Sunburned! An Evidence-Based Update on UVB Lighting for Captive Exotic Pets

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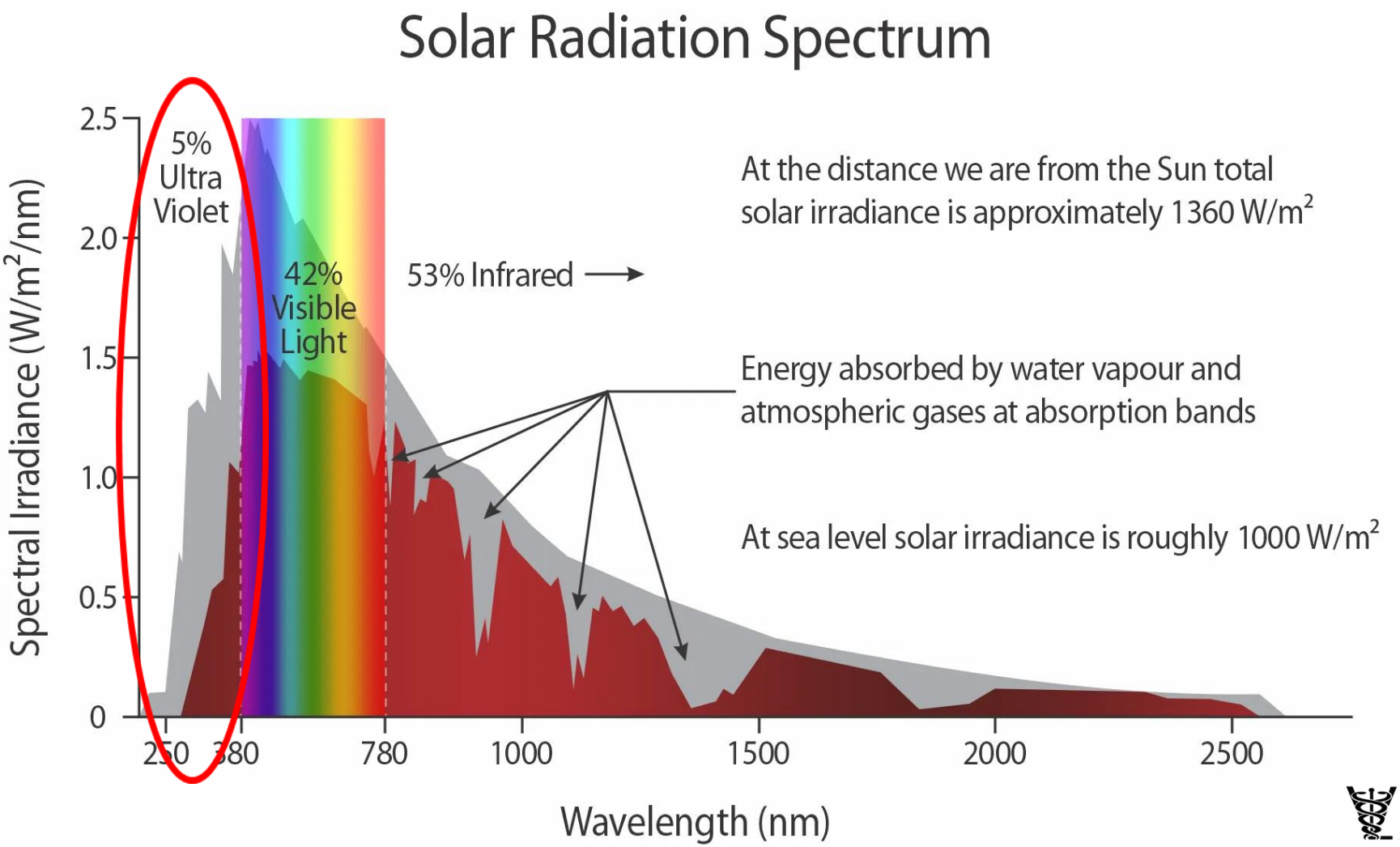
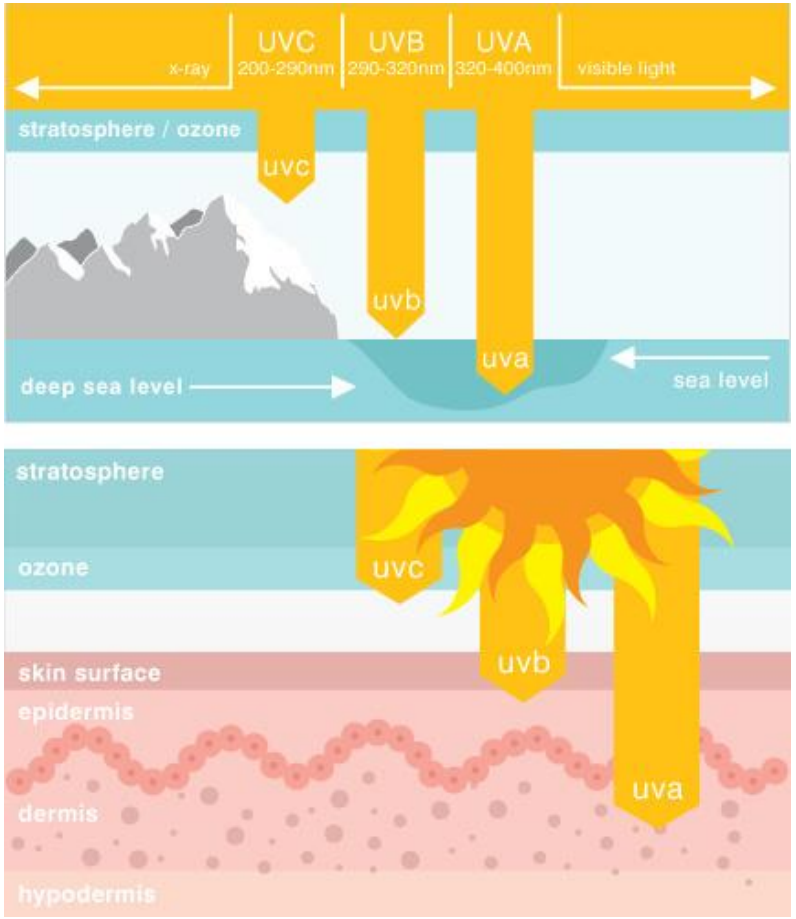
RACE program #1341921

Importance of the Sun

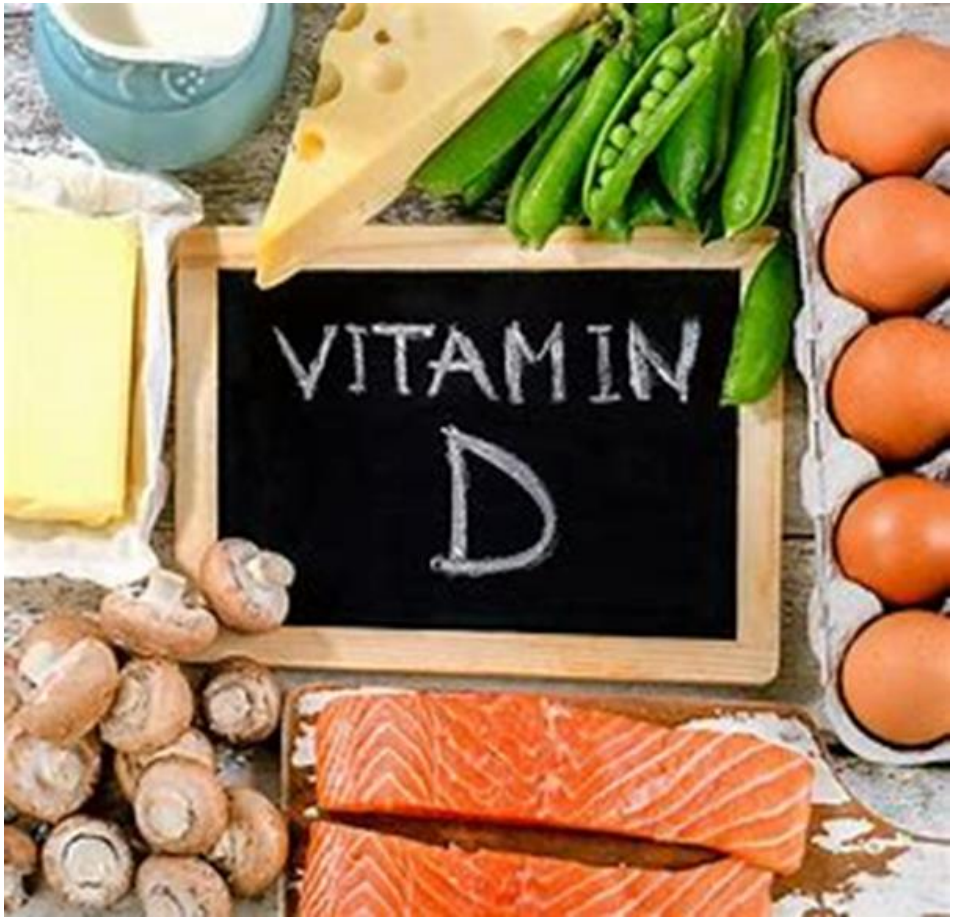


Ultraviolet radiation

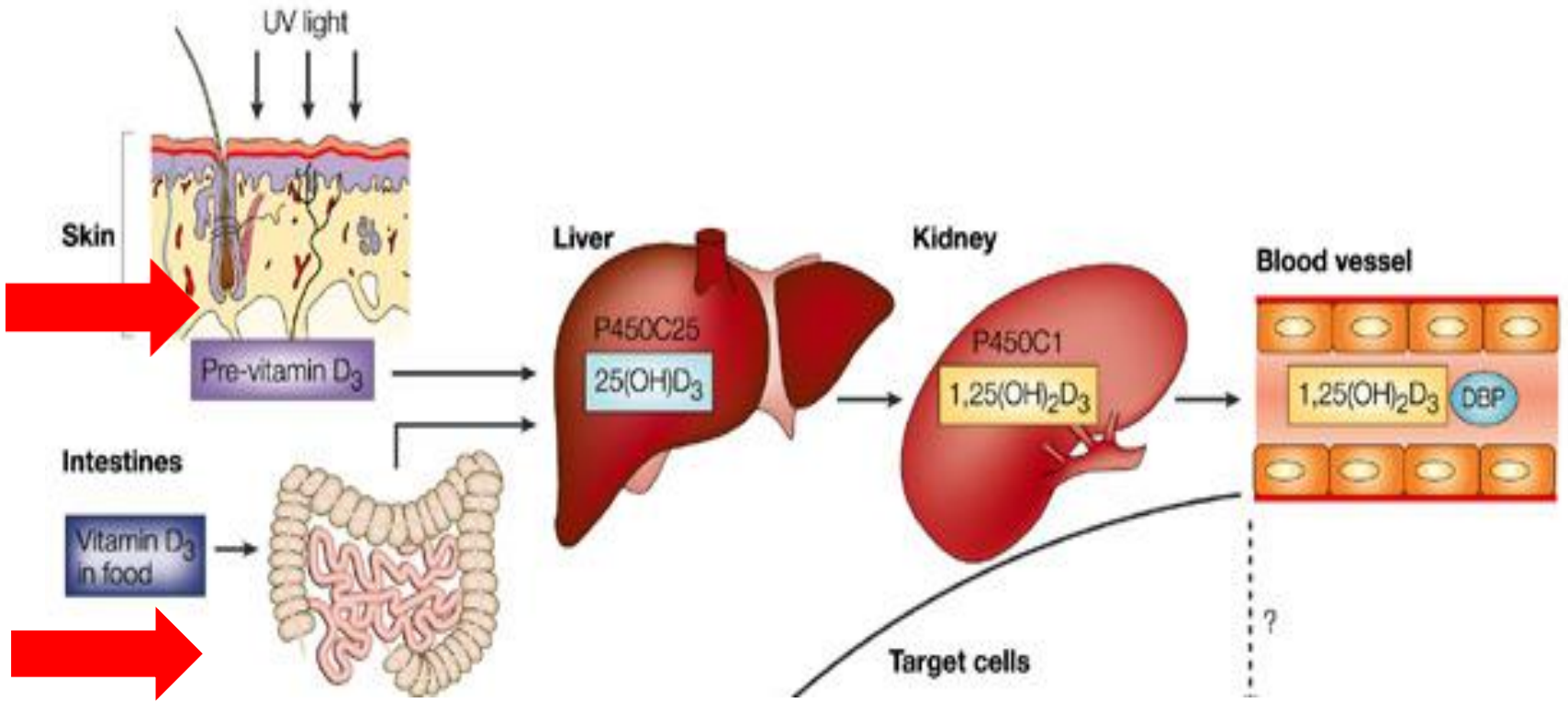
- Ultraviolet wavelengths
  - UVA = 315-400 nm
  - UVB = 285-315 nm
  - UVC = 100-285 nm



Importance of Vitamin D?



