体温、摄食、断尾和雌体繁殖状态对原尾蜥虎运动表现的影响

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摘要:设计 4 项实验研究 4 种内外因素(环境温度、摄食、断尾和怀卵状态)导致的肇庆原尾蜥虎运动表现种群内变异。环境温度通过影响体温而影响原尾蜥虎运动表现。两性成体疾跑速均具有在低体温范围内随体温升高而加快、在高体温范围内随体温升高而降低的一般模式。在任何体温下成年雌体的疾跑速均略大于雄体,但两者平均值在统计上无显著差异。体温对原尾蜥虎最大持续运动距离的影响存在两性间差异。成年雌体的最大持续运动距离在低体温范围(从 17 ℃到 27 ℃)内随体温升高而增加,而在相对较高的体温范围(从 27 ℃到 37 ℃)内无显著变化,成年雄体在实验体温范围(从 17 ℃到 37 ℃)内无显著变化;在任何体温下成年雌体的最大持续运动距离均显著大于雄性。性别与体温相互作用对最大持续运动距离有显著影响。两性个体的平均疾跑速和最大持续运动距离呈显著的正相关。当去除最大持续运动距离差异的影响后发现,疾跑速两性差异统计上仍不显著。摄食、尾自切和雌体怀卵在两个实验温度下(27 ℃和 31 ℃)均减小壁虎疾跑速;而仅尾自切减小壁虎的最大持续运动距离,摄食和雌体怀卵对其无影响。以上 3 种因子分别与体温、性别的交互作用均不显著。这些结果说明生理限制和尾自切是原尾蜥虎运动能力变异的重要来源。一些内外因素能近因性诱导蜥蜴功能表现发生一定程度的种群内变异。

关键词:壁虎科;原尾蜥虎;体温;运动表现;怀卵雌体;摄食;尾自切
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Effects of body temperature, feeding, caudal autotomy and reproductive condition on locomotor performance in the oriental leaf-toed gecko, (*Hemidactylus bowringii*)

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Abstract: We designed four separate experiments to study within population variation in locomotor performance in the oriental leaf-toed gecko (*Hemidactylus bowringii*) induced by four factors (body temperature, feeding, caudal autotomy and reproductive condition). Ambient temperature influenced the gecko's body temperature, thereby influencing its locomotor performance. Sprint speed increased with increasing in body temperature within the lower temperature range, and then decreased at higher body temperatures. The pattern of the thermal dependence of sprint speed was similar between both sexes, however, adult female run a little faster than adult male at any given level of body temperatures, but there was no statistically significance between the mean values for each sex. The maximal distance traveled without stopping (hereafter

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the maximal distance) increased with increasing in body temperature within the lower temperature range (from 17 ℃ to 27 ℃), and then did not vary at higher body temperatures (from 27 ℃ to 37 ℃) in adult females, but this pattern of the thermal dependence of maximal distance differed from adult males. Adult males run shorter than adult females at any given level of body temperatures, and were not significantly influenced by body temperature in the maximal distance. Sprint speed was positively correlated with the maximal distance in each sex. When the influence of variation in the maximal distance was removed, there was still no significant difference in sprint speed between both sexes. The feeding, tail loss and gravidity of females reduced sprint speed at the experimental body temperatures (27 ℃ and 31 ℃) in all case. And, tail loss of geckos also reduced the maximal distance, but taking food or gravidity of females did not. The effects of interaction of these factors with body temperature and sexes were not apparent in most case. These results suggest that physical burden and caudal autotomy should be the origin of variation in locomotor capacity in *H. bowringii*. We conclude that some internal and external factors may proximately induce a certain degree of intrapopulational variation in functional performance of lizards.

Key Words: Gekkonidae; *Hemidactylus bowringii*; body temperature; locomotor performance; gravid female; feeding; tail loss

某些显示生物适应特定生态环境能力的特征(例如捕食和逃避天敌能力等)可能对其存活、繁殖以及生长具有深远的影响[1]。爬行动物的运动表现与其摄食效率[2,3]、逃避天敌能力[4~7]、种内竞争力[8,9]之间存在着紧密联系,因而通常被认为是一个对动物适合度有重要影响的特征。近 20 多年来,涉及各种动物类群的运动表现进化的研究已经成为进化生物学的基石。相对其它脊椎动物来说,爬行动物运动表现的研究是较深入的。已报道的研究显示许多爬行动物种类具有显著的种内及种间变异,许多研究者针对这些变异设计不同实验方案,从各种角度探索变异的来源和程度[10,11]。爬行动物运动表现既受外在因子(如环境温度[12~27])的影响,也受内在因子[如激素水平[28]、胃内容物[29,30]、繁殖状态[5,31~33]、断尾状态[34~37]]的影响,并随个体发育而变化[38~41]。

