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Morphometric variation of *Androlaelaps fahrenholzi* (Mesostigmata: Laelapidae) associated with three Sigmodontinae (Rodentia: Cricetidae) from the north of Chile

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Abstract
Androlaelaps fahrenholzi is a mite with a large distribution and associated with a wide range of hosts. To assess morphometric variation of *A. fahrenholzi* associated with different host species (*Phyllotis xanthopygus* and *Akodon albiventer*, both from Putre, Chile) and localities (Las Chinchillas National Reserve, Fray Jorge National Park, and Llanos de Challe National Park, all in Chile and all from the host *Phyllotis darwini*), 41 morphological characters of each specimen were measured, and principal component analysis and discriminant analysis were used. Both analyses showed two groups separated for species of rodents. Mites associated with *P. xanthopygus* are smaller than those of *A. albiventer*. The analysis by location indicates two groups: group 1 comprises all mites collected from Fray Jorge National Park and Las Chinchillas National Reserve, and group 2 comprises only mites from Llanos de Challe National Park. These results indicate that *A. fahrenholzi* population can vary between hosts and geographical areas. Molecular analysis would be necessary to validate these results and determine whether they are subspecies or different species.

Keywords Parasite · Mesostigmata · Mites · Morphometry · Rodents

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Introduction

One of the most important variables that can be recorded in animals is body size because it has a strong influence on such diverse aspects as physiology, adaptation, performance, and fitness of the organisms. The divergence caused by geographical isolation (geographic differentiation) and ecological differences between hosts can cause changes in size due to the natural selection of genotypes that express a phenotype of size linked to characters with greater fitness (Dujardin 2000). Evolutionary changes in size and thermal sensitivity are key features of adaptation and diversification of organisms (Kingsolver and Huey 2008).

Androlaelaps fahrenholzi (Berlese) (Mesostigmata: Laelapidae) is a mite mainly associated with small terrestrial mammals and its nests. On some rare occasions, it has been found on birds, bats and small carnivores (Strandtmann and Wharton 1958; Evans and Till 1979; Krantz and Walter 2009). It feeds on scabs, desquamations, lacrimal secretions, small arthropods, fresh blood or lymph from wounds (Strandtmann and Wharton 1958; Radovsky 1994; Krantz and Walter 2009). *Androlaelaps fahrenholzi* has been registered in all continents except the Antarctic, and it has been reported for a wide diversity of rodents from Muridae, Cricetidae, Heteromyidae, Echimyidae, Sciuridae and marsupials of the family Didelphidae (Fonseca 1939; Tipton et al. 1966; Furman 1972; Lareschi et al. 2013).

Androlaelaps fahrenholzi showed a notorious variation in its morphology due mainly to its wide distribution and host diversity. The evidence seems to indicate the existence of a '*fahrenholzi* complex' (Lareschi et al. 2013). For example, Strandtmann (1949) observed intraspecific variation in *A. fahrenholzi* collected from different hosts, separating *A. fahrenholzi* in different morphs associated to the host from which it was collected. Tipton et al. (1966) also found differences in the length of the dorsal plate between specimens of *A. fahrenholzi* collected from two species of rodents, yet there are also differences in size of the mites between localities of origin of the hosts. Lareschi et al. (2013) observed morphological variation between *A. fahrenholzi* species analyzed from different hosts and localities. Despite the evidence, none of these studies carried out statistical analyses to confirm such variation among morphs. In addition, the works cited only included a few morphological characters (Lareschi et al. 2013) and therefore it has not been possible to classify these morphs into different mite species.

Chile presents an uncommon geographical configuration, with Andean elevations close to the sea, comprising a range of bioclimatic zones that go from regular and benign littoral to Alpine, all at a relative short distance from each other (Santibañez et al. 2008). These geographical characteristics cause isolation of organisms, which can lead to morphological, behavioral, ecological, physiological and genetic changes, which is called 'insular syndrome' (Morand et al. 2006). Besides, Chile presents a great variety of micromammals, especially rodents (Mella et al. 2002; Muñoz-Pedreros and Gil 2009; Iriarte 2008). Due to this quite unique scenery, it is highly suitable to investigate changes caused by geographical and host influences on *A. fahrenholzi* morphometry.

Because the mites are so small, their (much) larger host animals represent cornucopias of microhabitats to mites (Walter and Proctor 2013), therefore characteristics of the host and of locations it inhabits could cause changes in morphometry of the mites. As *A. fahrenholzi* is widely distributed and parasitizes a wide host range, it is hypothesized that the body size of *A. fahrenholzi* may change with host species and with the host habitat. The goal of this study was to evaluate morphometric variation of *A. fahrenholzi* associated with different host species and geographical localities.

