training is far superior to cage-based exercise protocols for conditioning rehabilitated peregrine falcons and brown goshawks before release. Without falconry-based training, mortality because of reduced ability to capture prey will be high in released raptors. This study also provides evidence that increased blood lactate concentrations following exercise and the rate at which concentrations return to normal are excellent tools for assessing the effectiveness of a training program and readiness of peregrine falcons and brown goshawks for release.

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