

孵化温度对白条草蜥孵出幼体大小、形态和运动表现的影响

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摘要:实验用白条草蜥(*Takydromus wolteri*)卵由 1999 年和 2000 年 4 月捕自安徽滁州的 19 条成年雌体产出。用 4 个恒定温度(24~33 °C)孵化白条草蜥卵,检测孵化温度对孵出幼体大小、形态和运动表现的影响。孵化卵从环境中吸水导致重量增加,卵重量增加与卵初始重量和孵化温度有关。24、27、30 和 33 °C 孵化期的平均值分别为 41.9、30.6、25.8 和 22.6 d。温度显著影响孵化成功率及孵出幼体的湿重、躯干干重和剩余卵黄干重,但对孵出幼体的性别、体长、尾长和干重无显著影响。24 °C 和 27 °C 孵出幼体湿重和躯干干重大于 33 °C 孵出幼体,剩余卵黄干重则小于 33 °C 孵出幼体;30 °C 和 33 °C 孵出幼体的湿重、躯干干重和剩余卵黄干重无显著差异。孵化温度显著影响孵出幼体一些局部形态特征:24 °C 和 27 °C 孵出幼体头长和头宽矫正值显著大于高温(33 °C)孵出幼体,24 °C 孵出幼体耳径矫正值一般小于较高温度孵出的幼体。疾跑速与幼体体长成正相关,与幼体尾长和状态无关。高温孵出幼体运动能力较差。雄性幼体腹鳞行数少于雌性幼体,尾长和后肢长大于雌性幼体,这些特征的两性差异与孵化温度无关。孵化热环境能诱导白条草蜥部分表型特征的变异,这些特征的变异可能对个体的适应性具有长期的影响。

关键词:蜥蜴科;白条草蜥;卵;孵化;孵出幼体;形态;运动表现

The influence of incubation temperature on size, morphology, and locomotor performance of hatchling grass lizards (*Takydromus wolteri*)

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Abstract: We incubated eggs of *Takydromus wolteri* at four constant temperatures to assess influence of incubation temperature on size, morphology, and locomotor performance of hatchlings. All viable eggs incubated in mass over the course of incubation due to absorption of water from surroundings, and mass gain was dependent on initial egg mass and incubation temperature. The duration of incubation at 24, 27, 30, and 33 °C averaged 41.9, 30.6, 25.8, and 22.6 d, respectively. Incubation temperature significantly affected hatching success and body wet mass, carcass dry mass, and residual yolk dry mass of hatchlings, but it did not affect sex ratio, total dry mass, snout-vent length, and tail length of hatchlings. Compared to those from 33 °C, hatchlings from 24 °C and 27 °C were greater in wet body mass and carcass dry mass, with a smaller quantity of yolk remaining unutilized at hatching. Incubation temperature affected some morphological traits of hatchlings, with hatchlings from 24 °C and 27 °C having larger size-free head length and width than did those from 33 °C, and hatchlings from 24 °C generally had smaller size-free tympanum diameter than did those from higher temperatures. Sprint speed was positively correlated with hatchling

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size (SVL), but it was independent of tail length and hatchling condition. Locomotor performance of hatchlings from lower temperatures (24 and 27 °C) was apparently better than that of those from higher temperatures (30 and 33 °C). Between-sex differences in the row number of ventral scales, tail length, and hind-limb length were found in hatchlings, but these sexual dimorphisms were not related to incubation temperature.

Key words: Lacertidae; *Takydromus wolteri*; egg; incubation; hatchling; morphology; locomotor performance