Vitamin D metabolism



Boron, W. F. and E. L. Boulpaep. *Medical Physiology, 2e* Elsevier Health Sciences, 2012.

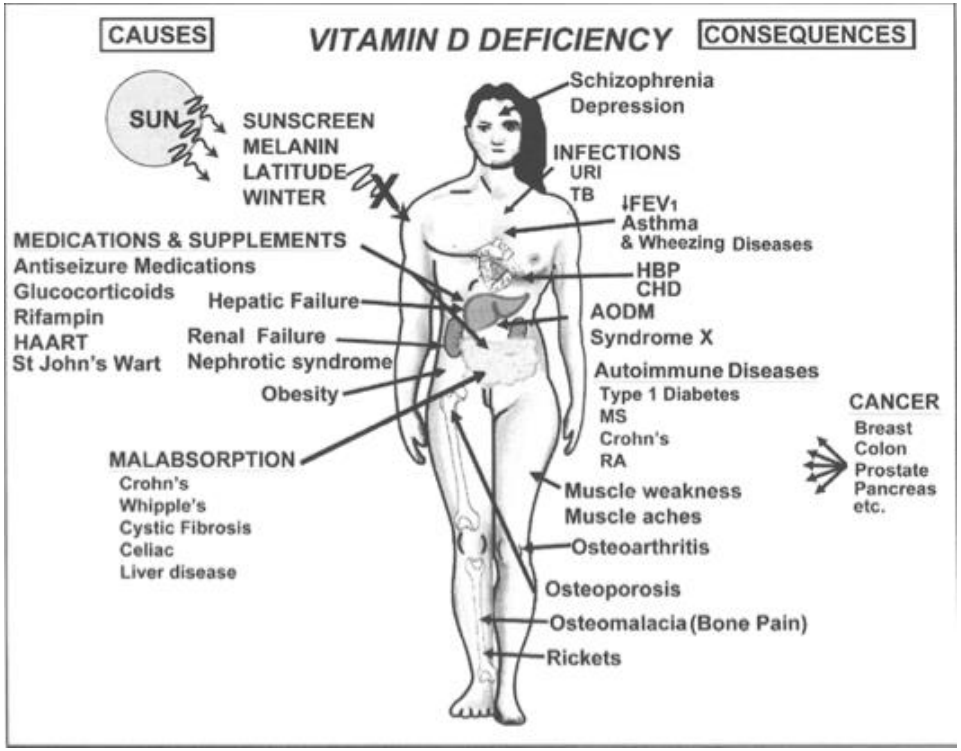
Photobiochemical synthesis

- UVB radiation
  - 280-320 nm

- 7-dehydrocholesterol to previtamin D3 →
  - **Tachysterol**
  - **Lumisterol**
  - **Provitamin** D3
  - **Vitamin D3 (cholecalciferol)**

Vitamin D deficiency

- ~ 1 billion people at risk
- 25-hydroxyvitamin D ($25OHD_3$)
  - Preferred measure for vitamin D status
  - Humans < 50 nmol/L considered deficient
- Common in medical inpatients



All species created equal?

- Dogs (Hazewinkel et al. 1989, How et al. 1994)
  - Unable to synthesize vitamin D with UVB exposure
  - Highly efficient at utilizing vitamin D in diet

- Cats (How et al. 1994 , Morris 1999)
  - Unable to convert 7-DHC
  - Presence of 7-DHC delta reductase

- Other carnivores? Herbivores?
  - Diet most important?

- What about captive exotic species?

?

Lizards

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THE OFFICIAL PUBLICATION OF THE ASSOCIATION OF REPTILIAN AND AMPHIBIAN VETERINARIANS

ORIGINAL RESEARCH

The Journal of Herpetological Medicine and Surgery, Volume 28, No. 1–2, 2018 pp. 34–39
DOI: 10.5818/17-11-136.1

Evaluating the Physiologic Effects of Short Duration Ultraviolet B Radiation Exposure in Leopard Geckos (*Eublepharis macularius*)

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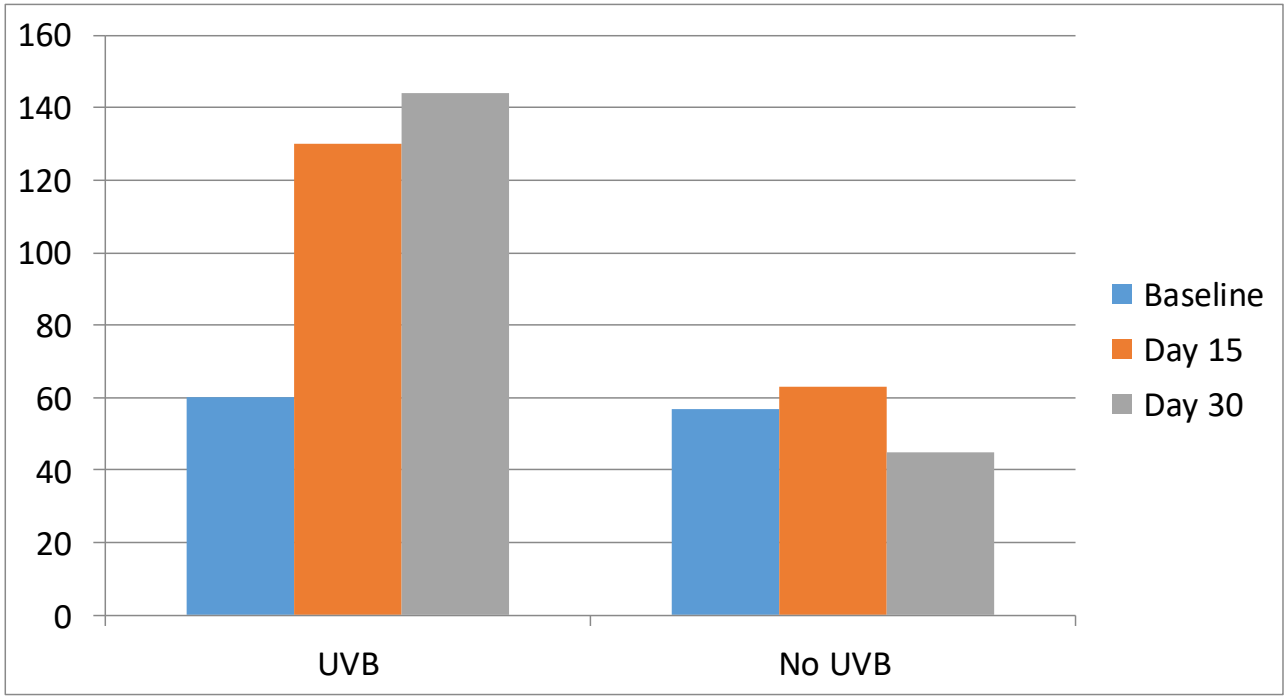
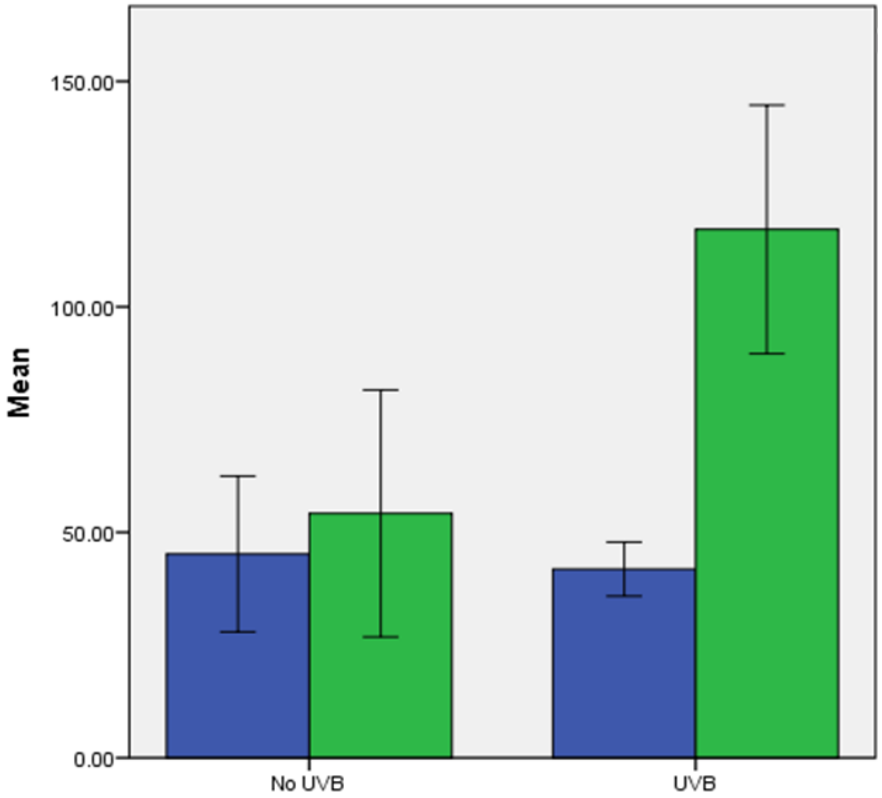
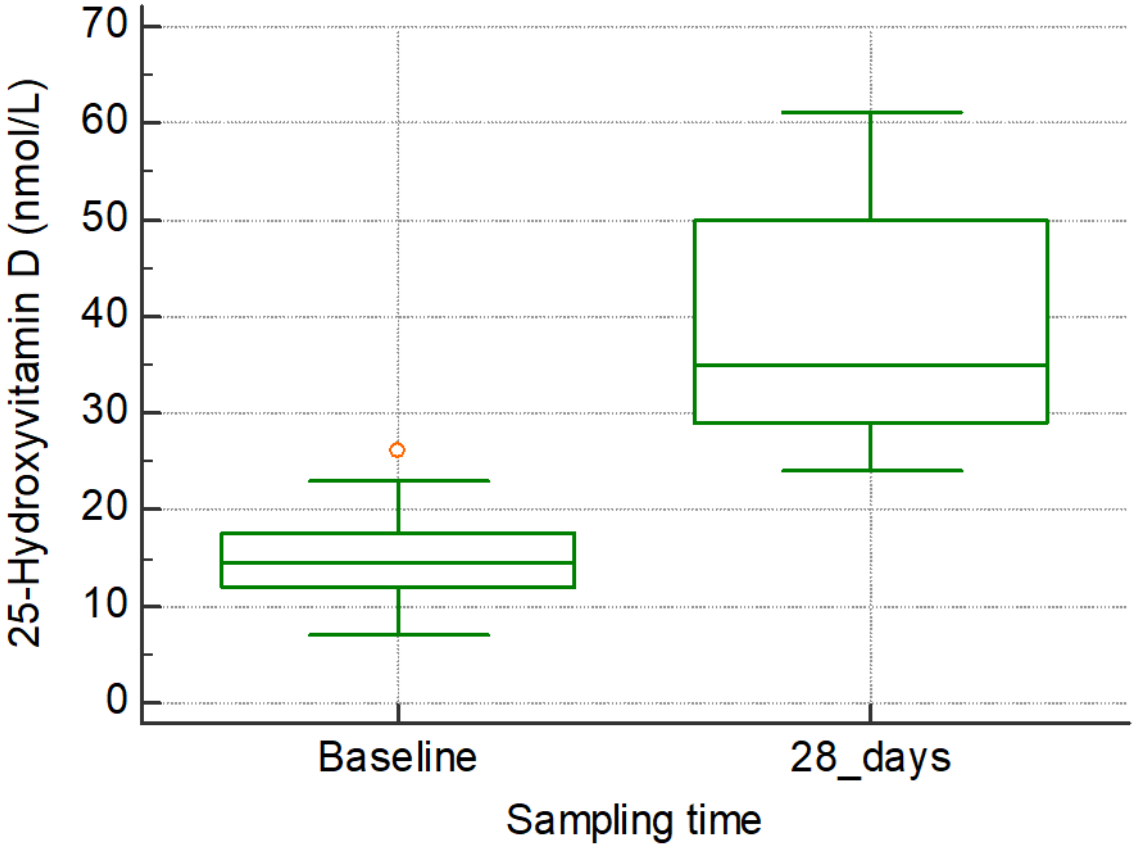
12 hours/day



