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ORIGINAL ARTICLE

Effects of Temperature on Organ Masses and Digestive Tract Morphology in *Apodemus chevrieri* from Hengduan Mountain Region

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In order to investigate the changes of plasticity of visceral organs and digestive tract morphology in *Apodemus chevrieri* which inhabit in Hengduan mountain region, the organ masses and digestive tract which include the changes of heart, lung, liver , spleen and kidney as well as the length and weight of stomach, small intestine, large intestine and cecum were measured during cold and warm acclimation. The results showed that the weight of heart and liver of cold acclimation group were obviously higher than that of warm acclimation group. The weight and length of small intestine showed significant differences between two groups. All of the results indicated that *A. chevrieri* maintain their normal life activities by increasing the weight of related organ masses and adjusting the weight and length of small intestine under cold temperature.

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Phenotypic plasticity is important aspect of biological diversity, is an important mechanism of ecological speciation, is the basic raw material of natural selection, and is the key to population differentiation (Bozinovic and Gallardo 2006). Phenotypic plasticity is prevalent in biological organisms, plasticity in response to physiological changes can range from morphology, life history and behavior of (Miner et al. 2005). Phenotypic plasticity in morphological and physiological aspects of organ have important effects on the efficiency of animal nutrition and energy (Pucek 1965). It found that weight and length of digestive tract showed the obvious seasonal changes in *Microtus brandti* under seasonal acclimation (Li and Wang 2005). Facing the gradient of ambient temperature and photoperiod, the visceral masses appeared adaptive changes with the environment changing in *Tupaia belangeri chinensis* (Zhu et al. 2013).

Chevrier's field mouse, *Apodemus chevrieri* (Mammalia: Rodentia: Muridae) is the inherent species in Hengduan mountains region (Zheng 1993). It were previous reported that *A. chevrieri* showed seasonal changes in body mass and digestive tract morphology (Zhu et al. 2012). It has been reported that *A. chevrieri* increased energy intake and thermogenesis in association with decreases in body mass, and serum leptin level during cold exposure (Zhu et al. 2011). However, we know nothing about the effects of cold and warm temperature on organ masses and digestive tract morphology in *A. chevrieri*. In the present study, we examined the effect of temperature on organ masses and digestive tract morphology in *A. chevrieri*. We hypothesized that *A. chevrieri* can increase the weight of related organ masses and adjust the weight and length of small intestine under cold temperature.

MATERIALS AND METHODS

Samples

Animals were captured (26.22°N, 99.48°E, and 2, 550-2, 615m in altitude) around Jianchuan County in July 2012, then brought and bred at the School of Life Sciences, Yunnan Normal University, Kunming (1, 910 m in altitude). Each mouse was housed individually in plastic boxes (260mm× 160mm×150mm) with sawdust bedding with no nest under a constant light cycle (12:12 h light-dark cycle, lights 0800-2000) and temperature (25±1°C), and maintained on a commercial standard rat pellet (produced by Kunming Medical College). Food and water were available *ad libitum*. Relative ambient humidity ranged from 60% to 75%. After 1 month stabilization, subjects were assigned to two experimental groups: cold acclimation group and warm acclimation group, samples of each group were 8, *A. chevrieri* are 16 (male 10; female 6), all of these samples were healthy adults. The acclimation condition of cold acclimation were light (12L: 12D, lights on am8:00 and off pm8:00), temperature (5±1 °C); the acclimation condition of warm acclimation group were light (12L: 12D, lights on am 8:00 and off pm 8:00), temperature (30±1 °C) last for 4 weeks. All pregnant, lactating or young individuals were excluded in present study.

Morphology

Between cold acclimation group and warm acclimation group (28 day), after collecting trunk blood, the visceral organs, including heart, lung, liver, kidneys, spleen and gastrointestinal tract (stomach, small intestine, cecum, large intestine), were extracted and weighed (±1 mg).

Statistical analysis

Data were analyzed using SPSS 15.0 software package. Prior to all statistical analyses, data were examined for assumptions of normality and homogeneity of variance, using Kolmogorov-Smirnov and Levene tests, respectively. Organ masses and gastrointestinal morphology were analyzed using independent-samples t test between cold and warm acclimation group. Results were presented as mean ± SEM, and $P < 0.05$ was considered to be statistically significant.

RESULTS

Weights of organ and gastrointestinal morphology

Temperature had significant effect of organ masses and gastrointestinal morphology of *A. chevrieri*. Weight of heart, liver and small intestine of cold acclimation group were obviously higher than that of warm acclimation group (Table 1).