Materials and methods

Area of study and specimen collection

The mites and hosts were collected from four localities in the north of Chile: Las Chinchillas National Reserve (LCHNR, 31° 28′ S–71° 03′ W, 558 m above sea level), Fray Jorge National Park (FJNP, 30° 30′ S–71° 35′ W, 234 m a.s.l.), Llanos de Challe National Park (LLCNP, 28° 10′ S–71° 00′ W, 39 m a.s.l.), and Putre (18° 11′ S–69° 35′ W, 3500 m a.s.l.) (Fig. 1). Rodents were captured between August 2010 and 2011, with live traps (7.5 × 18.5 × 9 cm), weighted and anesthetized with ketamine (0.044 mg/g) and Xylazine® (0.006 mg/g) (Kreeger and Arnemo 2012). To collect mites, the rodents were brushed and the specimens collected were preserved in 70% ethyl alcohol. All rodents were released after collection of the mites.

To evaluate morphometric differences of *A. fahrenholzi* between host species, we analyzed 23 mites in total, collected from seven *Phyllotis xanthopygus* (11 mites) and four *Akodon albiventer* (12 mites) from Putre. To evaluate morphometric differences of *A. fahrenholzi* between geographic localities, we analyzed 40 mites in total, collected from 29 *Phyllotis darwini* from three localities (LCHNR: 9 rodents, 13 mites; FJNP: 10 rodents, 12 mites, and LLCNP: 10 rodents, 15 mites).

Mites preparation and processing

The mites isolated were cleared in Nesbitt's solution and mounted in Berlese medium (Krantz and Walter 2009). The mites were identified based on the taxonomic literature (Tipton et al. 1966; Furman 1972). To assess morphometric variation, 41 relevant taxonomic characters were chosen in the diagnosis of *A. fahrenholzi*, including measures of the dorsal and sternal shields, coxa I mushrooms and hypostomal mushrooms (Strandtmann 1949; Furman 1972) (Table 1; Fig. 2). All characters were measured with optic microscope (Leica®) with an ocular micrometer. Mite voucher specimens were deposited in the Collection of Departamento de Ciencia Animal, Universidad de Concepción (Chillán, Chile). Additionally, other specimens were prepared for scanning electron microscopy (JEOL JSM6380-LV, Laboratorio de Microscopía Electrónica, Universidad de Concepción) using a technique described by Alberti and Nuzzaci (1996).

Statistical analysis

Mean, maximum, and minimum measurements of each variable were obtained. The distribution of data was evaluated using the Shapiro–Wilks test of normality ($\alpha = 0.05$). A principal component analysis (PCA) to reduce dimensionality of the morphometric data was performed. Eigenvectors were extracted from the variance–covariance matrix. Discriminant analysis was used to investigate the relationship between the groups. Univariate and multivariate analyses of variance (ANOVA, MANOVA) were conducted to test for differences among *A. fahrenholzi* collected from host species and localities when the discriminant analysis did not show clear differences among groups ($\alpha = 0.05$). Statistical