2 hours/day



15, 30, 60 minutes



veterinary sciences

MDPI

Article

Measuring the Rise and Fall of Plasma 25-Hydroxyvitamin D Concentrations in Blue-Tongued Skinks (*Tiliqua scincoides*) Following Ultraviolet B Exposure and Withdrawal

Ashleigh Godke, Haerin Rhim *, M. Graciela Aguilar, Keishla Marrero-Acosta and Mark A. Mitchell

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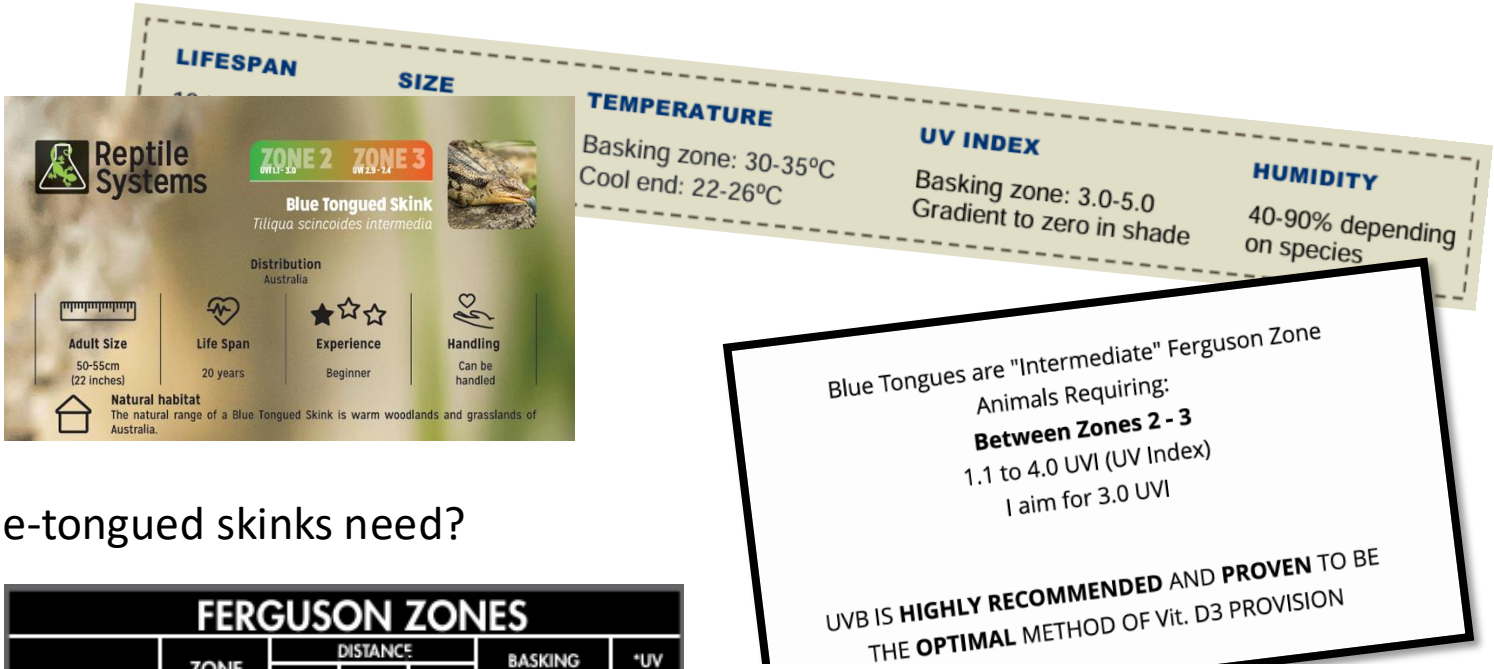
Simple Summary

Blue-tongued skinks (*Tiliqua scincoides*) are popular pet reptiles, but there is limited evidence-based information about their care. For example, the method they use to obtain vitamin D—a nutrient vital to reptile health—is still unknown. This study investigated whether these skinks can meet their vitamin D needs through diet alone or require ultraviolet B (UVB) exposure. Skinks were raised on a wet cat food containing vitamin D, then exposed to UVB light for either 12 or 2 h/day for 4 weeks. The baseline vitamin D concentrations were low; however, UVB exposure dramatically increased these values. After the UVB lighting was removed, vitamin D concentrations decreased for the 12-hour and 2-hour groups, requiring more than 7 and 4 months for the values to return to baseline, respectively. These results indicate that blue-tongued skinks can utilize UVB light to synthesize vitamin D.

UV-B

- How much do blue-tongued skinks need?



Blue Tongues are "Intermediate" Ferguson Zone Animals Requiring:
Between Zones 2 - 3
1.1 to 4.0 UVI (UV Index)
I aim for 3.0 UVI

UVB IS **HIGHLY RECOMMENDED** AND **PROVEN** TO BE THE **OPTIMAL** METHOD OF Vit. D3 PROVISION

FERGUSON ZONES

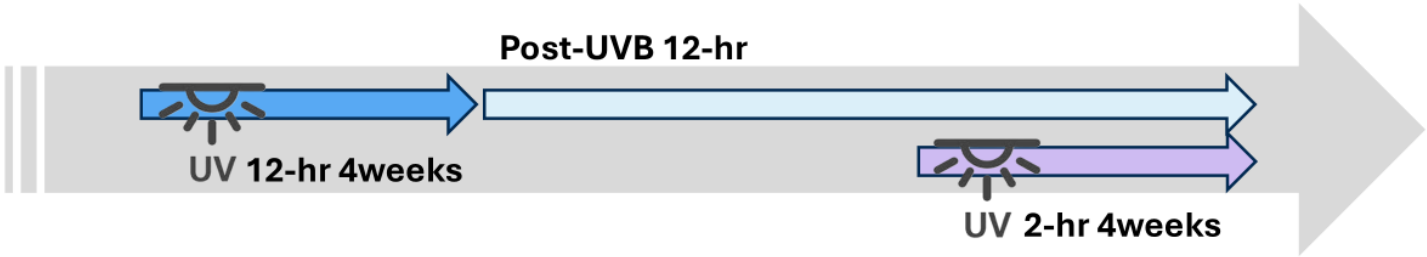
	ZONE	DISTANCE 80 W	DISTANCE 100 W	DISTANCE 160 W	BASKING BEHAVIOR	*UV INDEX
	ZONE 1	16"	20"	26"	SHADE	0.4 to 0.7
MINIMUM	ZONE 2	to 26"	to 32"	to 38"	MOSTLY PARTIAL SUNLIGHT	0.7 to 1.0
MODERATE	ZONE 3	6.0" to 16"	10" to 20"	16" to 26"	MOSTLY FULL SUNLIGHT	1.0 to 2.6
HIGH	ZONE 4	to 6.0"	to 10"	to 16"	MIDDAY FULL SUNLIGHT	3.5 or more
DANGER		ZERO to 4.0"	ZERO to 6.0"	ZERO to 7.0"		> 7.0

ZONE 3 *(moderate range):*

80 Watt: 6-16 inches (20-40 cm)
100 Watt: 10-20 inches (25-50 cm)
160 Watt: 16-26 inches (40-66 cm)

UVI 1.0 to 2.6 *(Mostly full sun/Occasional partial sun baskers)*

Zone 3 covers a fairly broad range and includes many species commonly kept as pets. These temperate, tropical, and sub-tropical species will bask in full sun early in the day or early afternoon. During mid-day, they may be found basking when conditions are partly cloudy. This zone is appropriate for most species of aquatic turtles and tortoises. Many of the small spiny lizards of the genus Sceloporus fall into this zone, as do Monitors and Tegus, Blue-tongued Skinks, Green Iguanas (Iguana iguana), and Curly-tailed Lizards of the genus Leiocephalus. With Zone 3 and above, it is **VERY IMPORTANT** to provide a UVB gradient down to Zone 1 UVB levels so that reptiles can photoregulate and adjust their UVB exposure as needed. Failure to provide a UVB gradient can result in illness, eye & skin damage, or even death. Always provide a shelter for reptiles to retreat completely from any light and UVB exposure.



Baseline

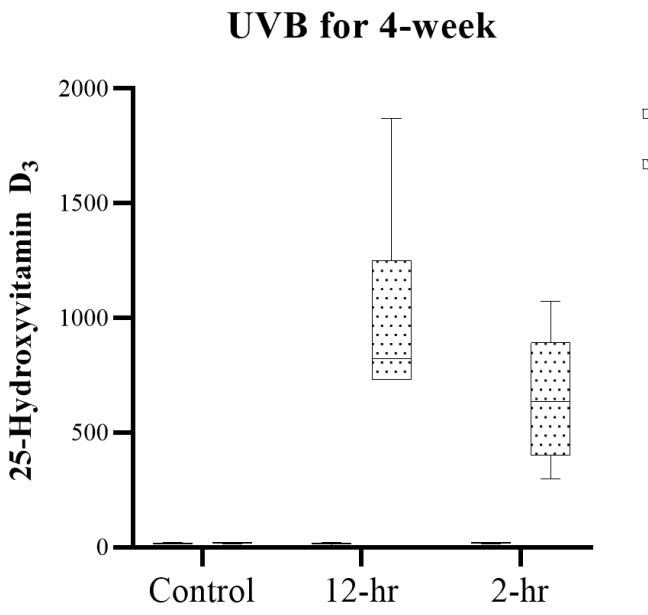
At week 4 (12hr)

At week 12 (12hr)

At week 16 (12hr)

At week 4 (2hr)

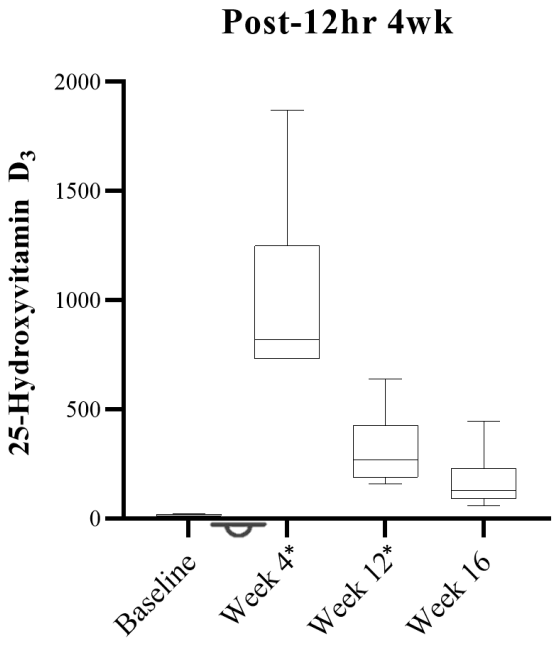
Results



- **25-hydroxyvitamin D3 (nmol/L)**

		Mean	SD	Min-Max	P value
Day 0	Control	16.40	2.881	14-21	
	12-hr UVB*	17	4.817	9-22	<0.001
	2-hr UVB§	19.4	3.715	14-22	0.001
Day 28	Control	19.4	3.715	14-22	
	12-hr UVB*	1002.5	440.622	730-1870	<0.001
	2-hr UVB§	644.4	285.625	297-1070	0.001

Results



- **25-hydroxyvitamin D3 (nmol/L)**

	Baseline	Week 4*	Week 12*	Week 16
Mean	17	1003	316.7	171
SD	4.817	440.6	173.9	139.8
MIN-MAX	9-22	730-1870	159-640	59-447
P value		0.013	0.038	

UVB	Time	Median	IQR	Min–Max	*p* Value
12-hour	Baseline	18.5	12.8–20.5	9–22	
	Week 4 *	820	730–1251.3	730–1870	<0.001
	Post 2M *	271.5	189–429.3	159–640	<0.001
	Post 3M *	129	92.8–230.3	59–447	0.002
	Post 7M *	44.5	33–60.3	21–67	0.038
	Post 8M	43.5	29.5–55	25–64	0.071
	Post 9M	27.5	21.5–37	22–34	0.504
2-hour	Baseline	22	15.5–22	14–22	
	Week 4 *	635	401–892.5	297–1070	<0.001
	Post 4M *	46	35–52.5	31–56	0.003
	Post 5M	30	27–42	26–49	0.072
	Post 6M	27	22–31.5	20–46	0.230