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孵化温度能影响爬行动物卵孵化成功率、孵化期和孵出幼体的大小、局部形态特征、行为和生长速率等^[1-3]。极端孵化温度导致胚胎死亡或畸形^[6]。存活孵化温度(Viable incubation temperature)范围内具有较高的孵化成功率,但此范围内的温度能诱导孵出幼体一些热可塑性特征(如性别、脊椎骨数目和一些局部形态特征等)永久性的变异,这些变异可能对动物的生理功能、行为表现和终生适应性产生长期的影响^[10-17]。因此,野外亲体选择热环境适宜的产卵巢址产卵或用适宜的温度人工孵化爬行动物卵将具有重要的生态学意义。由于野外产卵巢址不易定位,自然热环境对爬行动物孵化卵和孵出幼体的影响难以精确定量^[18]。实验室恒温孵卵虽不能反映野外的真实情况,但因温度易被控制而易于检测爬行动物胚胎发育的热需求及温度对孵出幼体特征的精细影响^[4-7, 14, 19-23]。

白条草蜥分布于江苏、安徽和江西,向西分布至湖北和四川东部,向北分布至东北诸省及朝鲜和俄罗斯(Southern Primorskiy Territory)^[24]。有关该种的繁殖和卵孵化数据仅零星见于一些动物志(如陈壁辉编《安徽两栖爬行动物志》)。作者在1999~2000年研究了该种的繁殖和卵孵化,本文报道4个恒定温度(24~33 °C)下孵化卵的孵化成功率和孵化期及温度对孵出幼体大小、形态和运动表现的影响。

1 材料和方法

研究用白条草蜥于1999年和2000年4月捕自安徽滁州琅琊山,蜥蜴带回杭州实验室,饲养在800 mm×500 mm×300 mm(长×宽×高)蜥蜴专用培养缸内。蜥蜴能在缸内自由取食黄粉虫幼虫(larvae of *Tenebrio molitor*)和饮水,接受自然光照。培养缸一端悬挂辅助加热光源,使得蜥蜴在光照期间能将体温调节至其喜好体温。定期在蜥蜴饮水中添加德产爬行动物专用复合维生素(Nekton-Rep[®])、21金维他和儿童钙粉,以丰富动物的营养。

触摸判断雌体怀卵和排卵状况,临产卵个体被单个关养在含潮湿沙质基底的产卵缸(200 mm×150 mm×250 mm)内。为避免失水或吸水导致卵初始重量的变化,所有卵均在产后1 h内收集、测量、称重和编号。记录产后母体体重、体长(SVL)、尾长、产卵时间、窝卵数。雌体繁殖输出和卵大小的详细数据由另文报道。

卵经可孵性鉴别后移入直径为120 mm加盖孵化罐内,孵化基质湿度恒定为-12 kPa,由干蛭石(Vermiculite):水=1:2配合而成^[14, 25]。同窝卵尽可能分配在不同的温度处理中。卵的1/3埋入基质,胚胎一端朝上。孵化罐置入温度为24、27、30和33(±0.3) °C的生化培养箱(LRH-250型,广东医疗仪器厂)中,箱内温度用电子点温计连续监视。每日向罐内加水,以使基质湿度恒定;每日按照预先设定的顺序调整孵化罐在孵化箱内的位置,以避免箱内可能存在的温度梯度的影响。每隔5d称孵化卵,直至幼体孵出。

幼体出壳后即被收集、测量和称重,然后测定其疾跑速。测定前,用培养箱将幼体体温控制在30 °C。用松下NV-DS77数码摄像机记录幼体在2000 mm×100 mm×150 mm直形跑道上的运动表现,每条幼体重复测定两次。疾跑速以幼体跑过250 mm的最大速度表示。部分幼体在跑道上表现不佳(如中途折返和拒绝跑动等),对应数据不被用于进一步的统计处理。跑动最大距离(简称最大距离)用幼体在跑道上不间断跑动的最大距离表示,动物在跑道上的停留次数(简称停留次数)用幼体在跑道上的停留次数表示。

完成运动表现测定后,冰冻处死幼体。这些幼体以后被解冻,鉴别性别,测量SVL、尾长、头长(吻端至外耳道前缘)、头宽(头两侧最大间距)、眼径(最大直径)、耳径(最大直径)、前肢长(肩关节至第一指基部)

和后肢长(髌关节至第一趾基部),计数腹鳞行数。幼体随后被解剖分离成躯干和剩余卵黄,65℃烘干至恒重,分别称其干重。幼体状态用 $\text{Log}(\text{体重})$ 与 $\text{Log}(\text{SVL})$ 的回归剩余值表示^[14, 23]。