爬行动物的行为表现和生理功能对体温具有明显的依赖性。在一定温度范围内,相对较高且稳定的体温有利于爬行动物较好地表达其生理功能和行为表现[12~15,42~45]。过高的体温会抑制动物的生理活动并显著影响其行为表现;而较低的体温会导致动物的生理进程和运动表现能力减缓。繁殖是爬行动物生活史中最重要的事件,但是通常需要付出较大的代价。评价爬行动物繁殖代价的研究主要是通过间接地利用雌体怀卵(或怀孕)状态导致的运动代价来说明。摄食活动获得的物质和能量可用于组织生长和繁殖输出。摄食效应与雌体繁殖状态相似,两者都使身体负荷加重,从而导致动物运动能力下降[5,30,32,46~50],提高这些种类个体受攻击的风险[4,51]。尾自切是许多蜥蜴种类最主要的反捕食策略。断尾使蜥蜴获得逃避天敌捕食的直接生存利益,但也须为此承受多方面的代价,例如功能表现。尾自切对蜥蜴运动能力的影响与断尾程度、断尾时间和尾功能的种间差异等因素有关[34,52~54],在不同种类中尾自切可减弱[53,55~57]、增强[58]或不改变[59,60]动物的运动能力。本研究中,以原尾蜥虎(*Hemidactylus bowringii*)两性成体为实验材料,检测性别、体温、摄食、尾自切和雌体繁殖状态等内外因子对其运动表现的影响,并主要从这些因子角度探讨原尾蜥虎运动表现的种群内变异。

1 材料与方法

1.1 实验动物采集与饲养

原尾蜥虎(*Hemidactyus bowringii*)为一种小型夜行性壁虎科动物,国内主要分布在广东、海南、台湾、广西、福建、云南等省(区),国外见于印度、锡金、缅甸和日本的琉球群岛[61],野外栖息在建筑物内壁、墙缝和路灯下等场所。该种壁虎两性性腺活动的年周期显著,雌性通常在 5 ~ 8 月份产 1 至 2 窝刚性卵,成体个体大小和头部大小的两性差异显著[62]。

研究用原尾蜥虎于 2004 年 4 月中下旬捕自广东肇庆郊区,将尾部完整、体长(SVL, snout-vent length,

SVL > 45.68mm[62])的成体[N=118(♀♀:♂♂=66:52)]带回肇庆学院动物实验室,饲养在专用(长×宽×高为:30 cm × 20 cm × 20 cm)的塑料网笼内,每笼原尾蜥虎不超过16条,性比接近1:1。网笼放置在室温为24℃的恒温室内,网笼上方一端悬挂1只60W灯泡,作为原尾蜥虎体温调节的点热源,光周期为7:00时自动开启,19:00时关闭。原尾蜥虎在网笼内能自行取食黄粉虫(*Tenebrio molitor*)幼虫,通过饮用添加钙和维生素的饮水获得较为全面的营养。至2004年5月开始测试时,部分雌体已经排卵,卵在输卵管内滞留期间胚胎处于不同的发育阶段,原尾蜥虎体色浅,透过体壁即可观察卵大小。运动表现测定实验在两周后进行,所有原尾蜥虎在全部实验结束后释放到原捕捉地点。

1.2　实验进程

1.2.1　体温影响运动表现实验

实验在5月上旬进行。实验原尾蜥虎[N=26(♀♀:♂♂=15:11)]尾部完整,选取的雌体为未怀卵个体。实验前记录原尾蜥虎的SVL和体重。按11(体温)×2(性别)因子实验设计,检测原尾蜥虎体温、性别及体温与性别交互作用对运动表现的影响。用随机数字表随机编排实验温度顺序,实验前1h将原尾蜥虎放置在温度预先设定的Shel lab恒温孵化箱内以控制其体温。每隔一天完成一个温度实验,动物单次运动表现测定完成后均用WMZ-3型电子点温计(上海医疗仪器厂)确认其体温,然后放回饲养网笼。