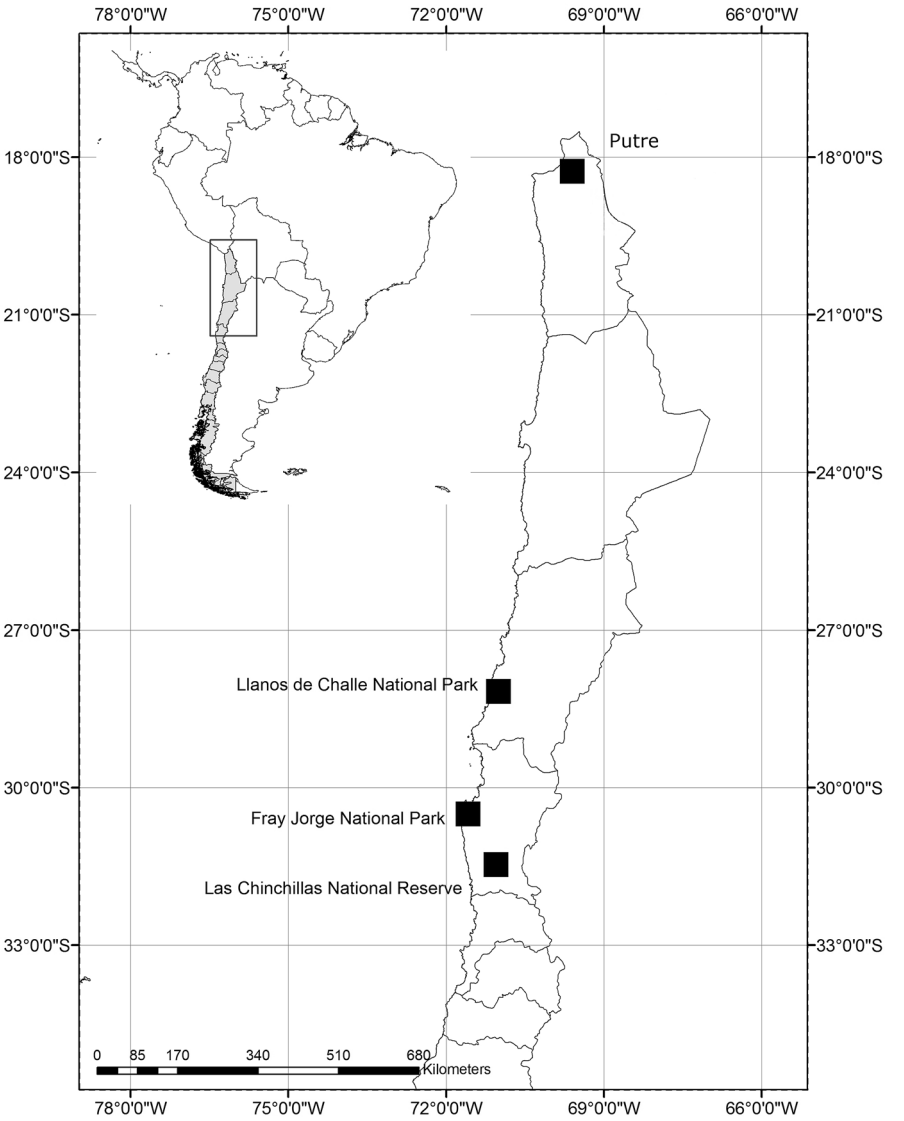

Fig. 1 Localities in the north of Chile from which host rodents and mites were collected