所有数据在作进一步统计分析前,用 Kolmogorov-Smirnov 和 Bartlett (Statistica 统计软件包)分别检验数据分布正态性和方差同质性。经检验,部分原始数据经 Log 转化能用于参数统计,并用线性回归、单因素(one-factor)或双因素(two-factor)方差分析(ANOVA)、单因素或双因素协方差分析(ANCOVA)和 Tukey 检验等处理和比较相应的数据。比较矫正平均值前检验斜率的均一性。文中涉及的非参数统计为 G 检验。描述性统计值用平均值 $\pm$ 标准误表示,显著性水平设置为 $\alpha = 0.05$ 。

2 结果

2.1 孵化卵重量变化

不同温度孵化的白条草蜥卵初始重量无显著差异(ANOVA, $F_{3,45} = 0.28$, $P = 0.842$)。孵化卵从孵化环境中净吸水导致重量增加(图1)。温度显著影响孵化卵重量的变化,高温孵化卵的吸水速率大于低温孵化卵(图1)。24℃和27℃孵化卵持续增重,30℃和33℃下孵化卵最后5d增重显著减缓;孵化温度对终末卵重量有显著的影响(ANOVA, $F_{3,45} = 2.95$, $P = 0.043$),24℃和27℃孵化卵的终末重量显著大于33℃孵化卵(图1)。

2.2 孵化期、孵化成功率和孵出幼体性比

两性孵化期(two-way ANOVA)和孵化成功率(G-test)无显著差异(both $P > 0.75$),故数据被合并。温度显著影响白条草蜥孵化期(Loge transformation, $F_{3,32} = 1452.15$, $P < 0.0001$),孵化期随孵化温度升高而缩短。27℃孵化期比24℃平均缩短11.3d,30℃孵化期比27℃平均缩短4.8d,33℃孵化期平均缩短3.2d(表1)。

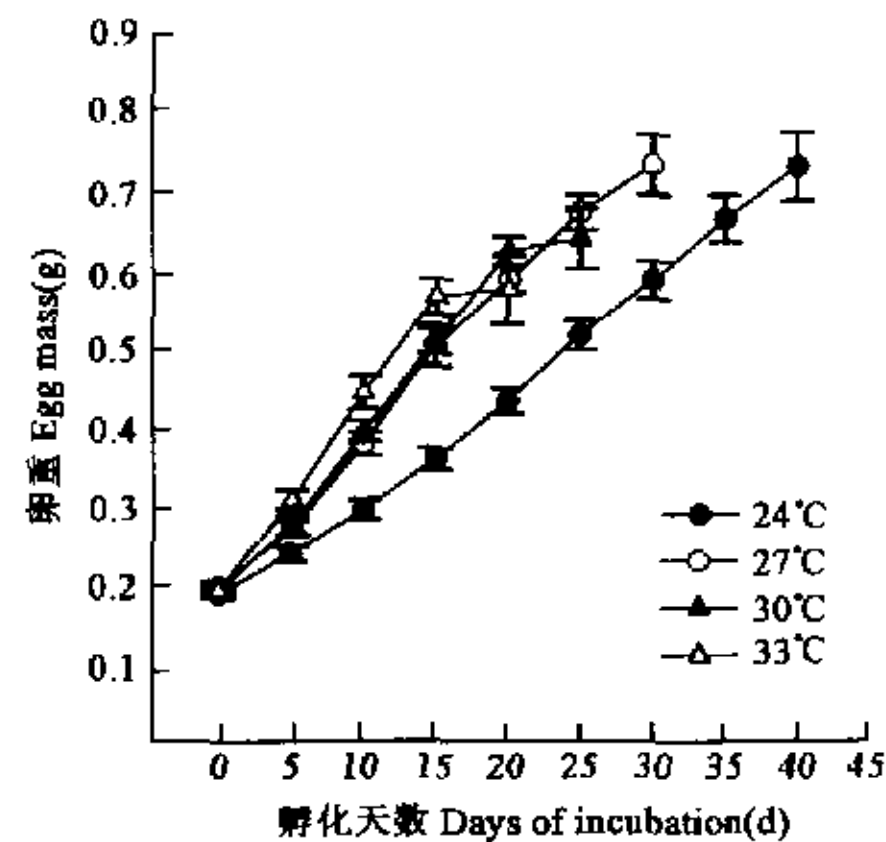


图1 白条草蜥卵孵化过程中的重量变化
Fig. 1 Temporal changes in mass of incubating *Takydromus wolteri* eggs