1.2.2　摄食影响运动表现实验

实验在5月中旬进行。用独立样本[N=48(♀♀:♂♂=24:24)]按2(体温)×2(性别)×2(摄食状态)因子实验设计,检测体温、性别、摄食状态及各因子交互作用对运动表现的影响。雌体仍为未怀卵个体。实验前将原尾蜥虎等分为两组,一组个体[N=24(♀♀:♂♂=12:12)]在室温下禁食3d,该组作为对照组;另一组个体[N=24(♀♀:♂♂=12:12)]提供过量食物(黄粉虫幼虫),该组作为实验组。然后在同一时间段内测定两组原尾蜥虎的运动表现。原尾蜥虎的平均体温分别控制在27 ℃和31 ℃,连续两次测试的时间间隔大于5 h。

1.2.3　尾自切影响运动表现实验

实验在5月下旬进行。用一组独立样本[N=48(♀♀:♂♂=24:24)],按2(体温)×2(性别)×5(尾自切状态)因子设计实验,检测体温、性别、尾自切及各因子交互作用对运动表现的影响。实验前所有原尾蜥虎均无明显断尾现象,雌体仍为未怀卵个体。先测定具完整尾部原尾蜥虎的运动表现,此定义为E0组数据,然后每隔3d前用解剖刀依次切去原尾蜥虎1/4、1/2、3/4和几乎全部尾,此测得的运动数据分别定义为E1、E2、E3和E4组。每次切尾后2d原尾蜥虎自行愈合伤口,第3天测定运动表现。测定两个体温(27 ℃和31 ℃)下的运动数据,连续2次测试的时间间隔大于5 h。

1.2.4　雌体繁殖状态影响运动表现实验

测定在6月中旬进行,此时部分雌体已经产卵。用总数为32(怀卵♀♀:产后♀♀:♂♂=10:11:11)的成体,按2(体温)×3(雌体繁殖状态及雄性对照)因子设计实验,检测体温、繁殖状态及交互作用对运动表现的影响。原尾蜥虎平均体温分别控制在27 ℃和31 ℃,连续两次测试的时间间隔大于5 h。

1.2.5　运动表现的测定

所有实验设计的运动表现均在长×宽×高为200 cm×20 cm×25 cm的专用跑道中测定。跑道上每间距5 cm设置一个刻度,测定时将原尾蜥虎放入跑道一端,毛刷驱赶使之奔跑,用Panasonic NV-DS77数码摄像机记录动物的运动过程,每条原尾蜥虎测定一个来回。磁带中的数据用MGI Video Wave III软件(MGI Software Co., Canada)读出。疾跑速用原尾蜥虎跑过25 cm的最大速度表示,最大持续跑动距离用不间断跑动的最大距离表示。

1.2.6　统计分析

个别个体在跑道上表现不佳(中途折返或拒绝跑动等),对应数据不被用于统计分析。所有被处理的数据在作进一步统计检验前,用Kolmogorov-Smirnov和F-max分别检验数据的正态性和方差同质性(statistica统

计软件包)。分析显示疾跑速和最大持续运动距离均与实验原尾蜥虎 SVL 无关(线性回归分析,all $P > 0.05$)。用 t 检验(t-test)、重复测量方差分析(repeated measures ANOVA)、单因子(one-factor)协方差分析(ANCOVA)、多因子方差分析,Tukey's 多重比较等分析处理相应的数据。描述性统计值用平均值 (标准误表示,显著性水平设置在 $\alpha = 0.05$。

2 结果

2.1 体温

原尾蜥虎体温对其运动表现的作用显著。成年两性个体的疾跑速均具有在较低体温范围内随体温升高而加快,在高体温范围内随体温升高而降低的一般规律(图 1);在任何体温下,成年雌体疾跑速平均值略大于成年雄体,但在统计上差异不显著;雌体体温为 29 ℃、雄体体温为 31 ℃时,平均疾跑速达到最大值(图 1)。体温对原尾蜥虎最大持续运动距离亦有显著作用,在较低体温范围内(< 25 ℃),原尾蜥虎的最大持续运动距离两性间差异不明显(t-test: all $P > 0.05$),而其余任何体温范围内,雌体的最大持续运动距离均较大(t-test: all $P < 0.04$, 图 1, 表 1);雌体最大持续运动距离随体温变化而变化的关系显著(repeated measures ANOVA: $F_{10, 140} = 9.16$, $P < 0.0001$),约在体温 27 ℃时,跑过的持续运动距离最大,而雄体随体温变化的关系不明显(repeated measures ANOVA: $F_{10, 100} = 1.83$, $P = 0.064$)。性别与体温交互作用对最大持续运动距离有显著的影响(表 1)。对两性各体温下的疾跑速和最大持续运动距离的平均值作线性回归显示,这两个运动表现变量之间存在显著的正相关(both $P < 0.01$)。以性别为因子的 ANCOVA 分析显示两性间疾跑速与最大持续运动距离的线性关系缺乏平行性($F_{1, 18} = 11.82$, $P < 0.003$),因此用疾跑速相对于最大持续运动距离的回归剩余值作方差分析,结果显示当去除最大持续运动距离差异的影响后,疾跑速的两性间差异仍不显著(图 2, $F_{1, 20} = 2.03$, $P = 0.170$)。