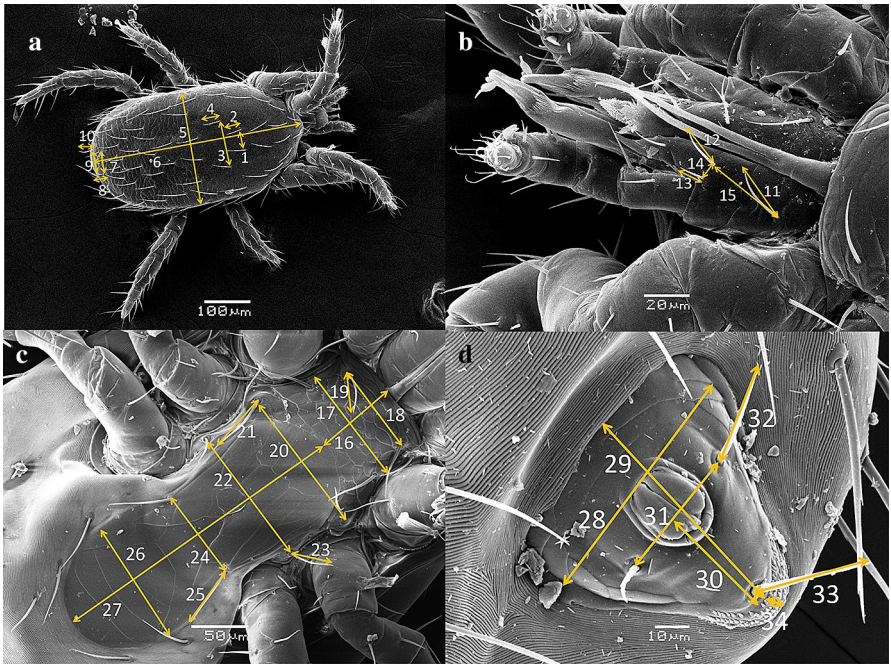

Fig. 2 Scanning electron microscopy images illustrating most of the measurements performed on *Androlaelaps fahrenholzi*. **a** 1. distance seta j5–j5; 2. length seta j5 (Lj5); 3. distance seta z5–z5; 4. length seta z5 (Lz5); 5. width dorsal shield (WDS); 6. length dorsal shield (LDS); 7. distance seta J5-J5; 8. length seta J5 (LJ5); 9. distance seta Z5–Z5; 10. length seta Z5 (LZ5). **b** 11. length seta gnatosomal (Lgn); 12. Length seta hipostomal (Lh3); 13. length seta hipostomal (Lh2); 14. Distance setae h2–h3 (h2–h3.); 15. distance gnatosomal–hipostomal setae (gn–h3). **c** 16. length sternal shield (LSS); 17. width sternal shield (WSS); 18. distance first sternal setae (st1–st1); 19. length first sternal setae (Lst1); 20. distance third sternal setae (st3–st3); 21. length third sternal setae (Lst3); 22. distance metasternal setae (st4–st4); 23. length metasternal seta (Lst4); 24. distance epyginial setae (st5–st5); 25. length epyginal seta (Lst5); 26. width epigynial shield (WES); 27. length epyginial shield (LES). **d** 28. maximum width anal shield (MWAS); 29. length anal shield (LAS); 30. average distance anal shield (ADAS); 31. distance paranals setae (paa–paa); 32. length paranal seta (Lpaa); 33. length postanal seta (Lpoa); 34. Cribum (cr)

analyses were performed with JMP7 software (SAS Institute) and the Real Statistic Supplemental data tool for Microsoft Excel.

Results

Mites from the same host species from diverse localities

In the PCA, the first four principal components account for 78.8% (30.4, 16.3, 14.7 and 11.6%) of the variance in the original 41 variables. For component 1 most loadings are positive and all are of approximately the same magnitude except length of the dorsal shield (LDS). A similar pattern is seen with components 2 and 3 where the highest loads are observed in length of the epyginial shield (LES) and width of the dorsal shield (WDS), respectively. Component 4 is dominated by positive coefficient for the distance of metasternal setae (st4–st4) and length of peritrema (per) (Table 1). Component 1 separates mites collected in LLCNP from those

Table 1 Weight of each measure in the components 1–4 of the principal component analysis (PCA) of *Androlaelaps fahrenholzi* collected on *Phyllotis darwini* and components 1 and 2 of *A. fahrenholzi* collected on *P. xanthopygus* and *Akodon albiventer*

Morphometric character	*P. darwini*				*P. xantophygus* and *A. albiventer*	
	PC1	PC2	PC3	PC4	PC1	PC2
Distance setae j5–j5 (j5–j5)	0.00796	0.00165	0.01578	− 0.05822	0.01201	− 0.01118
Length of seta j5 (Lj5)	0.04695	0.04098	0.04109	− 0.06591	0.13945	0.06911
Distance setae z5–z5 (z5–z5)	0	0	0	0	0	0
Length of seta z5 (Lz5)	0.0463	0.0816	0.05655	− 0.02735	0.14072	0.1376
Width dorsal shield (WDS)	0.34184	− 0.16276	**0.59294**	− 0.17033	**0.57047**	**− 0.47822**
Length dorsal shield (LDS)	**0.65921**	− 0.55736	− 0.26182	− 0.10285	**0.47359**	0.35635
Distance setae J5–J5 (J5–J5)	0.04864	− 0.00089	0.01422	− 0.04222	0.09047	0.07398
Length of seta J5 (LJ5)	0.02981	0.00023	0.01234	− 0.01563	0.13533	− 0.00441
Distance setae Z5–Z5 (Z5–Z5)	0.01365	0.00472	− 0.02184	− 0.0015	0.01179	0.01067
Length seta Z5 (LZ5)	0.10125	0.10273	0.03514	− 0.05879	0.10439	0.04557
Length gnathosomal seta (Lgn)	− 0.00282	0.03289	0.02529	− 0.03336	0.0859	0.05427
Distance gnatosomal–hipostomal setae (gn–h3)	0.01095	0.01165	− 0.01182	− 0.00543	0.00316	− 0.00035
Length hipostomal seta (Lh2)	− 0.00902	0.00258	0.0096	− 0.01331	0.0094	− 0.00146
Length hipostomal seta (Lh3)	− 0.00263	− 0.00415	0.02476	0.00598	0.04667	0.02637
Distance hipostomal setae(h2–h3)	0.03254	0.00433	− 0.00962	− 0.02238	0.01254	− 0.02945
Length first sternal seta (st1–st1)	0.0434	0.02364	0.0275	− 0.0507	0.06037	0.0305
Length first sternal seta (Lst1)	0.07201	0.00446	0.0335	− 0.08099	0.08268	0.04689
Width sternal shield (WSS)	0	0	0	0	0.14089	− 0.02164
Length sternal shield (LSS)	0.0978	0.07778	− 0.00627	− 0.08063	0.08551	0.03172
Distance third sternal setae (st3–st3)	0.13722	− 0.07352	0.24269	− 0.25071	**0.42049**	**0.48145**
Length sternal seta (Lst3)	0.10073	0.07071	0.0218	− 0.00401	0.09832	0.10234
Distance metasternal setae (st4–st4)	0.21342	− 0.12626	− 0.34943	**0.66961**	0.14025	− 0.03429