表1 孵化温度对白条草蜥孵化期、孵化成功率和幼体性比的影响

Table 1 Influence of incubation temperature on duration of incubation, hatching success, and sex ratio of hatchlings in the grass lizard, *Takydromus wolteri*

温 度 (℃)	孵化卵数	孵化期 (d)	孵化成功率 (%)	性 比 [*] (♀/♂)
Temperature	Incubated eggs	Duration of incubation	Hatching success	Sex ratio
24	18	41.9 ± 0.3 (40.5~43.8)	66.7 (12/18)	8/8
27	14	30.6 ± 0.2 (29.6~31.2)	71.4 (10/14)	10/3
30	12	25.8 ± 0.1 (25.5~26.2)	58.3 (7/12)	4/5
33	17	22.6 ± 0.2 (21.8~23.6)	41.2 (7/17)	6/4

* 性比数据包括后期死亡个体 Data on sex ratio including individuals that died at the late stage of incubation

在24~33℃范围内,孵化温度显著影响白条草蜥的孵化成功率($G = 28.05$, $df = 3$, $P < 0.001$),但对孵出幼体性别无显著的影响($G = 2.83$, $df = 3$, $P > 0.25$)(表1)。孵出幼体总性比不显著偏离1:1($G = 3.08$, $df = 1$, $P > 0.05$)。

2.3 孵出幼体大小、重量和形态

孵化温度影响孵出幼体的体重(ANCOVA, $F_{3,11} = 4.53$, $P < 0.01$),24℃和27℃孵出幼体体重大于30℃和33℃孵出幼体(表2)。孵化温度对幼体的SVL(ANCOVA, $F_{3,11} = 2.85$, $P = 0.054$)和TL

(ANCOVA, $F_{3,31} = 1.33$, $P = 0.282$)无显著的影响(表2)。

表2 不同温度中白条草蜥孵出幼体的体重、体长和尾长

Table 2 Body mass, snout-vent length and tail length of *Takydromus wolteri* hatchlings from different incubation temperatures

温度 (°C) Temperature	样本含量 n	入孵卵质量 (mg) Initial egg mass	幼体体重和大小 Hatchling size and mass		
			体重 (g) Body mass	体长 (mm) Snout-vent length	尾长 (mm) Tail length
24	12	191.4 ± 5.0 (158.0~221.0)	239.0 ^a ± 6.3 (202.7~293.0)	21.7 ± 0.4 (18.3~23.0)	38.8 ± 0.8 (32.0~42.3)
27	10	198.8 ± 7.1 (152.0~228.0)	244.7 ^a ± 7.8 (204.3~278.0)	22.6 ± 0.3 (21.2~24.7)	40.8 ± 1.2 (35.0~45.6)
30	7	199.0 ± 7.5 (178.0~225.0)	222.5 ^{ab} ± 13.4 (179.7~281.3)	22.4 ± 0.5 (20.1~24.4)	39.7 ± 1.5 (33.8~44.5)
33	7	193.6 ± 4.0 (178.0~209.0)	212.0 ^b ± 10.3 (173.1~246.1)	21.1 ± 0.3 (19.8~22.4)	37.2 ± 1.7 (29.8~43.5)

不同上标的平均值差异显著, Tukey's test, $\alpha = 0.05$. $a > b$ Means with different superscripts differ significantly, Tukey's test, $\alpha = 0.05$. $a > b$