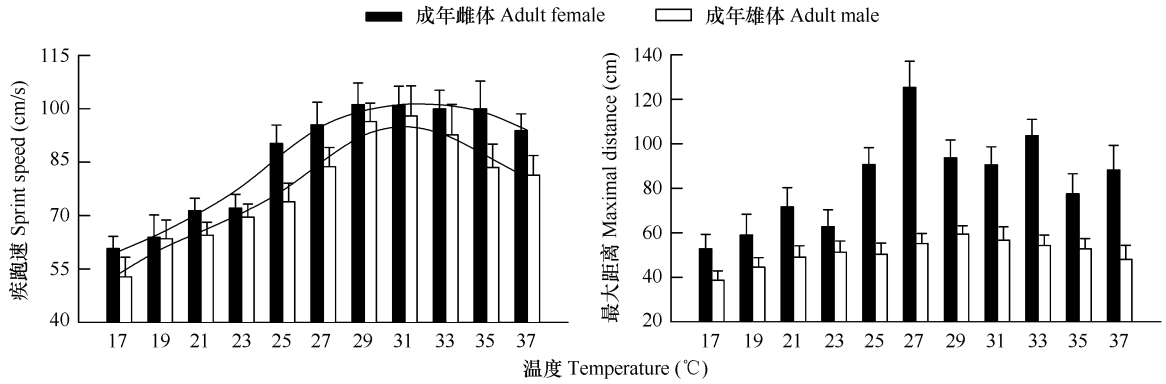

图 1 原尾蜥虎成体在不同体温下疾跑速和最大持续运动距离的平均值(±标准误)(上图中的曲线由对原始数据进行最小平方拟合获得)

Fig. 1 Mean values (±SE) for sprint speed and the maximal distance of adult *Hemidactylus bowringii* at different body temperatures (The curves in the upper plot are generated from a fit of least squares on the original data)

表 1 原尾蜥虎体温对运动表现的影响

Table 1 The effects of body temperature on locomotor performance of the oriental leaf-toed gecko, *Hemidactylus bowringii*

项目 Item	疾跑速 Sprint speed	最大持续运动距离 The maximal distance
性别 Sex	$F_{1,24} = 2.37$ $P = 0.137$	$F_{1,24} = 21.10$ $P < 0.0002^{**}$, *Female* > *Male*
体温 Body temperature	$F_{10,240} = 21.97$ $P < 0.0001^{**}$	$F_{10,240} = 8.16$ $P < 0.0001^{*}$
性别×体温交互作用 Sex × body temperature	$F_{10,240} = 0.73$ $P = 0.697$	$F_{10,240} = 3.79$ $P < 0.0001^{*}$

表中显示疾跑速和最大持续运动距离的重复测量方差分析结果 The table provides results from repeated-measures ANOVA for sprint speed and the maximal distance traveled without stopping; *, ** 显著相关 Significant

2.2 摄食

摄食均导致原尾蜥虎两性个体的疾跑速下降,但对最大持续运动距离的影响不显著(图 3,表 2)。实验

体温(27 和 31 ℃体温)对原尾蜥虎的运动表现无显著影响;各因子交互作用对运动表现亦无显著影响(表 2)。

2.3　尾自切

原尾蜥虎的尾自切状态对实验动物的疾跑速和最大持续运动距离均有显著影响,但性别和实验体温无显著影响(表 3,图 4)。断尾程度与实验动物的疾跑速和最大持续运动距离均呈显著的负相关关系,当原尾蜥虎剩余尾长为原长的 1/4 时,疾跑速和最大持续运动距离明显下降,完全失去尾部时,则疾跑速下降接近 24%(80 cm/s *vs* 104 cm/s),最大持续运动距离下降程度相似(66.3 cm *vs* 86.0 cm)。尾自切实验进一步证实成年雌体的持续运动能力较成年雄体强。各因子的相互作用对疾跑速和最大持续运动距离无显著的影响(表 3)。