Table 1 (continued)

Morphometric character	*P. darwini*				*P. xantophygus* and *A. albiventer*	
	PC1	PC2	PC3	PC4	PC1	PC2
Length metasternal seta (Lst4)	0.03473	− 0.05183	0.03754	− 0.01191	0.06162	− 0.01128
Distance epyginal setae (st5–st5)	0.059	0.00292	0.01663	− 0.02677	0.09937	0.04004
Length epyginal seta (Lst5)	0.11809	0.00339	− 0.00353	− 0.07373	0.0953	0.00539
Width epygynal shield (WES)	0.02685	0.02816	0.00461	0.00177	0.02388	− 0.00305
Lenght epyginial shield (LES)	0.5253	**0.75252**	− 0.22339	− 0.11998	0.05075	− 0.00501
Maximum width anal shield (MWAS)	− 0.01058	0.01682	0.01293	0.02945	0.02379	− 0.00216
Length anal shield (LAS)	− 0.00617	− 0.08278	0.04929	0.06022	− 0.06601	0.0211
Average distance shield (ADAS)	− 0.01131	− 0.01952	0.0434	− 0.00663	− 0.00326	0.05432
Distance paranal setae (paa–paa)	0.0031	0.03254	0.04617	− 0.0022	0.02901	0.05115
Length paranal seta (Lpaa)	0.03288	0.03107	0.01172	0.00259	0.0305	0.04524
Length postanal seta (Lpoa)	0.03795	0.05434	0.05705	− 0.01002	0.09138	− 0.04057
Length cribrum	0.0152	0.01298	− 0.05115	− 0.00714	0.00204	0.02691
Length peritrema (per)	0.19754	0.15267	0.56339	**0.62434**	0.26496	**− 0.5877**
Length proximal coxa I seta (LspcI)	0.00429	− 0.04184	0.03813	− 0.00389	0.06283	0.01173
Length distal coxa I seta (LsdcI)	− 0.00073	− 0.01327	0.0596	0.02843	0.04476	0.01484
Length posterior coxa III seta (LspcIII)	− 0.0081	− 0.00039	0.01184	0.00233	0.02531	− 0.0301
Length coxa IV seta (LscIV)	0.00114	− 0.01544	0.00464	− 0.00256	0.00468	0.01316
Length distal anterior femur I seta (LsdafI)	0.02118	− 0.03844	0.02177	− 0.01776	0.02713	− 0.03217
Length posterior genus I seta (LspgI)	0.01231	− 0.01775	0.02051	− 0.03689	0.03516	0.01253

Values in bold indicate high load character in component

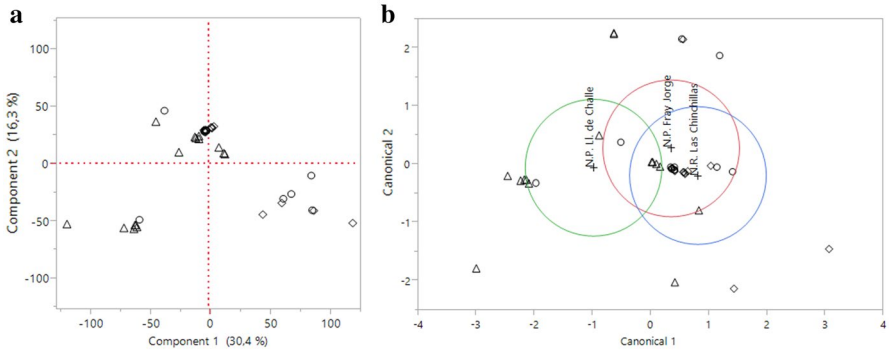

Fig. 3 Plots illustrating **a** the first two principal component scores from PCA and **b** discriminant analysis of *Androlaelaps fahrenholzi* collected from *Phyllotis darwini* from three localities in Chile: Llanos de Challe National Park (open triangle), Fray Jorge National Park (open circle), and Las Chinchillas National Reserve (open diamond)

collected in FJNP and LCHNR, the latter being larger (found to the left on component 1). Components 2 and 4 separate LLCNP from LCHNR, whereas component 3 shows no differences between localities. Figure 3a shows projections of the 40 *A. fahrenholzi* individuals into components 1 and 2.

Androlaelaps fahrenholzi specimens from different areas formed two distinct groups, with those from FJNP and LCHNR forming one group, and those from LLCNP forming a second group. The discriminant analysis supports this result, as it shows the same two groups of *A. fahrenholzi* on *P. darwini* from different localities (Fig. 3b).