孵化温度对孵出幼体的干重无显著的影响(ANCOVA, $F_{3,31} = 2.77$, $P = 0.058$),但显著影响躯干(ANCOVA, $F_{3,31} = 6.73$, $P < 0.001$)和剩余卵黄的干重(ANOVA, $F_{3,32} = 4.83$, $P < 0.007$)。24 °C 和 27 °C 孵出幼体的躯干干重显著大于 33 °C 孵出幼体, 30 °C 和 33 °C 孵出幼体的躯干干重无显著差异; 24 °C 和 27 °C 孵出幼体的剩余卵黄干重显著小于 33 °C 孵出幼体, 30 °C 和 33 °C 孵出幼体剩余卵黄干重无显著差异(表3)。

表3 不同温度中白条草蜥孵出幼体的总干重及躯干和剩余卵黄干重

Table 3 Total body dry mass and dry masses of carcass and residual yolk of *Takydromus wolteri* hatchlings from different incubation temperatures

温度 (°C) Temperature	样本含量 n	幼体干重 (mg) Hatchling dry mass	躯干干重 (mg) Body dry mass	剩余卵黄干重 (mg) Residual yolk dry mass
24	12	41.8 ± 0.9 (35.9~47.5)	41.4 ^a ± 0.8 (35.8~47.4)	0.39 ^b ± 0.24 (0.10~2.90)
27	10	42.3 ± 1.5 (34.2~49.2)	42.1 ^a ± 1.5 (34.1~49.1)	0.26 ^b ± 0.10 (0.10~1.00)
30	7	40.3 ± 2.1 (33.5~47.9)	39.7 ^{ab} ± 1.8 (33.4~47.0)	0.67 ^{ab} ± 0.36 (0.10~2.70)
33	7	38.0 ± 1.5 (33.8~43.0)	35.5 ^b ± 1.9 (28.0~42.9)	2.51 ^a ± 1.00 (0.10~6.30)

不同上标的平均值差异显著, Tukey's test, $\alpha = 0.05$. $a > b$ Means with different superscripts differ significantly, Tukey's test, $\alpha = 0.05$. $a > b$

雄性幼体腹鳞行数少于雌性幼体,尾长和后肢长大于雌性幼体,但这些特征的两性差异与孵化温度无关(表4)。孵化温度显著影响孵出幼体一些精细的形态特征,如头部大小和耳径。低温及温和温度(24 °C 和 27 °C)孵出幼体的头部显著大于高温(33 °C)孵出幼体(表4)。24 °C 孵出幼体的耳径小于较高温度孵出的幼体(表4)。

主成分分析显示第一和第二主成分(Eigenvalue > 1)解释形态变量 57.7% 的变异。头长和头宽在第一主成分有较高的正负载系数,耳径在第一主成分有较高的负负载系数(解释 33.1% 的变异);前、后肢长在第二主成分有较高的正负载系数(解释 24.6% 的变异)(表5)。不同温度孵出幼体的形态特征变量在第一主成分的分值差异显著(ANOVA, $F_{3,32} = 6.45$, $P < 0.002$),但在第二主成分的分值无显著的差异(ANOVA, $F_{3,32} = 0.09$, $P = 0.965$)。

表 4 孵化温度和性别对白条草蜥孵出幼体形态表性特征的影响

Table 4 Morphological phenotypes of *Takydromus wolteri* hatchlings, according to sex and incubation temperature