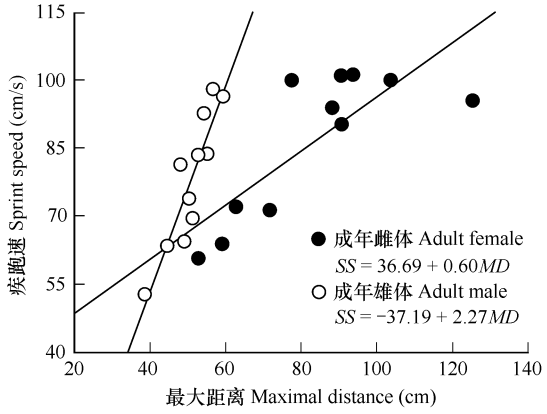

图 2　原尾蜥虎成体疾跑速和最大持续运动距离之间的关系

Fig. 2　The relationships between sprint speed and the maximal distance traveled without stopping of adult *Hemidactylus bowringii*

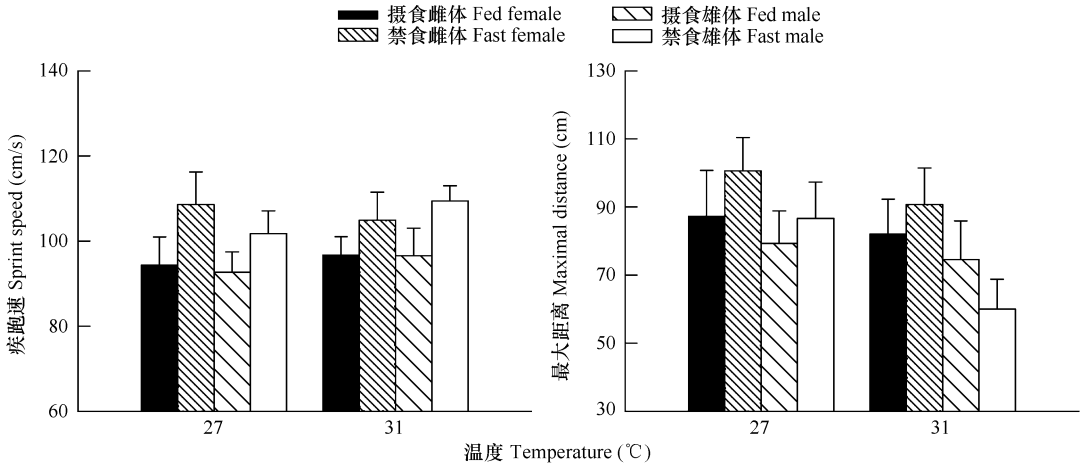

图 3　摄食及禁食状态下原尾蜥虎疾跑速和最大持续运动距离的平均值

Fig. 3　Mean values (± SE) for sprint speed and the maximal distance of the fed and fast geckos, *Hemidactylus bowringii*

表 2　原尾蜥虎摄食对运动表现的影响

Table 2　The effects of feeding on locomotor performance of the oriental leaf-toed gecko, *Hemidactylus bowringii*

项目 Item	疾跑速 Sprint speed	最大持续运动距离 The maximal distance
性别 Sex	$F_{1,44}=0.05$　$P=0.825$	$F_{1,44}=2.32$　$P=0.135$
体温 Temperature	$F_{1,44}=0.30$　$P=0.588$	$F_{1,44}=1.38$　$P=0.247$
摄食 Feeding	$F_{1,44}=10.30$　$P<0.003^{**}$, Fed < Fast	$F_{1,44}=0.83$　$P=0.368$
性别×体温交互作用 Sex × temperature interaction	$F_{1,44}=0.47$　$P=0.496$	$F_{1,44}=0.17$　$P=0.680$
性别 × 摄食交互作用 Sex × feeding interaction	$F_{1,44}=0.001$　$P=0.973$	$F_{1,44}=3.24$　$P=0.079$
体温 × 摄食交互作用 Temperature × feeding interaction	$F_{1,44}=0.03$　$P=0.873$	$F_{1,44}=2.67$　$P=0.110$
性别 × 体温 × 摄食交互作用 Sex × temperature × feeding interaction	$F_{1,44}=0.51$　$P=0.481$	$F_{1,44}=1.12$　$P=0.296$

表中显示疾跑速和最大持续运动距离的重复测量方差分析结果　The table provides results from repeated-measures ANOVA for sprint speed and the maximal distance traveled without stopping; ＊＊显著相关 Significant