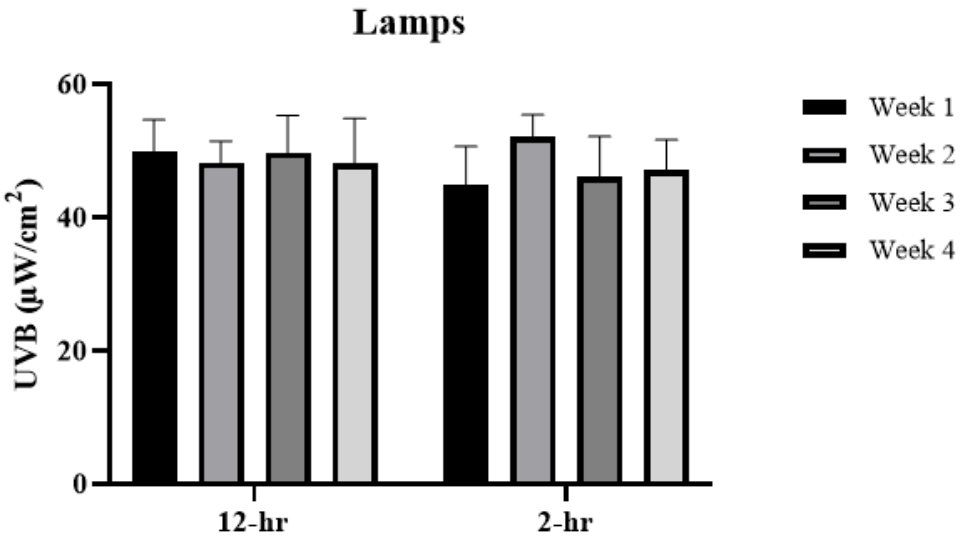
* $p < 0.05$.

Results

- No significant difference

In UVB output over time

All p>0.05



Group	Time	25-OHD$_3$ (nmol/L)	Min-Max	*P* values
2-hours every 3 days				
Control	Day 0	21 [15.5-29.5]	12-36	—
	Day 31	23 [17.5-27]	13-30	.96
Treatment	Day 0	17 [13.8-25]	13-31	—
	Day 31	587.5 [303.3-750]	130-885	.005[a]
2-hours every 7 days				
Treatment	Day 0	23 [17.5–27]	13-30	—
	Day 29	51 [42–222.5]	34-321	.043[b]

[a,b]Values with different superscripts are significantly [$P < .05$] different from their baselines.

Is there a reason short duration UVB is important to consider?

Chelonians

Effects of ultraviolet radiation on 25-hydroxyvitamin D_3 synthesis in red-eared slider turtles (*Trachemys scripta elegans*)

Mark J. Acierno, DVM; Mark A. Mitchell, DVM, PhD; Marlana K. Roundtree; Trevor T. Zachariah, DVM

Objective—To determine whether there are increased concentrations of 25-hydroxyvitaminn D_3 in red-eared slider turtles (*Trachemys scripta elegans*) after exposure to UV radiation.

Animals—12 yearling turtles recently removed from aestivation.

Procedures—Turtles were randomly allocated to 2 groups (6 turtles/group). An initial blood sample was collected from all turtles for measurement of 25-hydroxyvitamin D_3 concentrations. Turtles of 1 group were then provided no supplemental lighting, whereas turtles of the other group were exposed to full-spectrum coil bulbs at a distance of 22.86 cm. The UV-A and UV-B radiation generated by the supplemental lighting was measured by use of a radiometer-photometer at weekly intervals. Measurements were collected 2.54 and 22.86 cm from the bulb surface. The study was continued for a 4-week period. At the end of the study, a second blood sample was collected from all turtles for measurement of 25-hydroxyvitamin D_3.

Results—Mean ± SD 25-hydroxyvitamin D_3 concentrations differed significantly between turtles provided supplemental UV radiation (71.7 ± 46.9 nmol/L) and those not provided UV radiation (31.4 ± 13.2 nmol/L).

Conclusions and Clinical Relevance—Appropriate husbandry recommendations for raising and maintaining red-eared slider turtles should include use of sunlight that is unobstructed by UV-B filtering materi-

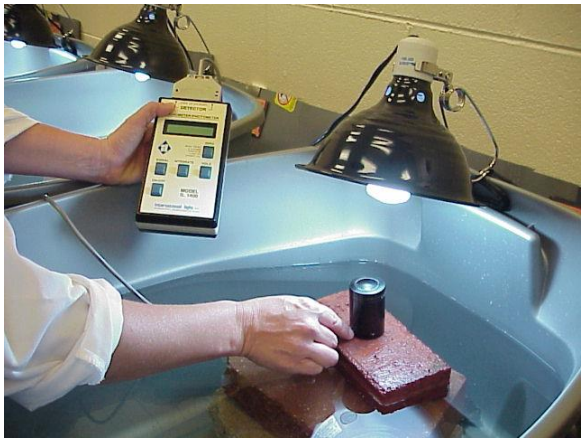
dietary requirements and synthesis during basking in various lizards. The authors are not aware of any studies to determine whether chelonians synthesize vitamin D_3 during basking or obtain vitamin D_3 from the diet. This is unfortunate because many of these species are raised in captivity as pets. Because these animals potentially have long lives, it is important that specific husbandry requirements be elucidated for them.

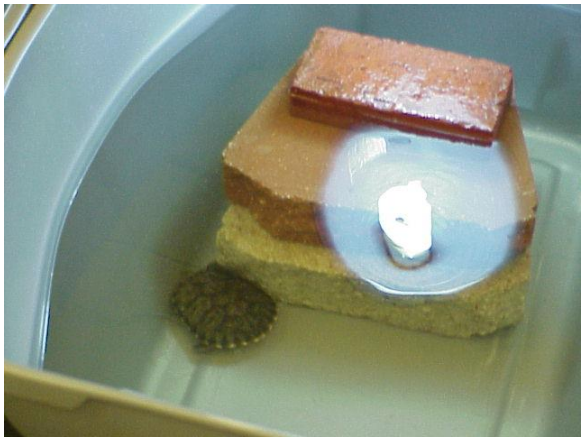
In addition to maintaining these animals as pets, there is an increased interest in the conservation of these reptiles. Currently, programs are underway to prepare juvenile chelonians in captivity for release to the wild. These programs typically release larger animals that are less likely to be preyed on. If exposure to UV-B radiation is required for chelonians to maximize serum 25-hydroxyvitamin D_3 concentrations, then full-spectrum lights capable of inducing production of this hormone should be used.

The purpose of the study reported here was to determine whether red-eared slider turtles (*Trachemys scripta elegans*) exposed to UV-B radiation under controlled conditions would have increased concentrations of 25-hydroxyvitamin D_3 concentrations, compared with concentrations for control turtles. We proposed to test 3 specific hypotheses. First, turtles exposed to UV-B radiation would have higher concentrations of 25-hydroxyvitamin D_3, compared with con-

Red-Eared Sliders

Treatment	Baseline	28 days
UVB + Diet	10.7	71.7± 46.9
Diet	11.7	31.4 ±13.2





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ORIGINAL/REVIEW/ROUNDTABLE ARTICLES

The Journal of Herpetological Medicine and Surgery, Volume 32, No. 3, 2022 pp. 1–5
DOI: 10.5818/JHMS-D-21-00039

Effects of Artificial Ultraviolet B Radiation on Plasma 25-Hydroxyvitamin D_3 Concentrations in Juvenile Blanding's Turtles (*Emydoidea blandingii*)

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Abstract

Vitamin D is an essential hormone that can be acquired via the diet, exposure to ultraviolet B (UVB) radiation, or a combination. Studies in reptiles suggest that the acquisition of vitamin D can vary between species; thus, species-specific evidence-based research should be pursued to develop appropriate husbandry recommendations. The objective of this study was to determine whether artificial UVB could be used to increase circulating 25-hydroxyvitamin D_3 (25-OHD_3) concentrations in juvenile Blanding's turtles (*Emydoidea blandingii*). Sixteen juvenile Blanding's turtles from an ongoing headstart

Blanding's Turtles

Treatment	25-OHD3
UVB + Diet	36.1
Diet	6.5

Hermann's Tortoises

Light	Baseline	35 days
Natural	387±114	411±189
UVB- mercury vapor	368±119	156±81
UVB- fluorescent	313±109	134±51

25-OHD decreased in artificial light groups
Significantly different between natural and artificial light

Snakes

Effects of ultraviolet radiation on plasma 25-hydroxyvitamin D_3 concentrations in corn snakes (*Elaphe guttata*)

Mark J. Acierno, MBA, DVM; Mark A. Mitchell, DVM, PhD; Trevor T. Zachariah, DVM; Marlana K. Roundtree; Megan S. Kirchgessner, DVM; David Sanchez-Migallon Guzman, Lic en Vit

Objective—To determine whether corn snakes exposed to UVB radiation have increased plasma 25-hydroxyvitamin D_3 concentrations, compared with control snakes.

Animals—12 corn snakes (*Elaphe guttata*).

Procedures—After an acclimation period in individual enclosures, a blood sample was collected from each snake for assessment of plasma 25-hydroxyvitamin D_3 concentration. Six snakes were provided with no supplemental lighting, and 6 snakes were exposed to light from 2 full-spectrum coil bulbs. By use of a radiometer-photometer, the UVA and UVB radiation generated by the bulbs were measured in each light-treated enclosure at 3 positions at the basking surface and at 2.54 cm (1 inch) below each bulb surface; the arithmetic mean values for the 3 positions at the basking surface and each individual bulb surface were calculated immediately after the start of the study and at weekly intervals thereafter. At the end of the study (day 28), another blood sample was collected from each snake to determine plasma 25-hydroxyvitamin D_3 concentration.

Results—Mean ± SD plasma concentration of 25-hydroxyvitamin D_3 in snakes that were provided with supplemental lighting (196 ± 16.73 nmol/L) differed significantly from the value in control snakes (57.17 ± 15.28 nmol/L). Mean exposure to UVA or UVB did not alter during the 4-week study period, although the amount of UVA recorded near the bulb surfaces did change significantly.

Clinical Relevance—These findings have provided important insight into the appropriate UV radiation requirements for corn snakes. Further investigation will be needed before exact husbandry requirements can be determined. (*Am J Vet Res* 2008;69:294–297)

Vitamin D_3 is an important hormone that has numerous physiologic properties.[1,2] Its most widely recognized function is the regulation of calcium metabolism, which is needed for the development and maintenance of healthy bones; however, the reproductive success of pan- various lizard species. Recently, an investigation[12] of the effects of UVB radiation in red-eared slider turtles (*Trachemys scripta elegans*) revealed that plasma concentration of 25-hydroxyvitamin D_3 increases significantly after exposure to UVB radiation. The authors are

Corn Snakes

Snake	Day 0 $25OHD_3$	Day 28 $25OHD_3$
UVB	57	196
No UVB	57	63

Ball Pythons

Snake	Day 0 $25OHD_3$	Day 70 $25OHD_3$
UVB	197±35	203.5±13.8
No UVB	77.7±41.5	83.0±41.93 +

Hedley and Eatwell, 2013, Vet Record, 173(14):345

Burmese Pythons

Snake	Day 0- $25OHD_3$	Day 310- $25OHD_3$
1	QNS	240
2	24	QNS
3	26	170
4	66	323

JH Bos, FC Klip, DGAB Oonincx, 2018, JZWM, 49(3):810-812.

So UVB is good and should be used in all cases?