幼体特征 Hatchling traits	性别 Sex	孵化温度 (°C) Incubation temperature				影响 Effects		
		24 °C	27 °C	30 °C	33 °C	性别 Sex $F_{1,27}$	温度 Temperature $F_{3,27}$	相互作用 Interaction $F_{3,27}$
体长 (mm)	M	21.3 ± 0.6	22.5 ± 0.7	21.8 ± 0.7	21.3 ± 0.8	1.18 ns	2.43 ns	0.52 ns
Snout-vent length	F	22.0 ± 0.4	22.7 ± 0.4	23.1 ± 0.7	21.0 ± 0.3			
体重 (mg)	M	242.0 ± 11.0	240.9 ± 19.7	212.3 ± 16.4	200.8 ± 20.2	0.55 ns	1.94 ns	0.70 ns
Body mass	F	236.7 ± 7.1	246.3 ± 8.6	236.1 ± 23.4	220.4 ± 10.6			
尾长 (mm)	M	38.6 ± 1.3	42.7 ± 2.0	40.3 ± 2.3	37.3 ± 4.0	6.32 *	0.51 ns	1.71 ns
Tail length	F	39.0 ± 1.0	39.9 ± 1.4	39.0 ± 2.0	37.2 ± 1.5			
头长 (mm)	M	5.9 ± 0.06	6.0 ± 0.02	5.9 ± 0.1	5.5 ± 0.1	1.16 ns	6.08 ** 24 ^a , 27 ^{ab} , 30 ^{ab} , 33 ^b	2.06 ns
Head length	F	6.0 ± 0.06	5.8 ± 0.07	5.9 ± 0.2	5.6 ± 0.1			
头宽 (mm)	M	3.9 ± 0.06	3.9 ± 0.02	3.7 ± 0.05	3.6 ± 0.05	0.48 ns	9.78 ** 24 ^a , 27 ^{ab} , 30 ^{ab} , 33 ^c	0.51 ns
Head width	F	3.9 ± 0.03	3.8 ± 0.03	3.7 ± 0.1	3.7 ± 0.04			
腹鳞	M	27.8 ± 0.2	26.8 ± 0.4	27.5 ± 0.7	29.3 ± 1.0	19.63 *** $F > M$	0.31 ns	2.40 ns
Ventral scale	F	30.1 ± 0.4	30.3 ± 0.5	30.3 ± 1.1	29.2 ± 0.7			
前肢长 (mm)	M	5.4 ± 0.2	5.7 ± 0.2	5.5 ± 0.2	5.6 ± 0.2	0.91 ns	0.48 ns	0.39 ns
Foreleg length	F	5.6 ± 0.2	5.7 ± 0.1	5.7 ± 0.1	5.4 ± 0.1			
后肢长 (mm)	M	6.3 ± 0.2	6.6 ± 0.1	6.6 ± 0.2	6.4 ± 0.3	5.44 *	0.04 ns	0.57 ns
Hindleg length	F	6.4 ± 0.2	6.5 ± 0.1	6.5 ± 0.2	6.1 ± 0.2			
耳径 (mm)	M	0.83 ± 0.03	0.93 ± 0.03	0.92 ± 0.05	0.98 ± 0.03	0.01 ns	2.96 * 24 ^b , 27 ^a , 30 ^{ab} , 33 ^{ab}	1.95 ns
Tympanum length	F	0.86 ± 0.03	0.99 ± 0.03	1.0 ± 0.05	0.84 ± 0.06			
眼径 (mm)	M	1.5 ± 0.03	1.6 ± 0.06	1.6 ± 0.04	1.5 ± 0.04	0.01 ns	0.31 ns	1.49 ns
Eye length	F	1.6 ± 0.04	1.5 ± 0.03	1.5 ± 0.04	1.6 ± 0.05			

双因素 ANOVA (体长和腹鳞数目) 或双因素 ANCOVA (其余幼体形态特征, SVL 为协变量) 的 F 值。不同上标的平均值差异显著, Tukey's test, $\alpha = 0.05$. $a > b$, ns $P > 0.05$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. F values correspond to single effects and factor interactions in two-factor ANOVA (for snout vent length and ventral scales) or ANCOVAs (with SVL as the covariate, for all other traits). Means with different superscripts differ significantly, Tukey's test, $\alpha = 0.05$. $a > b$, ns $P > 0.05$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