The morphometrics of the mites from these three localities are statistically different. Character measurements on the body of each mite are shown in Table 2.

Mites from diverse host species from a single locality

In the PCA, the first two principal components account for 74.8% (62.7 and 12.2%) of the variance in the original 41 variables. For component 1 all loading is positive except two variables (length of the anal shield, LAS and average distance of the anal shield, ADAS). For this component only three characters loaded heavily, the highest load is observed in width and length of the dorsal shield (WDS and LDS) and distance of third sternal setae (st3–st3). Similarly, for component 2 only three characters loaded heavily but the highest loads are negative (per and WDS) and only one variable had a positive coefficient (st3–st3) (Table 1; Fig. 4).

The mites on *A. albiventer* had the highest values for (almost) all morphometric characters compared to the mites on *P. xanthopygus* (Table 3). In the plot of the principal component scores two host-associated groups are observed, but only component 1 separates the groups (Fig. 4).

Discussion

The present study shows that *A. fahrenholzi* has morphometric variation between hosts and geographical localities. This variation mainly corresponds to the size of plates and setae, which matches the variation found by other authors (Strandtmann 1949; Till 1963; Evans

Table 2 Character measurements of the body of *Androlaelaps fahrenholzi* collected from *Phyllotis darwini* at three localities

Morphometric character	Locality			ANOVA	
	Llanos de Challe National Park	Las Chinchillas National Reserve	Fray Jorge National Park	*F*	P
j5–j5	50	55 (40–60)	50.8 (40–60)	0.3568	0.70
Lj5	32 (30–40)	42.3 (30–50)	38.3 (30–40)	167.908	< 0.001
z5–z5	100	100	100	–	–
Lz5	32.7 (30–40)	42.3 (30–60)	43.3 (40–50)	128.927	< 0.001
WDS	386.7 (300–400)	407.7 (400–500)	391.7 (300–400)	16.927	0.20
LDS	600 (600)	630.8 (600–700)	633.3 (600–700)	32.811	0.049
J5–J5	68 (60–80)	70.8 (60–80)	69.2 (60–70)	0.9670	0.39
LJ5	30 (30)	33.1 (30–40)	32.5 (30–40)	27.856	0.075
Z5–Z5	98.7 (80–100)	98.5 (80–100)	99.2 (90–100)	0.0725	0.93
LZ5	70 (60–80)	90.8 (80–100)	87.5 (80–90)	494.720	< 0.001
Lgn	39.3 (30–40)	36.9 (30–40)	37.5 (30–40)	0.9818	0.38
gn–h3	47.3 (40–50)	50.8 (50–60)	51.7 (50–60)	57.813	0.0065
Lh2	20 (20)	19.2 (10–20)	19.2 (10–20)	0.6059	0.55
Lh3	52.7 (50–60)	54.6 (40–70)	55.8 (50–60)	13.909	0.26
h2–h3	7.3 (4–9)	9	9	48.633	0.013
st1–st1	72 (70–80)	78.5 (70–90)	80 (80)	114.482	0.0001
Lst1	52.7 (50–60)	60 (50–80)	56.7 (50–70)	51.351	0.011
WSS	100 (100)	100 (100)	100 (100)	–	–
LSS	80.7 (70–90)	96.2 (80–100)	95.8 (90–100)	315.535	< 0.0001
st3–st3	106.7 (100–200)	107.7 (100–200)	100	0.4344	0.65
Lst3	65.3 (40–70)	73.8 (60–90)	71.7 (70–80)	49.899	0.012
st4–st4	113.3 (100–200)	107.7 (100–200)	108.3 (100–200)	0.1394	0.87
Lst4	53.3 (40–60)	56.2 (40–70)	50.8 (40–60)	1.672	0.20
st5–st5	76.7 (90 – 70)	80 (70–90)	79.2 (70–90)	1.2837	0.29
Lst5	52 (20–70)	64.6 (50–70)	59.2 (50–70)	6.6837	0.0033
WES	97.3 (90–100)	100	100	4.2045	0.023
LES	260 (200–300)	300	291.7 (200–300)	5.1541	0.011
MWAS	99.3 (90–100)	96.2 (80–100)	99.2 (90–100)	2.2650	0.12
LAS	94 (70–100)	85.4 (70–100)	88.3 (80–100)	3.0755	0.058
ADAS	48 (40–60)	43.8 (30–60)	43.3 (40–50)	2.3955	0.11
paa–paa	40 (30–50)	40.8 (30–50)	38.3 (30–40)	0.8297	0.44
Lpaa	40	45.4 (40–60)	45 (40–60)	4.6007	0.016
Lpoa	59.3 (50–70)	68.5 (30–80)	68.3 (60–70)	5.4233	0.0086
CRIBUM	14.4 (9–20)	16.8 (9–20)	13.2 (9–20)	1.6159	0.21
Per	286.7 (200–300)	292.3 (200–300)	308.3 (300–400)	1.6927	0.20
LspcI	42.7 (40–70)	42.3 (40–50)	40	0.8788	0.42
LsdcI	36.7 (30–60)	35.4 (30–40)	34.2 (30–40)	0.5010	0.61
LspcIII	31.3 (30–40)	30.8 (30–40)	30	0.8259	0.45
LssIV	30.7 (30–40)	29.2 (20–30)	31.7 (30–40)	1.9793	0.15
LsdafI	29.3 (20–40)	27.7 (10–40)	30.8 (30–40)	1.1243	0.34
LsdpgI	29.3 (20–30)	30.8 (20–40)	29.2 (20–30)	0.7826	0.46
MANOVA				2.1420	0.047

