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Polydactyly in the Tyrrhenian wall lizard (*Podarcis tiliguerta*)

Antigoni Kaliontzopoulou[1,*], Daniele Salvi[1], Verónica Gomes[1], João P.M.C. Maia[1,2,3], Panagiotis Kaliontzopoulos[4]

[1] *CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, Campus Agrário de Vairão, 4485-661, Vairão, Portugal. *Corresponding author.* E-mail: antigoni@cibio.up.pt
[2] *Departamento de Biologia, Faculdade de Ciências, Universidade do Porto, Rua do Campo Alegre FC4 4169-007 Porto, Portugal*
[3] *Institut de Biologia Evolutiva (CSIC-UPF), Passeig Marítim de la Barceloneta, 37-49, 08003, Barcelona, Spain*
[4] *Florinis 54, Vrilissia, Greece*

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Abstract. Polydactyly is a fairly frequent phenomenon in tetrapod populations, but it is relatively rare in reptiles. Here we report the occurrence of polydactyly in a random sample of the Tyrrhenian wall lizard (*Podarcis tiliguerta*) from Sardinia. In the locality of Siniscola (NE Sardinia), we found two polydactylous female lizards, one of which showed polydactyly in one and the other in both hind limbs. This observation constitutes, to the best of our knowledge, the highest frequency of polydactyly ever reported in a single lizard population (4.54%). While providing a direct explanation for polydactyly is complicated, the genetic data available show that the two polydactylous individuals are not direct siblings, excluding the hypothesis of direct maternal inheritance of this condition.

Keywords. Polydactyly, skeletal abnormalities, Tyrrhenian wall lizard.

Polydactyly is an interesting phenomenon that frequently occurs in tetrapod populations but has never been evolutionarily truly re-established in any species. Strikingly, while a reduction in the number of digits has repeatedly occurred in several instances throughout tetrapod evolution, this condition has never been reversed (Lande, 1978; Tabin, 1992; Galis et al., 2001). This is intriguing, as a selective advantage of increased digit number exists under several evolutionary situations, enhancing for instance swimming, digging or grasping (Galis et al., 2001). However, this evolutionary advantage is always attained by extra digit-like structures that are in reality never "true" digits, but are rather modified wrist bones or extra phalanges (Caroll, 1997). The lack of polydactyly in evolution is not due to lack of heritable variation for that trait, as it is a condition very frequently encountered in many tetrapod taxa. For instance, the presence of an additional finger or toe is the most common anomaly at birth in humans (Castilla et al., 1996). Polydactyly is also quite frequent in other mammal species (Brignolo et al., 2002; Chapman, 2006; Moore et al., 2007; Gugolek et al., 2011), as well as birds (Fox, 1989; Huang et al., 2006; Sakai, 2006), and particularly amphibians (Mizgireuv et al., 1984; Johnson et al., 1999; Vorobyeva, 1999; Kiesecker, 2002; Taylor et al., 2005; Piha et al., 2006). It is less frequent in reptiles, with a single known case in chelonians (Martínez-Silvestre et al., 1998), and a few rare cases reported in lizards (Bauer et al., 2009).

While sampling a population of *Podarcis tiliguerta* (Gmelin, 1789) near Siniscola (40.48° N, 9.78° E, Datum WGS1984; Fig. 1), Sardinia (Italy), we found two female lizards with postaxial polydactyly. The sampling site was located in a natural area characterised by low Mediterranean maqui vegetation and very low anthropogenic disturbance. The first lizard was 54 mm in snout vent length (SVL) and exhibited six digits in each of the hind feet (Fig. 2Ai and 2Aii). On the right foot the polydactyly cannot easily be described without radiography, but it seems to result from the duplication of digit III, while

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Figure 1. Geographic location of the studied population of *Podarcis tiliguerta* from Siniscola in Sardinia (Italy).

on the left foot it is clearly a duplication of digit I. The second polydactylous lizard was 52 mm in SVL and presented six toes on the left hind limb, which also seems to be the result of a metatarsal duplication of digit III (Fig. 1B). Unfortunately, the animals in question were released before noting this condition and could not be examined radiographically to identify the osteological basis of the polydactyly. However, at least in two of the three cases (those in Fig. 1Aii and 1B), the polydactyly appears to involve a normal number of metatarsals but an abnormal number of digits (brachydactyly *sensu* Bauer et al., 2009), as the supernumerary digits are clearly stemmed at a position posterior to the metatarsals.

Both polydactylous females were adults, and their body size was within the normal range of the population (47-59 mm for the female individuals sampled in Siniscola). They both seemed in normal physical condition, and only presented a few red mite parasites (as seen in Fig. 2B), as was also the case for most of the individuals examined from the same population. Both presented copulation marks, indicating that they had mated recently, and the larger one was gravid when captured. Available DNA sequence data for the mitochondrial 12S rRNA gene obtained following the procedure described in Salvi et al. (2011), showed that the two polydactylous individuals present similar, but different haplotypes (Accession Numbers HF948026 and HF948027). Given the matrilineal inheritance of the mitochondrial genome, the occurrence of different haplotypes in the two polydactylous individuals indicates that they are not siblings from a single clutch.