Squamous Cell Carcinomas in Inland Bearded Dragons (*Pogona vitticeps*)

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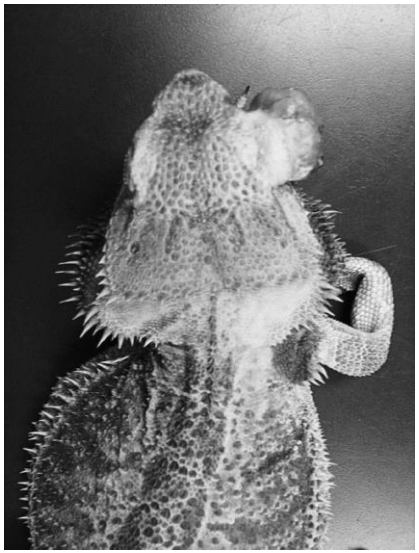
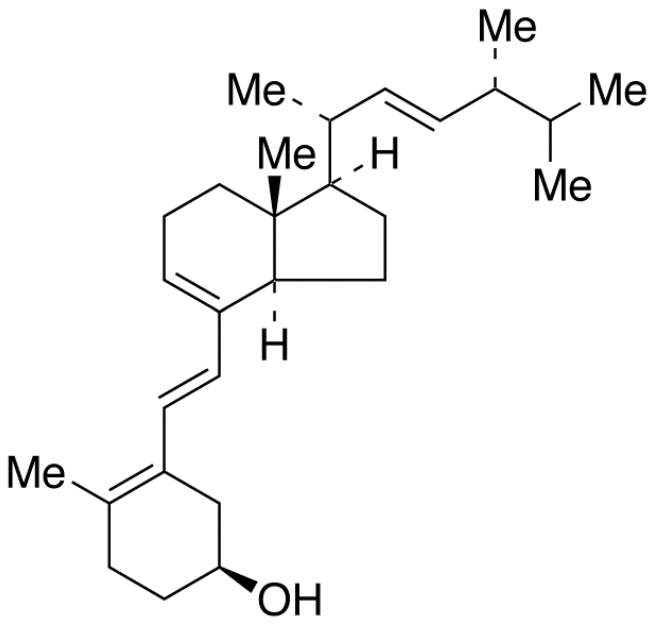
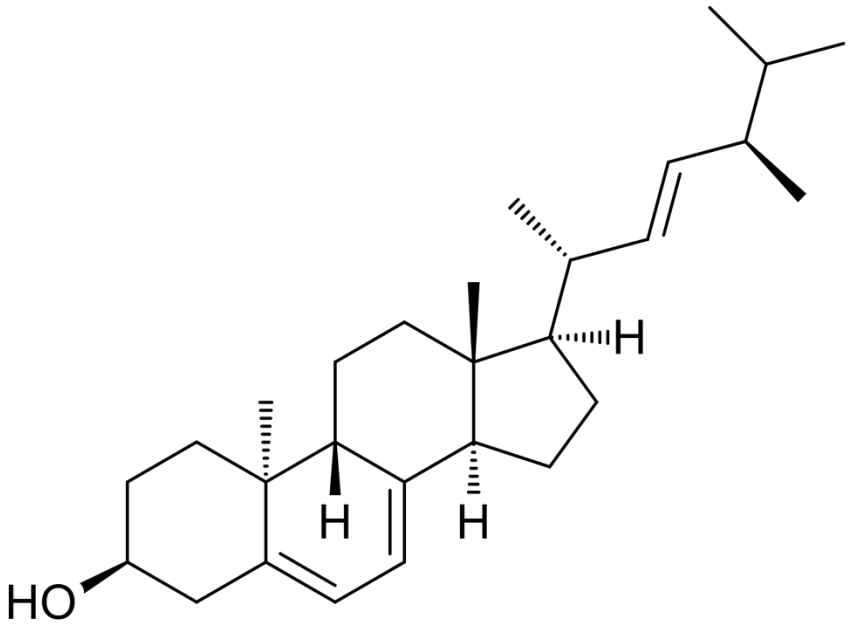


ABSTRACT: An 8-yr-old male bearded dragon (*Pogona vitticeps*) was presented for evaluation of a mass involving the right eyelid. The mass was surgically removed in conjunction with enucleation of the right eye. Tissues were submitted for histopathology, which revealed that the eyelid mass was a squamous cell carcinoma (SCC). A review of the records from two separate zoological pathology laboratories identified a total of 12 reports of SCC in bearded dragons; this represented 6% of the neoplasms documented in bearded dragons from the two laboratories over a 10 yr period. Nine (75%) of the 12 SCCs were located in the eyelids or periocular tissues; one (8.3%) was located on the rostral mandible; one (8.3%) was located adjacent to the vent; and one (8.3%) was on the proximal right rear leg. These findings suggest a predilection of SCCs in bearded dragons in proximity to a mucocutaneous junction (11/12, 91.6%), particularly in the periocular tissues (9/12, 75%).

Role of metabolites?



Tachysterol



Lumisterol

Any other options?

SCIENTIFIC REPORTS

OPEN

Evidence of vitamin D synthesis in insects exposed to UVb light

D. G. A. B. Oonincx[1], P. van Keulen[2], M. D. Finke[3], F. M. Baines[4], M. Vermeulen[5,6] & G. Bosch[2]

Received: 18 December 2017
Accepted: 9 July 2018
Published online: 17 July 2018

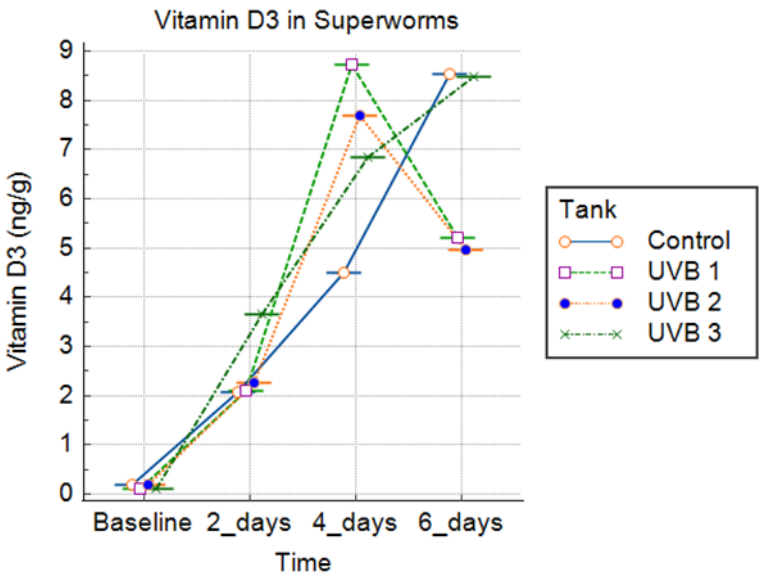
Vertebrates obtain the prohormone vitamin D primarily by endogenous cutaneous synthesis under ultraviolet b (UVb) exposure. To date, endogenous synthesis of vitamin D in insects has never been investigated. In an initial experiment, we exposed four insect species which differ in ecology and morphology (migratory locusts, house crickets, yellow mealworms and black soldier fly larvae (BSFL)) to a low irradiance UVb source. In a second experiment we exposed these species to a higher UV irradiance, and in a third we tested the effect of exposure duration on vitamin D concentrations in yellow mealworms. Low irradiance UVb tended to increase vitamin D_3 levels in house crickets, vitamin D_2 levels in BSFL and vitamin D_2 and D_3 in yellow mealworms. Higher UVb irradiance increased vitamin D_3 levels in all species but BSFL. Both BSFL and migratory locusts had increased vitamin D_2 levels. Longer UVb exposure of yellow mealworms increased vitamin D_2 and increased vitamin D_3 until a plateau was reached at 6400 IU/kg. This study shows that insects can synthesize vitamin D *de novo* and that the amounts depend on UVb irradiance and exposure duration.

Vitamin D metabolites perform a hormonal function in a wide variety of animal species[1–3]. These animals can obtain vitamin D either by oral ingestion or via *de novo* synthesis[4,5]. *De novo* synthesis requires exposure of a vitamin D precursor to ultraviolet light with a wavelength between 280 and 320 nm (UVb), followed by a temperature dependent step[6,7]. Humans, birds, reptiles, amphibians and fish can use both strategies, although *de novo* synthesis seems the primary route to acquire a sufficient vitamin D status[8–11]. Ergosterol is the primary vitamin D precursor in plants, yeasts and fungi, which UVb light converts to vitamin D_2, whereas 7-dehydrocholesterol (7DHC) is the precursor which forms vitamin D_3 in vertebrates[12,13]. The vertebrate liver hydroxylates either form of vitamin D to 25-hydroxycholecalciferol (25(OH)D) which is the major circulating form of vitamin D[14]. This can be further hydroxylated to 1,25-dihydroxycholecalciferol ($1,25(OH)_2D$) which is the hormonally most active form of vitamin D[14]. This form is best known as an endocrine regulator of calcium and phosphorus metabolism in vertebrates[15]. However, it also serves autocrine and paracrine functions in cellular proliferation, differentiation, and apoptosis, as well as in the innate immune system[16–21].

Whereas the importance of vitamin D in vertebrate physiology is well documented, little is known for inver-

Low, high, and long UVB irradiance provides variable Results- D_2 and D_3

Pending…..


Vitamin D3 in Superworms
Vitamin D3 (ng/g)
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1
2
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4
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Baseline
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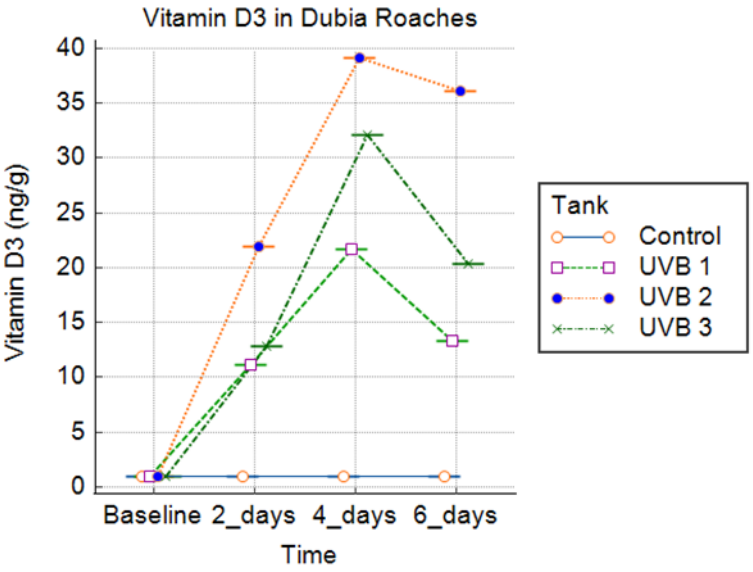
Time
Tank
Control
UVB 1
UVB 2
UVB 3


Vitamin D3 in Dubia Roaches
Vitamin D3 (ng/g)
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Baseline
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4_days
6_days
Time
Tank
Control
UVB 1
UVB 2
UVB 3

What does it all mean??

Received: 4 December 2019 | Revised: 6 October 2020 | Accepted: 25 January 2021

DOI: 10.1002/zoo.21591

RESEARCH ARTICLE

ZOOBIOLOGY WILEY

Is the natural UV zone important for successful captive propagation of the Panther Chameleon (*Furcifer pardalis*); are different UVB irradiance exposures that generate a similar dose equally successful?