2.4 孵出幼体运动表现

疾跑速与幼体 SVL 成正相关 ($r = 0.46$, $F_{1,27} = 6.00$, $P = 0.023$), 与幼体尾长 ($r = 0.15$, $F_{1,22} = 0.48$, $P = 0.498$) 和状态 ($r = 0.08$, $F_{1,22} = 0.14$, $P = 0.713$) 无关。持续跑动的最大距离与幼体 SVL 无关 ($r = 0.16$, $F_{1,22} = 0.58$, $P = 0.456$)。高温孵出幼体的运动能力表现上比低温孵出幼体差, 但 ANOVA ($F_{2,21} = 0.24$, $P = 0.789$) 和 ANCOVA ($F_{2,20} = 0.12$, $P = 0.888$) 均表明 (在实验温度范围和样本含量内) 孵化温度对孵出幼体疾跑速的影响在统计上不显著。孵化温度对持续跑动最大距离 (ANOVA, $F_{2,21} = 0.35$, $P = 0.706$) 和单次测定停留次数 (ANOVA, $F_{2,21} = 1.04$, $P = 0.371$) 的影响在统计上亦不显著 (表 6)。

表 5 8 个白条草蜥孵出幼体形态特征变量的主成分分析的负载系数

Table 5 Loading of the first two axes of a principal component analysis on eight morphological variables in *Takydromus wolteri* hatchlings

变量 Variable	负载系数 Factor loading	
	PC1	PC2
体重 Body mass	0.646	-0.232
尾长 Tail length	0.200	0.613
头长 Head length	0.774	0.167
头宽 Head width	0.889	0.005
前肢长 Foreleg length	-0.159	0.798
后肢长 Hindleg length	-0.033	0.835
耳径 Tympanum length	-0.795	-0.346
眼径 Eye length	0.373	-0.231
解释变异 Variance explained	33.1 %	24.6 %

个体大小的影响用变量与体长的回归剩余值去除, 对每个主成分有主要贡献的变量用黑体注明 Size effects are removed in all cases by using residuals from the regressions on snout vent length. Variables with the main contribution to each factor are in bold face

表 6 孵化温度对白条草蜥孵出幼体(体温 30℃)运动能力(疾跑速、持续跑动的最大距离和单次测定的停留次数)的影响

Table 6 The effects of incubation temperature on locomotor performance of *Takydromus wolteri* hatchlings tested at 30℃. Performance variables are sprint speed, maximal distance between stopping, and total number of stops in a single trial

温度(℃) Temperature	样本含量 <i>n</i>	疾跑速(mm/s) Sprint speed		最大距离(mm) Maximum distance	停留次数 Number of stops
		观测值 Observed value	矫正值 Adjusted value		
24	9	408.2 ± 46.7 (185.2~625.0)	423.6 ± 44.3 (229.7~634.3)	655.6 ± 56.8 (500.0~950.0)	2.3 ± 0.3 (1~4)
27	8	434.9 ± 31.8 (312.5~583.3)	410.1 ± 34.7 (265.4~543.0)	603.1 ± 63.1 (375.0~900.0)	2.5 ± 0.3 (1~3)
30~33	7	391.2 ± 51.2 (238.1~625.0)	395.7 ± 33.8 (299.4~576.4)	571.4 ± 98.7 (400.0~1150)	3.1 ± 0.7 (1~7)

3 讨论

24~33℃范围内,孵化温度影响白条草蜥卵孵化和孵出幼体的一些特征,其中最为显著的影响包括:(1)孵化卵的吸水速率,(2)孵化期和孵化成功率,(3)胚胎对卵黄的利用,以及(4)孵出幼体的湿重、躯干干重、头部大小和耳径。孵出幼体的性别与孵化温度无关。雄性幼体的腹鳞行数少于雌性幼体,尾长和后肢长大于雌性幼体,这些特征的两性差异与孵化温度无关。幼体局部形态特征两性差异见于许多爬行动物,如地中海岩蜥(*Podarcis muralis*)^[10]、北草蜥(*Takydromus septentrionalis*)^[23]及作者另文报道的变色树蜥(*Calotes versicolor*)和山地麻蜥(*Fremias breichleyi*)。雄性孵出幼体的头部大于雌性幼体,地中海岩蜥^[10]及作者另文报道变色树蜥、渔异色蛇(*Xenochrophis piscator*)^[4]、眼镜蛇(*Naja atra*)^[5]雄性孵出幼体的尾长大于雌性幼体。蜥蜴科(Lacertidae)动物雄性个体腹鳞行数少于雌性个体可能是该科动物较为普遍的现象,见于所有已被研究的种类,如地中海岩蜥^[10, 14, 25]及作者另文报道的北草蜥、南草蜥(*Takydromus sexlineatus*)和山地麻蜥。