ANOVA and MANOVA results are shown

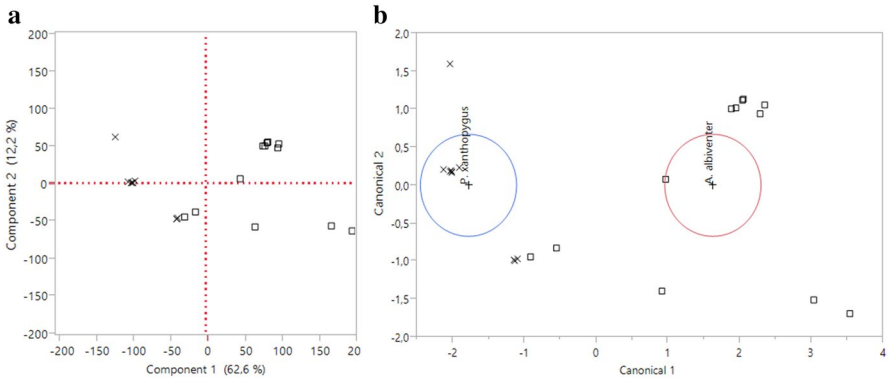

Fig. 4 Plots illustrating **a** the first two principal component scores from PCA and **b** discriminant analysis of *Androlaelaps fahrenholzi* collected from *Phyllotis xanthopygus* (X) and *Akodon albiventes* (□) in Putre, Chile

and Till 1979; Strandtmann and Wharton 1958; Tipton et al. 1966; Furman 1972; Lareschi et al. 2013; Table 4). Apparently, the differences in the morphology of *A. fahrenholzi* may be given by geography and by host. In the present study, we observed two morphologically different groups of *A. fahrenholzi* collected from three localities of the north of Chile. These differences could be influenced by climatic conditions. *Androlaelaps fahrenholzi* on *P. darwini* from FJPN and LCHNR (LPD = 633 and 630 µm, respectively) are larger than those found in LLCNP (LPD = 600 µm). FJNP and LCHNR are characterized by a Mediterranean appearance, and a marked decrease in desert influence (dryness), with the presence of forest associations, whereas LLCNP has a cloudy coastal desert climate, with scarce rainfall or totally absent, with high environmental humidity, and poor vegetation (Fuenzalida 1950). Remmert (1981) predicts that body size increases with aridity because desiccation resistance increases with body size owing to stronger cuticle and smaller surface area-to-volume ratio; this is contrary to what was recorded in the present study. This could be a result of accelerated development because high temperatures lead to smaller adult size (Atkinson 1995; Kaspari 2005).

However, the morphological variation observed may also be determined by the identity of the host. For example, Gettinger and Owen (2000) analyzed mites from rodents from Paraguay, where they observed four morphologically distinct groups of *Androlaelaps rotundus* (Fonseca), isolated from the four rodent species *Akodon cursor* (Winger), *Akodon azarae* (Fischer), *Akodon toba* (Thomas) and *Necromys* (*Bolomys*) *lasiurus* (Lund); *Ak. cursor* mites were smaller than the ones present on *Ak. azarae* and *Ak. toba*, and the mites from *N. lasiurus* were intermediate. Posteriorly, those specimens preliminarily identified as *A. rotundus* were described as a new species, host-specific of akodontine rodents from the *Akodon* division (Lareschi and Gettinger 2009; Lareschi 2010, 2011; Lareschi and Velazco 2013), and *A. rotundus* species group was proposed to include the nominal, as well as close species (Lareschi 2011). Gettinger et al. (2011) detected through PCA that *Laelaps manguinhosi* mites from different rodent hosts from Paraguay are morphologically different and established four groups of mites. Martins-Hatano et al. (2012) performed a morphometric analysis of *Gigantolaelaps vitzthumi* (Fonseca) from Brazil, and detected two groups associated with different hosts: one found on *Cerradomys vivoi* (Percequillo, Hingst-Zaher and Bonvicino) collected from Chapada Diamantina and another group