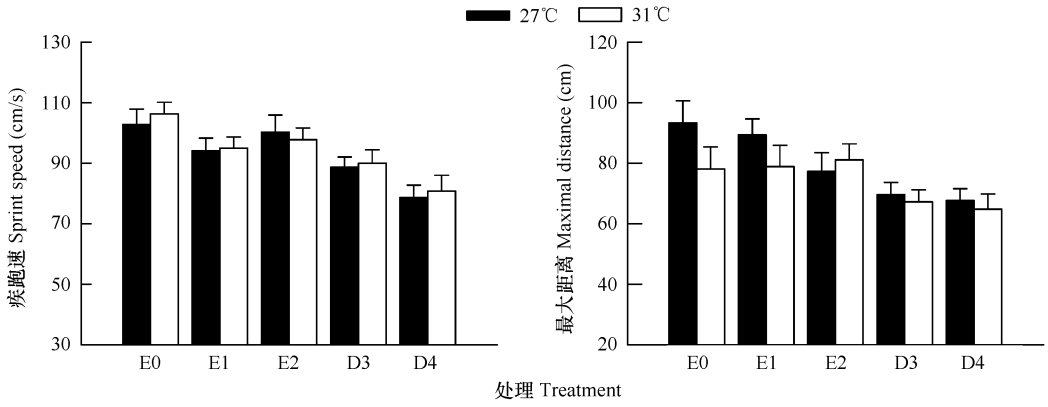

图 4 不同断尾状态下原尾蜥虎的疾跑速和最大持续运动距离的平均值

Fig. 4 Mean values (±SE) for sprint speed and the maximal distance of adult *Hemidactylus bowringii* at different position of tail loss

表 3 原尾蜥虎断尾对运动表现的影响

Table 3 The effects of tail loss on locomotor performance of the oriental leaf-toed gecko, *Hemidactylus bowringii*

项目 Item	疾跑速 Sprint speed	最大持续运动距离 The maximal distance
性别 Sex	$F_{1,44}=0.03$ $P=0.873$	$F_{1,44}=6.57$ $P=0.014$, $F_e$male > Male**
体温 Body tem*P*erature	$F_{1,44}=0.07$ $P=0.792$	$F_{1,44}=1.15$ $P=0.290$
断尾状态 Tail loss condition	$F_{4,176}=12.64$ $P<0.0001$**	$F_{4,176}=8.40$ $P<0.0001$**
性别×体温交互作用 Sex×body temperature	$F_{1,44}=0.30$ $P=0.588$	$F_{1,44}=0.12$ $P=0.735$
性别×断尾状态交互作用 Sex×tail loss condition	$F_{4,176}=2.41$ $P=0.051$	$F_{4,176}=0.47$ $P=0.758$
体温×断尾状态交互作用 Body temperature×tail loss condition	$F_{4,176}=0.16$ $P=0.960$	$F_{4,176}=1.50$ $P=0.203$
性别×体温×断尾状态交互作用 Sex×body temperature×tail loss condition	$F_{4,176}=1.28$ $P=0.281$	$F_{4,176}=0.59$ $P=0.674$

表中显示疾跑速和最大持续运动距离的重复测量方差分析结果 The table provides results from repeated-measures ANOVA for sprint speed and the maximal distance traveled without stopping; **显著相关 Significant

2.4 繁殖状态

怀卵雌体疾跑速均小于产后雌体和成年雄体,但产后雌体和成年雄体的疾跑速无显著差异;怀卵雌体、产后雌体和成年雄体的最大持续运动距离无显著差异(图 5,表 4)。3 组实验动物总合数据显示,体温 31 ℃下的疾跑速大于 27 ℃,但最大持续运动距离无差异(表 4)。

表 4 原尾蜥虎雌体繁殖状态对运动表现的影响

Table 4 The effects of female reproductive condition on locomotor performance of *Hemidactylus bowringii*

	疾跑速 Sprint speed	最大持续运动距离 The maximal distance
繁殖状态 Reproductive condition	$F_{2,29}=6.48$ $P<0.005$, $G<NG=M$**	$F_{2,29}=2.34$ $P=0.115$
体温 Body temperature	$F_{1,29}=5.03$ $P<0.033$, 27℃ < 31℃ **	$F_{1,29}=1.24$ $P=0.274$
繁殖状态×体温交互作用 Reproductive condition×body temperature	$F_{2,29}=2.60$ $P=0.091$	$F_{2,29}=2.78$ $P=0.079$

表中显示疾跑速和最大持续运动距离的双因子方差分析结果;G:怀卵雌体;NG:产后雌体;M:成年雄体 The table provides results from two-factor ANOVA for sprint speed and the maximal distance traveled without stopping; G: gravid females; NG: post-oviposition females; M: adult males; **显著相关 Significant