温度显著影响白条草蜥孵化卵的吸水速率,这一结果见于所有已被研究的产柔性卵(pliable-shelled egg)的有鳞类^[4~6, 14, 19, 20]。不同的吸水速率导致孵化卵内水环境的差异,但这种差异对有鳞类柔性卵孵化无重要的影响^[4~6, 10, 14, 19, 20, 27~30]。小型柔性卵早期失水对胚胎发育有致死性的影响^[4, 19, 20, 31],因失水而产生表面凹陷的白条草蜥新生卵通常是不可孵的。不同温度孵出幼体的湿重差异显著,但幼体干重无显著差异。这一结果说明 24℃和 27℃孵出幼体湿重较大主要与幼体水分含量较高有关。

33℃孵出的幼体躯干发育程度低,表现为躯干干重小、剩余卵黄多。在缺乏产后亲代抚育的爬行动物中,剩余卵黄是母体投入到卵内的超过胚胎发育所需的一部分物质和能量。剩余卵黄的主要功能之一是用子孵出幼体躯干的早期生长^[19]。33℃孵出幼体剩余卵黄虽然较多,但幼体总干重与其它温度孵出幼体无显著差异。由于剩余卵黄内的部分物质和能量将被用于维持幼体的活动^[4~6, 11, 19, 33~35],33℃孵出的白条草蜥幼体难以凭动用剩余卵黄内的物质和能量达到其它温度孵出幼体的躯干发育水平。

高温(30℃和 33℃)孵出幼体运动表现(疾跑速、最大距离和停留次数)的观测值小于 24℃和 27℃孵出幼体,表明前者运动表现比后者差。不同温度孵出幼体运动表现的差异在统计上不显著,主要与样本含量较小有关。高温孵出运动表现较差的幼体也见于其它蜥蜴科动物,如地中海岩蜥^[10, 23]和北草蜥^[20]。由于幼体运动表现与其捕食和逃避天敌等能力有关,运动表现较好的个体将具有较强的野外适应性^[10, 20, 23, 32, 33]。

蜥蜴头部大小与摄食能力有关,头部较大的个体摄食较大食物的潜力较大^[22, 31~38],个体发育过程中蜥蜴能因头部逐渐增长而增强摄食大型食物的能力^[16, 17, 39]。据此可以推测,24℃和 27℃孵出幼体因头部较大而能摄食较大的食物,因而具有比头部较小的 30℃和 33℃孵出幼体更强的适应性。温和温度孵出头部较大的幼体也见于地中海岩蜥^[10]及作者另文报道的北草蜥、中国石龙子、山地麻蜥和变色树蜥。24℃孵

出幼体的耳径较小,这一现象的生物学意义有待于进一步论证。

24℃和27℃孵化的白条草蜥卵孵化成功率较高,孵出幼体的躯干发育较好、头部较大且有较好的运动表现,这些结果表明该种卵适宜在低或温和温度下孵化。24℃和27℃孵出幼体的特征极为相似,但27℃孵化期比24℃约短11d(表1)。由于幼体较早孵出意味着当年越冬前有较长的生长时间,27℃应当比21℃更适合用来孵化白条草蜥卵。此外,由于胚胎发育时期是爬行动物生活史中最脆弱的时期,加之卵生爬行动物缺乏产后的孵卵和护卵行为,卵在27℃下孵化会因孵化期比24℃较短缩短不利环境条件作用的时间,从而提高孵化成功率。30℃孵化期虽比27℃约短5d,但孵化成功率明显较低且幼体特征介于27℃和33℃孵出幼体之间,因而30℃不是一个较为适宜的孵化温度。33℃孵化成功率最低,孵出幼体的躯干发育状况和运动表现最差,因而是本研究中最不利的孵化温度。

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