Two aspects are worth noting in the case of polydactyly reported herein. First, this is the third case of polydactyly reported in wall lizards *Podarcis* (after *P. pityusensis* by Carretero et al., 1995 and *P. muralis* by Lazić and Crnobrnja-Isailović, 2012). Given the low number of reported cases in lizards, totalling seven that we are aware of (i.e. Carretero et al., 1995; Cuadrado, 1996; Pelegrin, 2007; Bauer et al., 2009; Minoli et al., 2009; Lazić and Crnobrnja-Isailović, 2012; Megía, 2012; but see also Norval et al., 2009), this means that a very high frequency of reported cases is observed in the genus *Podarcis* (representing almost half of the existing observations). While this may be the result of a reporting bias, it may also indicate that this condition is for some unknown reason more frequent in *Podarcis* wall lizards. Similarly high frequencies are only known from chameleons, where polydactyly seems to be quite frequent and has been observed in several populations of the same species (Cuadrado, 1996). Second, this is the first time that two polydactylous individuals have been encountered in a random lizard sample. In fact, this is the highest reported frequency of polydactyly in a lizard population, since the two observations come from a total, random sample, of 44 individuals (4.54%). This is remarkably high for lizards, where reported frequencies range between 0.2 and 0.6% (Bauer et al., 2009). According to genetic data, a direct sibling association could not be established between the two individuals. Consequently, while a genetic cause underlying this observation of polydactyly cannot be excluded at the population level, the high frequency reported here does not seem to be the outcome of the reproduction of a single pair of lizards.

The causes of polydactyly are difficult to decipher. Mutations in genes involved in digit development and specification (such as the Hedgehog, BmP, FgF and Hox gene families) are known to cause polydactyly in mammals, birds, and amphibians (Zákány et al., 1997; Villagómez and Alonso, 1998; Yokoyama et al., 1998; Kraus et al., 2001; Huang et al., 2006). Polydactyly is also

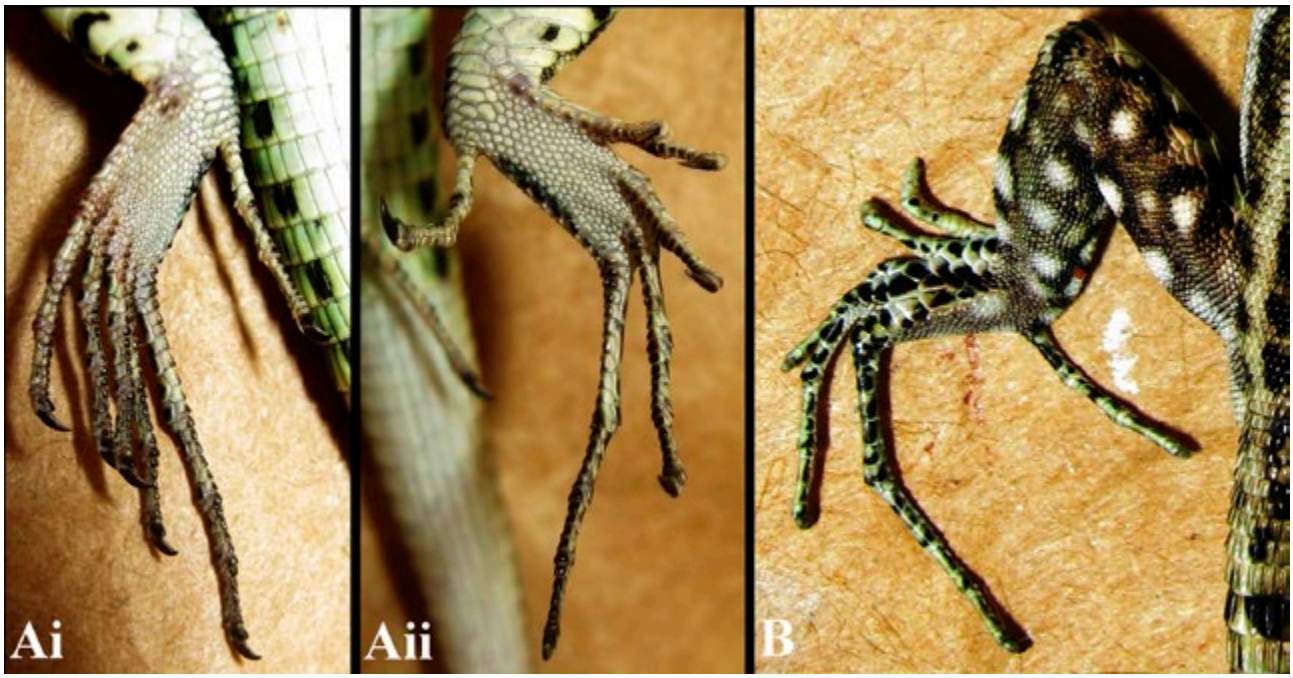

Figure 2. Polydactyly in two female individuals of the Siniscola population of *Podarcis tiliguerta*, encompassing polydactyly in both hind feet in the first (Ai and Aii) and only in the left hind limb in the second (B).

known to be frequently associated to chromosomal trisomies, at least in mammals (Pugsley, 1985; Brignolo et al., 2002; Moore et al., 2007). In amphibians, polydactyly has been associated with infection from some parasites (Jonhson et al., 1999; Kiesecker, 2002) or viruses (Borkin and Pikulik, 1986), as well as environmental contamination due to the use of pesticides (Mizgireuv et al., 1984; Diana and Beasley, 1998; Kiesecker, 2002; Taylor et al., 2005; Piha et al., 2006). In reptiles, the endogenous (genetic) and exogenous (environmental) causes of polydactyly are not fully understood, yet the case study reported herein and previous observations suggest that lizards of the genus *Podarcis* would be a promising model organism for investigating the occurrence of polydactyly and its proximate determinants.

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