4 讨论

脊椎动物的体温调节方式有两种:生理调温和行为调温。变温动物的生理调温能力相当有限,其体温的变化主要通过与环境热量进行交换来实现。对于爬行动物而言,温和至相对较高的体温通常有利于个体较好

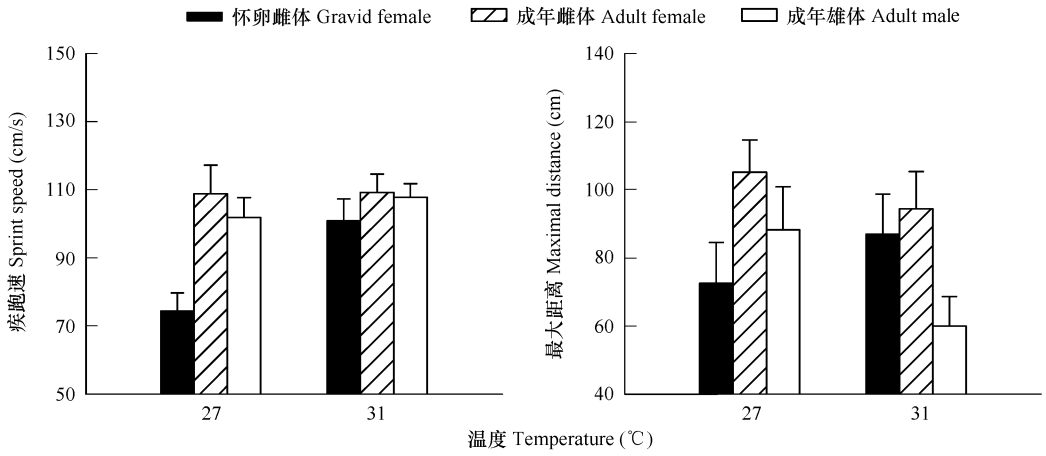

图 5　繁殖状态下的雌性和雄性原尾蜥虎疾跑速和最大持续运动距离的平均值

Fig. 5　Mean values ((SE) for sprint speed and the maximal distance of gravid, postpartum females and males of *Hemidactylus bowringii*

地表达生理功能并有较好的行为表现,野外活动的爬行动物须通过选择性利用时间和空间上呈异质性分布的外热源进行体温调节,以维持相对较高且稳定的体温水平[15,44,63,64]。昼行性爬行动物可利用的异质热环境较多,能通过姿势、阴阳穿梭和选择活动时间等行为来调节体温。但是,夜行性的壁虎可利用的异质热环境非常有限,夜间只能通过基底热传导来调节体温。在恒温实验室条件下,爬行动物的体温会随着恒温室环境温度的变化而变化。此外,因其具有一定程度的生理调温能力使体温并不与恒温室环境温度完全一致[63~65]。在所有的实验中均通过利用环境温度控制体温来研究动物运动表现的热依赖性,结果显示,环境温度通过影响体温而影响原尾蜥虎的运动表现,在低体温范围内疾跑速随体温升高而增加、在高体温范围内疾跑速随体温升高而下降(图 1)。类似结果也见于其它蜥蜴种类,例如,中国石龙子[19]、北草蜥[20]、南草蜥[25]、丽斑麻蜥[26]、山地麻蜥[41]和蓝尾石龙子[42]。两性个体疾跑速随体温变化的一般性规律相似,但各体温下的平均值和热敏感性稍有差异。成年雌体的疾跑速平均值略大于雄体(但该差异在统计上并不显著)。最大疾跑速 95% 水平的体温范围可显示疾跑速的热敏感性,范围越大热敏感性越低,原尾蜥虎成年雌体(约 8.6 ℃)相对较宽的 95% 最大疾跑速体温范围表明其运动速度受体温变化影响的敏感度小于成年雄性(约 5.4 ℃)(图 1)。此外,体温对最大持续运动距离作用的两性间差异更为明显,雌体个体有显著影响,但雄体个体无影响。运动表现的两性间差异可能与繁殖期两性个体野外活动时间和选择行为策略存在差异有关。