Other organ masses and gastrointestinal morphology showed no significant differences between two groups.

Length of gastrointestinal morphology

Temperature had significant effect on length of small intestine in *A. chevrieri* between cold and warm acclimation group (P<0.05, Table 2), but stomach, large intestine and cecum showed no significant differences between two groups.

Table1 The effects of temperature on masses of organs in *A. chevrieri*

	Cold acclimation （n = 8）	Warm acclimation （n = 8）	P value
Heart (g)	0.250±0.023	0.186±0.054	0.023
Lung (g)	0.224±0.015	0.236±0.017	0.062
Liver (g)	1.563±0.102	1.258±0.146	0.029
Kidney (g)	0.302±0.009	0.311±0.013	0.089
Spleen (g)	0.059±0.003	0.064±0.004	0.081
Stomach (g)	0.512±0.059	0.489±0.034	0.325
Small intestine (g)	0.803±0.059	0.596±0.051	0.029
Large intestine (g)	0.419±0.011	0.415±0.021	0.562
Cecum (g)	0.236±0.009	0.201±0.006	0.756

Table 2 The effects of temperature on lengths of digestive organs in *A. chevrieri*

	Cold acclimation （n = 8）	Warm acclimation （n = 8）	P value
Stomach length (cm)	2.142±0.025	2.012±0.036	0.852
Small intestine length (cm)	41.236±2.321	35.623±3.206	0.036
Large intestine length (cm)	11.234±0.036	10.523±0.015	0.565
Caecum length (cm)	7.362±0.011	7.469±0.015	0.765

DISCUSSION

Phenotypic plasticity of organ generally regarded as adaptive responses of organisms respond to changes in environmental conditions, is an important adaptation to deal with energy demand and food quality changes (Derting and Bogue 1993). Heart is the impetus of systemic blood flow, provide nutrients for the organs and tissues, and the delivery of O_2, at the same time take tissue cells produce metabolic waste and CO_2, thereby maintaining the morphology and metabolic activity of normal tissue cells, in the present study, weight of heart increased during cold acclimation, which reflects the enhancement of energy metabolic activities in *A. chevrieri* under cold environment. Liver has been considered as an important source of heat production in small rodents, liver heat production is about 1/4 of total heat production for mammals (Schmidt-Nielsen 1997). In our results, cold temperature had significant effect on liver mass, which accordance with the increase of RMR under cold acclimation in *A. chevrieri* (Zhu et al. 2011).

The stomach is a muscular, hollow, dilated part of the digestion system which functions as an important organ of the digestive tract in some animals, length and weight of the stomach was affected by reproduction, temperature, food quality and the other components (Bozinovic et al. 1990). In the present study, food quality was indifference and rich, all *A. chevrieri* were non reproductive body in acclimation, so the length and weight of the stomach showed no differences between two groups, which may indicant that temperature had no effects on the phenotype of stomach, morphology of stomach may be more susceptible to the effects of food quality and reproductive state.

The large intestine (or colon) is the last part of the digestive system in vertebrate animals. Its function is to absorb water from the remaining indigestible food matter, and then to pass useless waste material from the body (Wang et al. 2006). It showed no significant difference of weight and length of large intestine between cold acclimation and warm acclimation group, which may be relate to the indifference of ambient humidity.

The small intestine (or small bowel) is the part of the gastrointestinal tract following the stomach and followed by the large intestine, and is where much of the digestion and absorption of food takes place (Zhu et al. 2012). The weight and length of the small intestine in *Abrothrix andinus* has significant differences in different seasons (Bozinovic et al. 1990). In the present study, the weight and length of small intestine increased significantly in cold acclimation group compared with warm acclimation group, which showed that *A. chevrieri* demand more energy intake under cold acclimation, and showed stronger phenotypic plasticity of small intestine. Moreover, *A. chevrieri* was an non hibernating small mammal, longer small intestine can make food retention time extending in the digestive tract, and can obtain more energy intake.

The cecum or caecum is a pouch, usually peritoneal, that is considered to be the beginning of the large intestine, it is a part of food fermentation, is sensitive to cellulose content of food, and its size adjust by food quality and cellulose proportion (Gross et al. 1985). It showed no significant difference of weight and length of cecum between cold acclimation and warm acclimation group, which may be relate to the indifference of food quality.

In conclusion, heart, liver and small intestine in *A. chevrieri* showed stronger phenotypic plasticity, which indicated that *A. chevrieri* maintain their normal life activities by increasing the weight of related organ masses and adjusting the weight and length of small intestine under cold temperature.

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