Gary W. Ferguson[1] | William H. Gehrmann[1,†] | Matthew S. Vaughan[2] | Glenn C. Kroh[1] | Deborah Chase[3] | Kriss Slaets[4] | Michael F. Holick[5]

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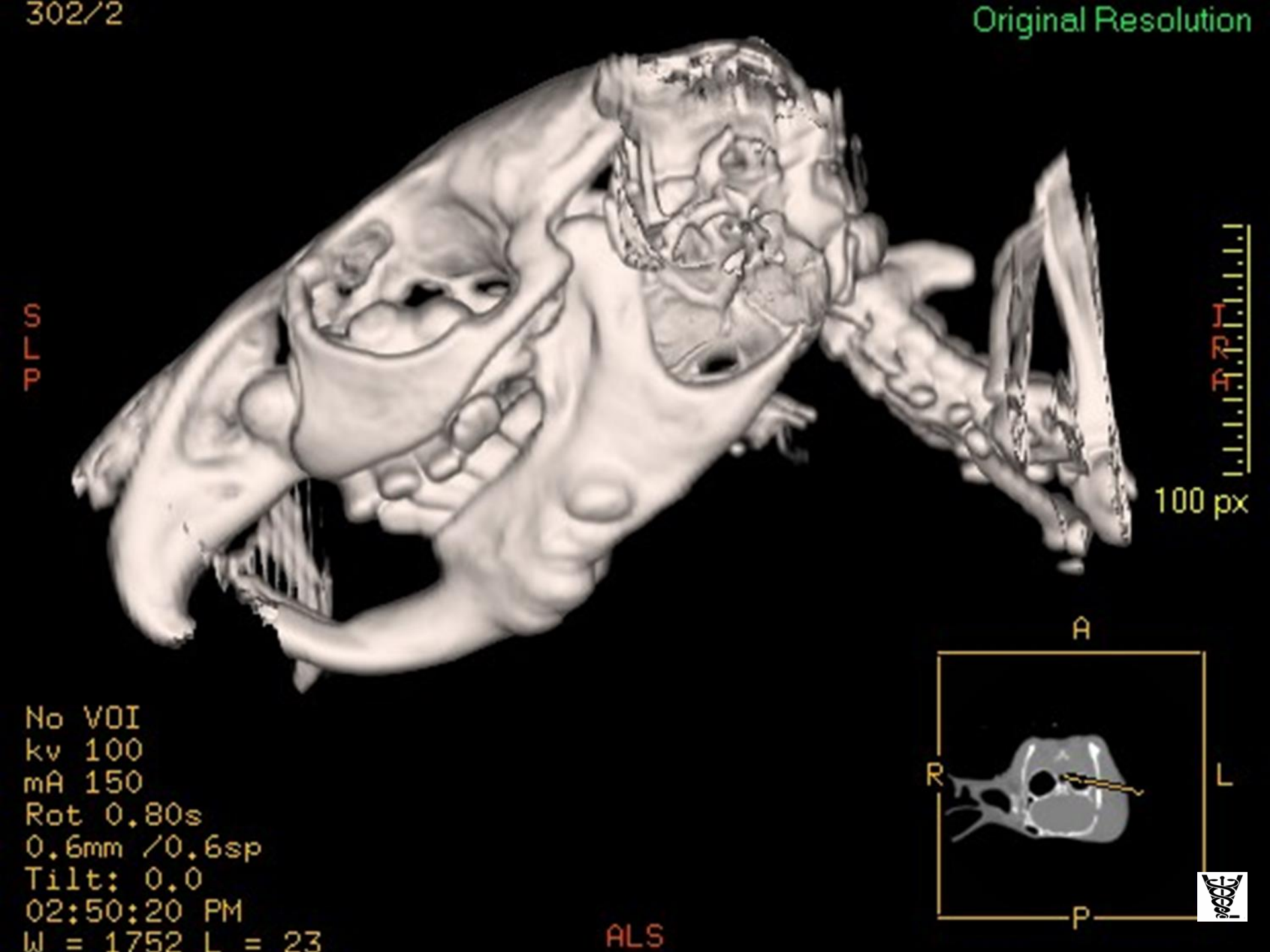
Abstract

While we generally understand the optimal ultraviolet B (UVB) environment for the growth and reproduction of female Panther Chameleons *Furcifer pardalis*, we do not know the relative importance of UVB irradiance and dose for optimal husbandry outcomes. Accordingly, we experimented with Panther Chameleon females to test the hypothesis that UVB dose (irradiance × exposure duration) determines the outcome, regardless of the combination of UVB irradiance and exposure duration generating the dose. We varied UVB irradiance and exposure duration across treatment groups while keeping dose similar and within a range previously documented to result in reproductive success. The growth rate, age of maturity, and measurable vitamin D status were not significantly different among the treatment groups. Individuals in all groups produced viable eggs that successfully hatched. Thus, we found some support for the hypothesis that the UVB dose determines the outcome regardless of UVB irradiance. However, mean egg vitamin D_3 concentration and percent hatching were higher in the highest UVB irradiance group, despite similar doses among the three groups. Preliminary field data reveal that this species occupies UV irradiance Zone 4 in Madagascar, the highest zone for reptiles recorded. Only the irradiance of the high UVB irradiance group in our experiment approached this zone and resulted in the best reproductive success. Biosynthesis of vitamin D_3 and provisioning to eggs is more efficient when exposure to UVB irradiance is similar to that in their natural environment. Establishing an optimal UVB environment, based on knowledge of the natural UVB environment, is important for the propagation of Panther Chameleons in captivity.

Dose more important than irradiance…..
……although irradiance tied to higher egg D_3 and hatching success

?

?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ALS

Effects of ultraviolet radiation produced from artificial lights on serum 25-hydroxyvitamin D concentration in captive domestic rabbits (*Oryctolagus cuniculi*)

Jessica A. Emerson, DVM; Julia K. Whittington, DVM; Matthew C. Allender, DVM, PhD; Mark A. Mitchell, DVM, PhD

Objective—To determine the effects of UVB radiation produced by artificial lights on serum 25-hydroxyvitamin D concentrations in domestic rabbits (*Oryctolagus cuniculi*).

Animals—9 juvenile domestic rabbits.

Procedures—After an acclimation period, rabbits were anesthetized with isoflurane, and an initial blood sample was collected for determination of serum 25-hydroxyvitamin D concentration. Rabbits were randomly assigned to receive 12-hour exposure to UVB radiation produced by 2 compact fluorescent lights daily (n = 5) or no UVB supplementation (4) commencing on day 1. The UVB radiation emitted into the cage was measured at 9 points approximately 34 cm from the surface of the UVB light sources (representing the position of the rabbits in the cage) after 10 hours of exposure on days 1, 8, and 14. On day 14, another blood sample was collected from anesthetized rabbits for determination of serum 25-hydroxyvitamin D concentration.

Results—The UVB radiation level was 8.3 to 58.1 $\mu W/cm^2$ for the exposed rabbits and consistently < 0.001 $\mu W/cm^2$ for the control rabbits. Mean ± SD serum 25-hydroxyvitamin D concentrations in the rabbits that were or were not provided supplemental UVB radiation for 14 days differed significantly (66.4 ± 14.3 nmol/L and 31.7 ± 9.9 nmol/L, respectively).

Conclusions and Clinical Relevance—Exposure to UVB radiation produced by artificial light significantly increased serum 25-hydroxyvitamin D concentration in juvenile rabbits. Because vitamin D is an essential hormone in vertebrates, these findings suggest- ed that the provision of supplemental UVB radiation to captive rabbits may be important. (*Am J Vet Res* 2014;75:380–384)

Variable	Serum 25-hydroxyvitamin D concentration (nmol/L) Mean ± SD	Range
Day 0		
No UVB exposure	29.7 ± 14.9	14 to 44.0
UVB exposure	38.8 ± 21.4	15.0 to 63.0
Day 14		
No UVB exposure	31.7 ± 9.9	22.0 to 45.0
UVB exposure	66.4 ± 14.3*	44.0 to 81.0
Difference in 25-hydroxyvitamin D concentration between time points		
No UVB exposure	2.0 ± 11.7	–14.0 to 13.0
UVB exposure	27.6 ± 14.8†	10.0 to 49.0

For all rabbits, the daily diet consisted of timothy hay (unlimited access) and 1 cup of alfalfa-based pelleted diet each. General room lighting was provided with non–UVB-producing fluorescent lighting. The UVB radiation emitted into the rabbits' cages was measured at 9 points approximately 34 cm from the surface of the UVB light sources (representing the position of the rabbits in the cage) after 10 hours of exposure on days 1, 8, and 14. The UVB radiation level ranged from 8.3 to 58.1 $\mu W/cm^2$ for the UVB-exposed rabbits and was consistently < 0.001 $\mu W/cm^2$ for the control rabbits.

*Mean value for the treatment group is significantly (P = 0.005) greater than that for the control group. †Mean value for the treatment group is significantly (P = 0.026) greater than that for the control group.

EFFECTS OF ARTIFICIAL ULTRAVIOLET RADIATION ON SERUM 25-HYDROXYVITAMIN D_3 CONCENTRATIONS IN CAPTIVE GUINEA PIGS (*CAVIA PORCELLUS*)

Samantha J. Sander, DVM, Mark A. Mitchell, DVM, MS, PhD, Dip. ECZM (Herpetology), Julia K. Whittington, DVM, Matthew C. Allender, DVM, MS, PhD, Dip. ACZM, and Kenneth Welle, DVM, Dip. ABVP (Avian)

Abstract

Under natural conditions, guinea pigs (*Cavia porcellus*) are exposed to ultraviolet B (UVB) radiation. Although the role of UVB radiation in the photobiochemical synthesis of vitamin D is well documented in humans and other vertebrates, to date it has not been evaluated in guinea pigs. The purpose of this study was to determine whether artificial UVB radiation has an effect on serum 25-hydroxyvitamin D_3 levels in guinea pigs. A total of 12 juvenile guinea pigs were randomly assigned to 1 of 2 treatment groups: Group A was exposed to 12 hours of artificial UVB radiation (290 to 315 nm) daily and Group B received ambient fluorescent light with no UVB supplementation for 12 hours/day. Blood samples were collected under anesthesia on days 0 and 18 to measure serum 25-hydroxyvitamin D_3 levels. Animals in both groups were offered the same diet. There was a significant difference in 25-hydroxyvitamin D_3 concentrations over time ($F = 399.3$, $P = 0.0001$) and by group ($F = 63.6$, $P = 0.0001$), with an average increase between sampling periods of 56.5 nmol/L in Group A (UVB) and 2.33 nmol/L in Group B (no UVB). This study represents the first attempt to measure the effect of UVB radiation on 25-hydroxyvitamin D_3 levels in guinea pigs. In vertebrates, vitamin D is an essential hormone that regulates many physiologic functions within the body. These preliminary findings confirm that guinea pigs can obtain vitamin D via photobiochemical synthesis, but additional work is needed to determine the physiologic importance of this finding and potential risks associated with UVB exposure in these rodents.

Key words: *Cavia porcellus*; guinea pig; lighting; vitamin D; ultraviolet B

TABLE. 25-hydroxyvitamin D3 concentrations (nmol/L) in guinea pigs by day and group

Group	Day	Mean, nmol/L	SD, nmol/L	Min-Max, nmol/L
No UVB	Day 0	28.8	9.0	19.0 to 45.0
	Day 18	31.2	7.8	22.0 to 42.0
UVB	Day 0	46.8	13.2	30.0 to 66.0
	Day 18	103.3	8.7	92.0 to 116.0

EFFECTS OF ULTRAVIOLET RADIATION ON SERUM 25-HYDROXYVITAMIN D CONCENTRATIONS IN CAPTIVE CHINCHILLAS (*CHINCHILLA LANIGER*)

Anne E. Rivas, DVM, Mark A. Mitchell, DVM, MS, PhD, Dip. ECZM (Herpetology), Jennifer Flower, DVM, Kenneth R. Welle, DVM, Dip. ABVP (Avian), and Julia K. Whittington, DVM

Abstract

Vitamin D is an important hormone in vertebrates, and most animals acquire this hormone through their diet and/or exposure to ultraviolet B (UVB) radiation. To date, no study has determined how chinchillas (*Chinchilla laniger*) acquire vitamin D. The objective of this study was to determine whether exposure to UVB radiation had an effect on serum 25-hydroxyvitamin D levels in captive chinchillas. Overall, 10 juvenile chinchillas were used for this scientific investigation. Baseline blood samples were collected from the animals while under isoflurane anesthesia to determine their serum 25-hydroxyvitamin D concentrations. The chinchillas were then randomly assigned to 2 treatment groups: Group A, 12 hours of UVB exposure per day and Group B, no UVB exposure. At the end of the study (Day 16), a second blood sample was collected from each animal while again under isoflurane anesthesia to measure serum 25-hydroxyvitamin D concentrations. Mean ± standard deviation serum 25-hydroxyvitamin D concentrations differed significantly ($P = 0.048$) between juvenile chinchillas provided supplemental UVB radiation (189.0 ± 102.7 nmol/L) and those not provided supplemental UVB radiation (87.8 ± 34.4 nmol/L). This study found that exposing juvenile chinchillas to UVB radiation significantly increased their circulating serum 25-hydroxyvitamin D levels. Because vitamin D is an essential hormone in vertebrates, these findings suggest that the provision of UVB radiation to captive chinchillas may be important. Further research to elucidate the importance of 25-hydroxyvitamin D and UVB radiation in captive chinchillas is required.