与已报道的绝大部分蜥蜴结果一致[4,5,26,30,34,36,38,46,66~68],原尾蜥虎怀卵雌体的运动速度显著下降。怀卵或怀孕状态导致雌体运动速度下降的程度具有明显的种间差异,下降的比值在 12% ~45% 之间。27 ℃体温下原尾蜥虎怀卵雌体比产后雌体运动速度约低 31.6%,比雄性成体约低 26.9%,速度下降比例处于其它蜥蜴的相关比例范围内;但是 31 ℃体温下怀卵雌体比产后雌体约低 7.6%,比雄性成体约低 6.3%,3 组平均值无显著差异(图 5)。本研究结果部分支持了怀卵导致雌体运动速度下降的结论。31 ℃体温接近原尾蜥虎行为表现的最适温度,高水平表达的行为表现可能部分削弱了雌体怀卵效应。27 ℃和 31 ℃体温下原尾蜥虎产后雌体运动速度均比成年雄体略大,分别为 6.4% 和 1.3%,但两者之间的差异在统计上不显著,该结果与体温对原尾蜥虎运动表现影响的实验结果一致。此外也发现有些蜥蜴种类的雌体怀卵并不直接引起运动速度的下降,例如澳大利亚花园石龙子(*Lampropholis guichenoti*)[50]。蜥蜴怀卵或怀孕状态导致运动速度下降主要与其体内物理负荷沉重有关,也有部分生理负荷的原因[67]。

值得注意的是怀卵雌体在两个实验温度下的疾跑速差异显著(成对样本 *t*-test: $t = 2.94$, $df = 9$, $P < 0.02$),而产后雌体($t = 0.04$, $df = 10$, $P = 0.972$)和成年雄体($t = 0.88$, $df = 10$, $P = 0.400$)无差异。相对较高且稳定的体温对体内胚胎发育和生长是非常有利的,许多蜥蜴种类雌体在怀卵或怀孕期通常会维持高于非繁殖期时的体温,例如多疣壁虎怀卵雌体的选择体温明显大于未怀卵雌体及成年雄体[69]。因此可以推测壁

虎在繁殖期对维持较高体温的需求可能会导致其某些生理及行为特征的热敏感性的增加。

摄食导致原尾蜥虎运动速度下降。27 ℃和31 ℃体温下,原尾蜥虎摄食个体分别比禁食个体约低11.0%和9.7%。类似的结果也见于其它有鳞类爬行动物[29,35,46],但摄食影响运动表现的程度存在种间差异,已报道的物种中,摄食作用最大可导致运动速度下降约1/3。其结果(体温27 ℃下降约11.0%;31 ℃下降约9.7%)与中国石龙子[36](约8%)相近。因本研究只计算动物的最大疾跑速,从平均速度角度比较摄食作用导致的运动速度的下降程度可能会大于以上的比值。同雌体怀卵导致运动速度下降相似,摄食后个体运动表现较差应主要与胃内容物增加、身体负荷加重有关。

许多壁虎种类的自然断尾率较高,且断尾程度亦大(常断至尾基部)。严重断尾(如本研究处理E4)将使原尾蜥虎身体主要部分比例失衡,因而导致运动失衡。合并两个温度(27 ℃和31 ℃)的数据显示,当原尾蜥虎切去的尾长分别为完整尾的1/4、1/2 和3/4 时,其运动速度比具有完整尾部的个体约低9.5%、5.2%和23.7%(图4)。部分断尾对原尾蜥虎的运动能力无显著的影响,这与其它相似研究结果一致(例如:中国石龙子[37],北草蜥[53]);而完全断尾导致的运动下降程度处于已报道的其它蜥蜴种类的相关比例范围内(12% ~ 48%[34,53~57])。然而,在另外一些蜥蜴中,断尾不仅不影响运动速度[59,60],还会提高运动速度[58]。尾自切对蜥蜴运动表现的影响在不同种类中有很大的差别,主要与尾部功能(如平衡、储能、社群地位象征、逃避天敌等)和形态在不同种类之间有很大的差异有关;此外,尾自切对运动表现的影响还与断尾程度和断尾时间有关[54]。原尾蜥虎尾部在运动过程中对平衡身体具有重要作用。尾股肌活动引起蜥蜴后肢运动,尾自切导致尾部摆动频率和后肢运动的变化最终影响运动速度。

本研究检测的内外因子效应对原尾蜥虎的运动表现均有影响,特别是对速度的影响更为明显。相对于最大持续运动距离,疾跑速的生态学意义可能更为重要。最大持续运动距离通常显示蜥蜴的运动耐力。在较低或较高的体温,原尾蜥虎的运动耐力较小;原尾蜥虎的运动耐力雌性个体比雄性好,会因尾自切而显著降低,但并不受摄食或怀卵状态的影响。疾跑速与最大持续运动距离呈显著的正相关,说明运动速度较快的个体一般具有较好的持续运动能力,反之亦然。野外原尾蜥虎个体的体温差异、断尾情况、摄食和雌体繁殖状态均可能是该动物种群内运动表现的重要变异来源。

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