Key words: *Chinchilla laniger*; rodent; UVB; vitamin D; 25-hydroxyvitamin D

TABLE 1. 25-hydroxyvitamin D levels (nmol/L) in juvenile chinchillas (*Chinchilla laniger*) exposed or not exposed to UVB-producing artificial lighting

Group	Day	Mean	SD	Min-Max
UVB group	0	110.7	39.5	63.0 to 158.0
	16	189.0	102.7	91.0 to 319.0
No UVB group	0	92.2	52.0	31.0 to 166.0
	16	87.8	34.4	53.0 to 126.0

Group	Day	Mean, nmol/L	SD, nmol/L	Min-Max, nmol/L
UVB group	0	110.7	39.5	63.0 to 158.0
	16	189.0	102.7	91.0 to 319.0
UVB	Day 0	46.8	13.2	30.0 to 66.0
	Day 18	103.3	8.7	92.0 to 116.0
	Day 14			
UVB exposure		66.4 ± 14.3*		44.0 to 81.0

PLOS ONE

RESEARCH ARTICLE

Evaluating the Clinical and Physiological Effects of Long Term Ultraviolet B Radiation on Guinea Pigs (*Cavia porcellus*)

Megan K. Watson[1], Adam W. Stern[2], Amber L. Labelle[1], Stephen Joslyn[1], Timothy M. Fan[1], Katie Leister[1], Micah Kohles[3], Kemba Marshall[4], Mark A. Mitchell[1]*

1. Department of Veterinary Clinical Medicine, University of Illinois, Urbana, Illinois, United States of America, **2.** Department of Pathobiology, University of Illinois, Urbana, Illinois, United States of America, **3.** School of Veterinary Medicine and Biomedical Sciences, University of Nebraska-Lincoln, Lincoln, Nebraska, United States of America; Oxbow Animal Health, Murdock, Nebraska, United States of America, **4.** PetSmart, Phoenix, Arizona, United States of America

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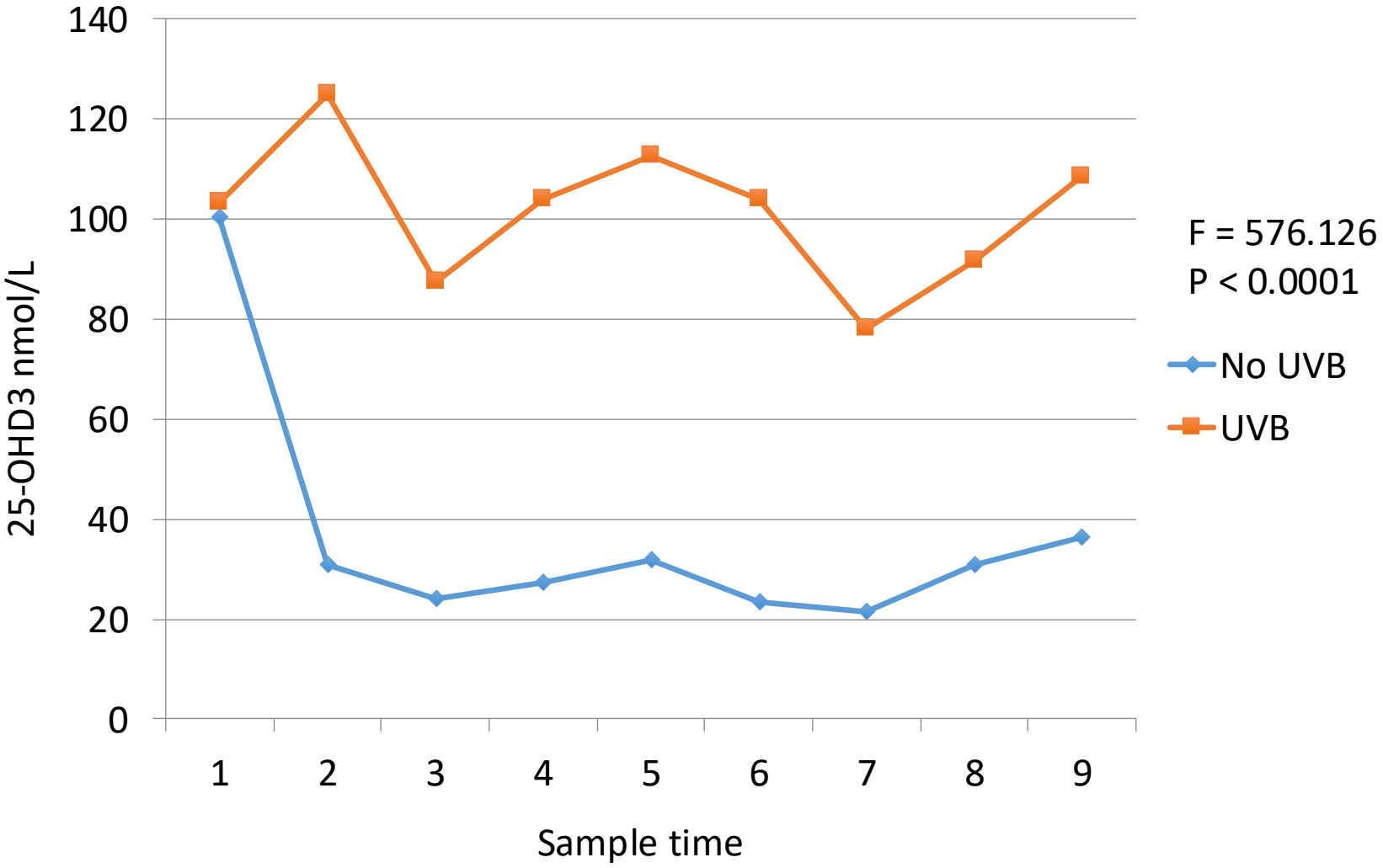
Citation: Watson MK, Stern AW, Labelle AL, Joslyn S, Fan TM, et al. (2014) Evaluating the Clinical and Physiological Effects of Long Term Ultraviolet B Radiation on Guinea Pigs (*Cavia porcellus*). PLoS ONE 9(12): e114413. doi:10.1371/journal.pone.0114413

Editor: Silvana Allodi, Federal University of Rio de Janeiro, Brazil

Received: August 27, 2014

Guinea pigs

Results


140
120
100
80
60
40
20
0
25-OHD3 nmol/L
1
2
3
4
5
6
7
8
9
Sample time
F = 576.126
P < 0.0001
No UVB
UVB

EVALUATING THE CLINICAL AND PHYSIOLOGICAL EFFECTS OF LONG-TERM ULTRAVIOLET B RADIATION ON RABBITS (*ORYCTOLAGUS CUNICULUS*)

Megan K. Watson, DVM, MS, Mark A. Mitchell, DVM, MS, PhD, Dip. ECZM (Herpetology), Adam W. Stern, DVM, PhD, Dip. ACVP, Amber L. Labelle, DVM, MS, Dip. ACVO, Stephen Joslyn, DVM, Dip. ECDVI, Timothy M. Fan, DVM, PhD, Dip. ACVIM (Internal Medicine, Oncology), Melissa Cavaretta, DVM, Micah Kohles, DVM, and Kemba Marshall, DVM, Dip. ABVP (Avian)

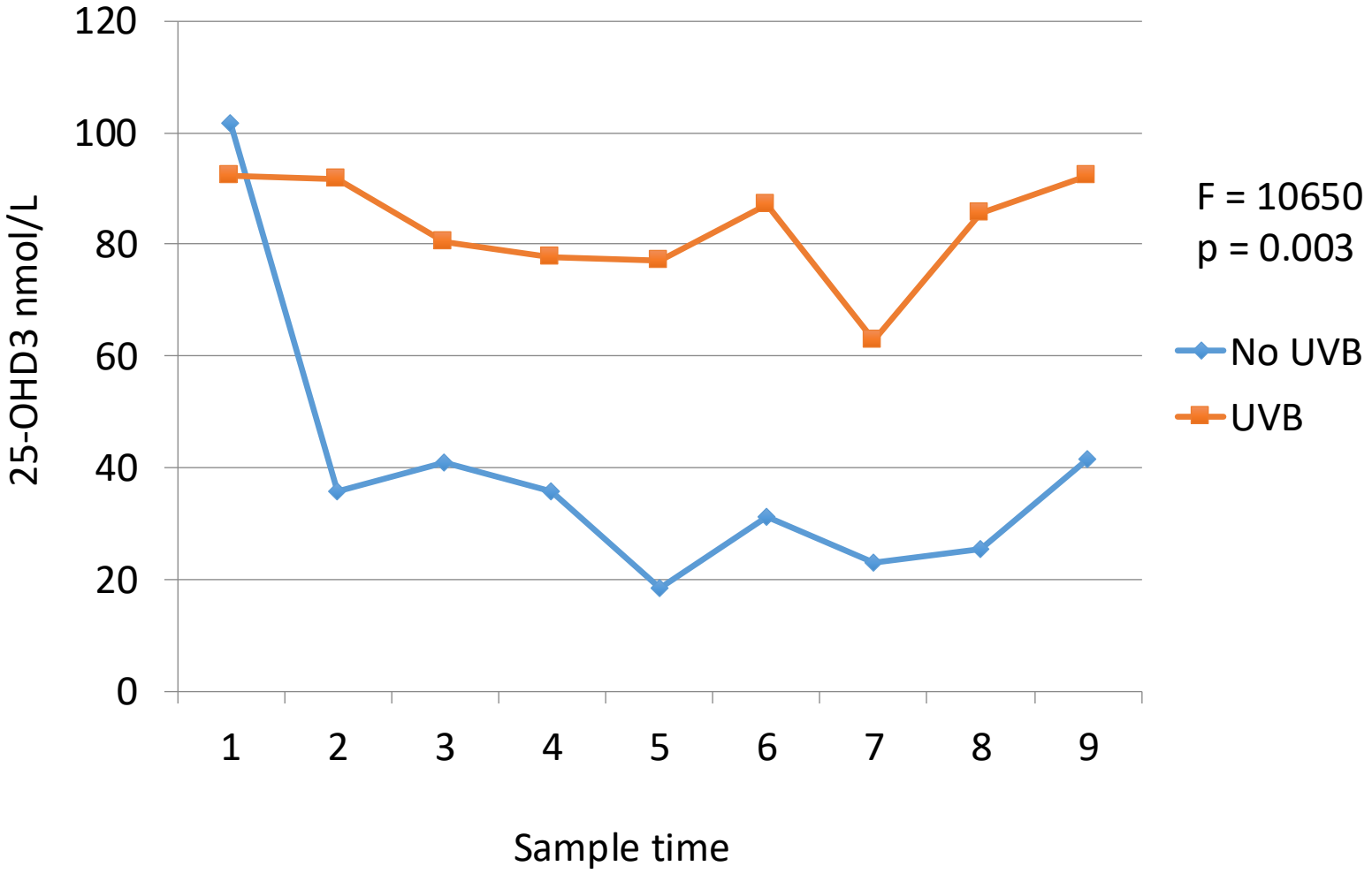
Abstract

Vitamin D is an essential hormone in vertebrates. Most animals acquire this hormone through their diet and/or exposure to ultraviolet B (UVB) radiation. The objectives for this research were to evaluate the clinical and physiologic effects of artificial UVB light supplementation on rabbits (*Oryctolagus cuniculus*) and to evaluate the long-term safety of artificial UVB light supplementation over a 6-month period. Twelve New Zealand white rabbits were randomly assigned to one of two treatment groups: Group A was exposed to 12 hours of artificial UVB radiation daily and Group B received ambient fluorescent light with no UVB supplementation for 12 hours daily. All animals were offered the same diet and housed under the same conditions. Blood samples were collected every 3 weeks over 6 months to measure blood chemistry values, parathyroid hormone, ionized calcium, and serum 25-hydroxyvitamin D_3 (25-OHD_3) levels. Serial ophthalmologic examinations were performed at the beginning of the study and every 2 months thereafter. At the end of the study the animals were euthanized and necropsied. Mean ± SD serum 25-OHD_3 concentrations differed significantly ($P = 0.003$) between animals provided supplemental UVB radiation (83.12 ± 22.44 nmol/L) and those not provided UVB radiation (39.33 ± 26.07 nmol/L). There were no apparent negative dinical or pathologic side effects noted between the groups. This study found that exposing rabbits to UVB radiation long term significantly increased their circulating serum 25-OHD_3 levels, which was sustainable over time.

Key words: *Oryctolagus cuniculus*; rabbit; ultraviolet B radiation; vitamin D

Rabbits

Results


120
100
80
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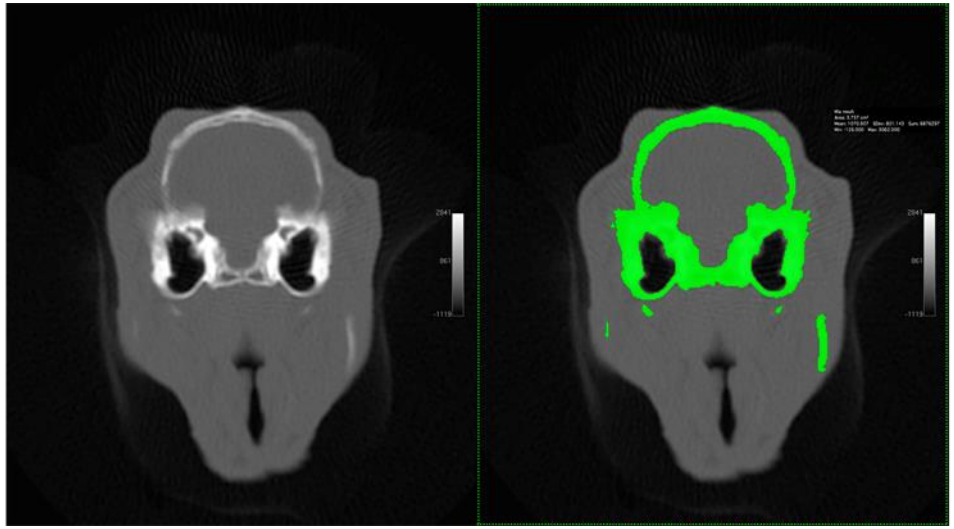
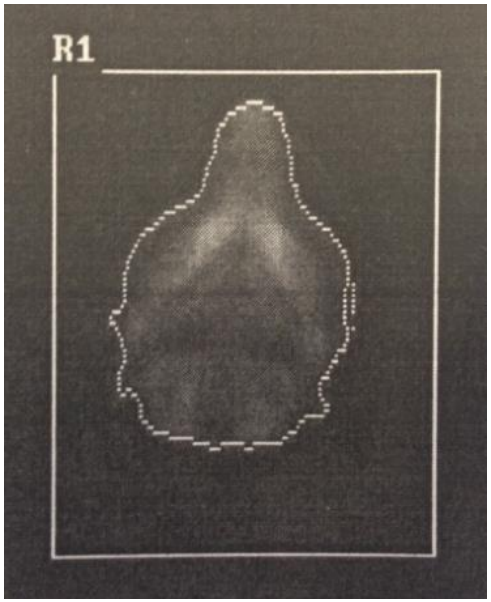
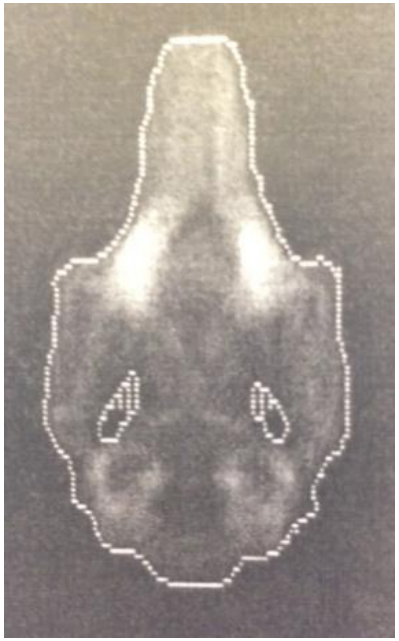
25-OHD3 nmol/L
1
2
3
4
5
6
7
8
9
Sample time
F = 10650
p = 0.003
No UVB
UVB

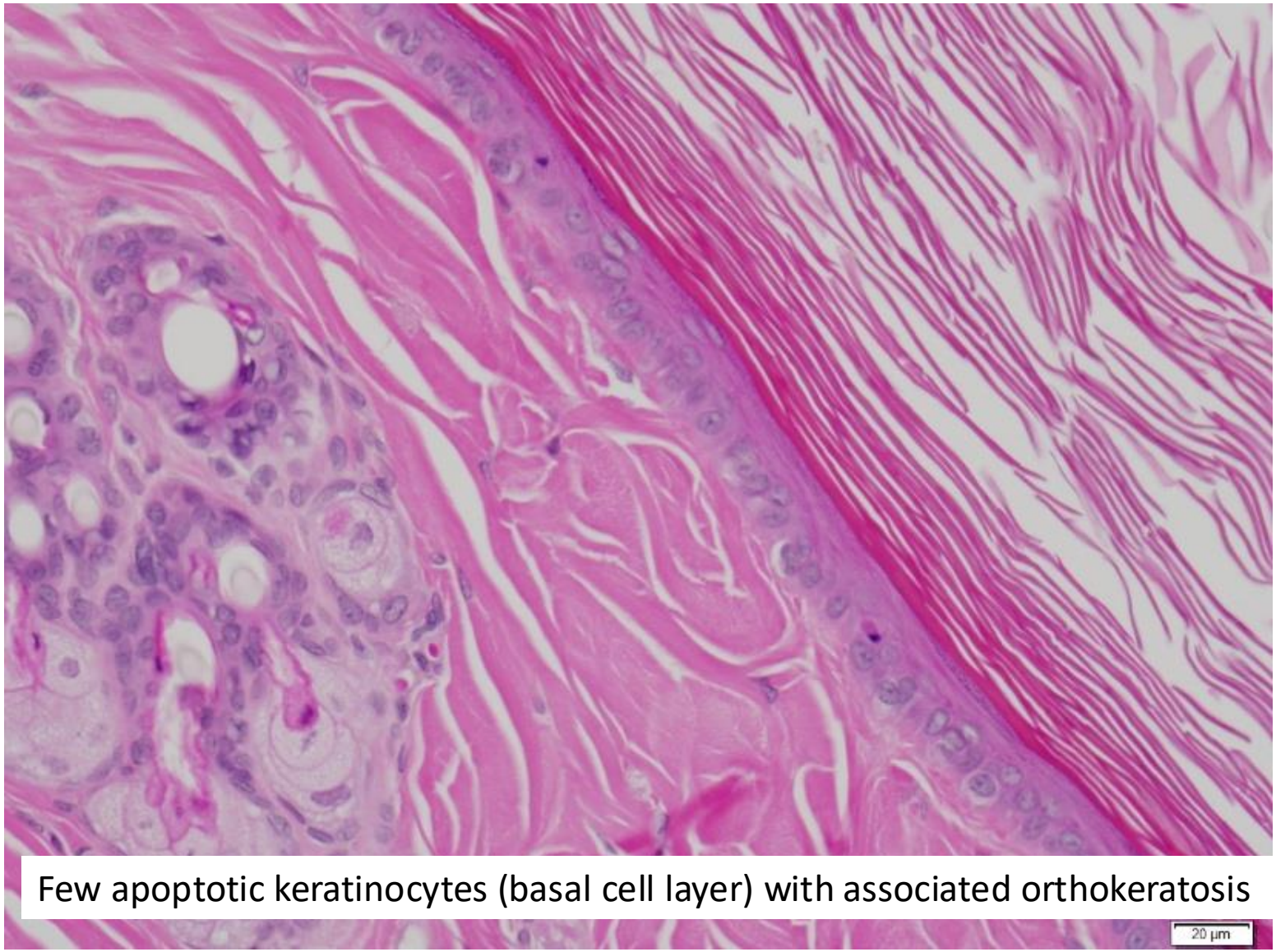
Results







Results



Few apoptotic keratinocytes (basal cell layer) with associated orthokeratosis

animals

MDPI

Article

Effects of Short-Duration Artificial Ultraviolet B Exposure on 25-Hydroxyvitamin D_3 Concentrations in Domestic Rabbits (*Oryctolagus cuniculus*)

Laure E. Molitor *, Kelly Rockwell, Amelia Gould and Mark A. Mitchell

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* Correspondence: Molitor.DVM@gmail.com

Simple Summary: Vitamin D is an important hormone that can be acquired through diet or exposure to ultraviolet B (UVB) radiation. Few studies have evaluated the effects of UVB radiation on vitamin D concentrations in the domestic rabbit (*Oryctolagus cuniculus*); however, initial findings have found they can increase their serum 25-hydroxyvitamin D_3 (25-OHD_3) following 12 h of artificial UVB exposure. Current husbandry recommendations for rabbits do not include specific UVB lighting requirements. Rabbits are a common pet and research model and are frequently housed indoors without access to natural UVB lighting. Rabbits that are chronically vitamin D deficient may develop mineral deficiencies that can lead to poor calcification of the teeth and skull, predisposing these animals to dental abnormalities, bone infections, and other debilitating diseases. While initial results suggest artificial UVB is positive for rabbits, UVB can also be detrimental to the health of vertebrates. The aim of this study was to determine if shorter-duration UVB exposure could also increase 25-OHD_3 concentrations. Rabbits were provided 6 h of artificial UVB daily for 14 days, and there was a significant increase in 25-OHD_3 concentrations over time. These findings affirm that rabbits can use short-duration artificial UVB to increase 25-OHD_3 concentrations.

Table 1. Rabbit 25-OHD_3 (nmol/L) concentrations in juvenile domestic rabbits at baseline ($n = 6$) and 14 days later ($n = 6$) after 6 h of artificial UVB exposure per day. The samples collected at 14 days were significantly ($p = 0.002$) higher than the baseline.

Time	Sample	Mean	SD	Min-Max
	baseline	27.7	8.1	17–42
6 h	14 days	79.8	13.6	67–102

Next step….what about natural UVB exposure?

EFFECTS OF NATURAL ULTRAVIOLET RADIATION ON 25-HYDROXYVITAMIN D_3 CONCENTRATIONS IN FEMALE GUINEA PIGS (*CAVIA PORCELLUS*)

Megan K. Watson, DVM, MS, Jennifer Flower, DVM, MS, Dip. ACZM, Ken Welle, DVM, Dip. ABVP (Avian), Micah Kohles, DVM, Dave Webster, MS, Heather Purdeu, BS, and Mark A. Mitchell, DVM, MS, PhD, Dip. ECZM (Herpetology)

Abstract

Vertebrates have 2 methods of acquiring vitamin D: through the diet and/or secondary to exposure to ultraviolet B (UVB) radiation. Although some species (e.g., dogs) can only acquire vitamin D through their diet, many others also utilize UVB radiation to generate vitamin D. Prior to their extirpation, guinea pigs were naturally exposed to varying levels of sunlight (UVB) in their native habitat; however, in captivity we do not routinely recommend UVB radiation for these animals. Recently, it has been shown that captive guinea pigs can synthesize 25-hydroxyvitamin D (25-OHD_3) after exposure to UVB lightbulbs. However, it is not known how natural sunlight impacts 25-OHD_3 concentrations in this species. The purpose of this study was to determine whether 25-OHD_3 concentrations in female guinea pigs exposed to natural sunlight would increase as a result of UVB exposure. Eight adult female guinea pigs were used for this study. The animals were held indoors during winter months and then placed outside in the spring when temperatures were appropriate. Blood samples were collected before the animals were placed outdoors (baseline) and 30 days after being exposed to natural sunlight. There was a significant difference in 25-OHD_3 concentrations over time (P = 0.006) and values collected after the guinea pigs were housed outdoors were 1.8 times higher than baseline. This study confirmed that female guinea pigs can increase 25-OHD_3 concentrations after exposure to natural sunlight. This suggests that these animals have conserved this pathway despite domestication, and supplementation should be considered to optimize captive guinea pig habitats.

Key words: *Cavia porcellus*, guinea pig, sunlight, ultraviolet B radiation, vitamin D

TABLE 1. 25-Hydroxyvitamin D concentrations (nmol/L) in 8 female guinea pigs housed indoors (baseline) and outdoors (30-day sample)

Time Collected	Mean	Standard Deviation	Minimum-Maximum
Baseline	53.5	14.5	23.0 to 71.0
30 day sample	95.9	21.0	72.0 to 137.0

Birds?

What to recommend?

- Full spectrum lighting
  - Measure UVB concentrations
    - 5.0 bulbs
  - Distance important
  - > 12 cm
    - <24 cm
- Provide shelter
- Photoperiod
  - UVB light 2-6 hours
- No glass or plexiglass to defract UVB
- Prefer UVB to be > 5 µwatts, <30 µwatts
- Measure plasma 25-hydroxyvitamin D

So, do the exotic pets need UVB?

- Need to determine species by species
- Benefits of full spectrum lighting
  - UVB, visible, and infrared
- Risks of UV light?
- Risks of oral vitamin D?

Conclusions