Table 3 Character measurements of the body of *Androlaelaps fahrenholzi* collected from two host species at Putre

Morphometric character	Host species		ANOVA	
	Phyllotis xanthopygus	*Akodon albiventer*	*F*	P
j5–j5	50	52.5 (50–60)	3.34	0.082
Lj5	30	57.5 (30–70)	74.40	< 0.0001
z5–z5	100	100	–	–
Lz5	30.9 (30–40)	60 (30–70)	68.41	< 0.0001
WDS	327.3 (300–400)	416.7 (400–500)	25.02	< 0.0001
LDS	600 (600)	683.3 (600–700)	50.21	< 0.0001
J5—J5	67.3 (60–70)	80.8 (50–100)	11.60	0.0027
LJ5	29.1 (20–30)	52.5 (30–70)	50.18	< 0.0001
Z5–Z5	97.3 (90–100)	100	4.10	0.056
LZ5	77.3 (70–90)	100	100.70	< 0.0001
Lgn	30	39.2 (30–40)	110.47	< 0.0001
gn–h3	50 (50)	51.7 (50–60)	2.00	0.17
Lh2	18.2 (10–20)	20	2.43	0.13
Lh3	50 (50)	66.7 (60–80)	71.73	< 0.0001
h2–h3	8.5 (4–9)	9.2 (9–10)	1.90	0.18
st1–st1	73.6 (70–80)	85 (80–90)	28.06	< 0.0001
Lst1	50.9 (50–60)	65 (50–70)	24.14	< 0.0001
WSS	100 (100)	116.7 (100–200)	2.00	0.17
LSS	80.9 (70–90)	100	150.99	< 0.0001
st3–st3	100	166.7 (100–200)	20.08	0.0002
Lst3	61.8 (50–70)	83.3 (70–100)	54.14	< 0.0001
st4–st4	100 (100)	116.7 (100–200)	2.00	0.17
Lst4	46.4 (40–50)	61.7 (50–80)	34.36	< 0.0001
st5–st5	71.8 (70–80)	90 (70–100)	52.17	< 0.0001
Lst5	50 (40–60)	68.3 (60–80)	52.73	< 0.0001
WES	95.5 (80–100)	100	5.26	0.032
LES	290.9 (200–300)	300	1.09	0.31
MWAS	95.5 (90–100)	100	9.13	0.0065
LAS	100	84.2 (70–90)	61.45	< 0.0001
ADAS	42.7 (40–50)	42.5 (40–50)	0.01	0.91
paa–paa	40	45 (40–50)	10.04	0.0046
Lpaa	42.7 (40–50)	49.2 (40–60)	9.80	0.0051
Lpoa	55.5 (50–70)	74.2 (60–80)	30.92	< 0.0001
CRIBUM	15.5 (50–70)	15.8 (10–20)	0.86	0.031
Per	290.9 (200–300)	325 (300–400)	44.33	0.047
LspcI	39.1 (30–40)	50.8 (40–60)	43.43	< 0.0001
LsdcI	30.9 (30–40)	39.2 (30–40)	45.01	< 0.0001
LspcIII	30	33.3 (30–40)	5.02	0.036
LssIV	30	30.8 (30–40)	0.91	0.35
LsdafI	29.1 (20–30)	32.5 (30–40)	4.43	0.047
LsdpgI	28.2 (20–30)	35 (30–40)	12.08	0.0023
MANOVA			274.53	< 0.0001

ANOVA and MANOVA results are shown

Table 4 Length (μm) of dorsal shield (LDS) on *Androlaelaps fahrenholzi* reported by other authors and the present study

Rodent host	Dorsal shield (μm)	Locality	Reference
Hoplomys grymnurus	> 800	Venezuela	Tipton et al. (1966)
Sigmodon hispidus	572	Venezuela	Tipton et al. (1966)
Otomys irroratus	600–653	Ethiopia	Till (1963)
Premnoplex brunnescens	778	Costa Rica	Lareschi et al. (2013)
Unknown	714	England	Evans and Till (1979)
Phyllotis darwini	600	Chile, Llanos de Challe National Park	Present study
	630.8	Chile, Las Chinchillas National Reserve	Present study
	633.3	Chile, Fray Jorge National Park	Present study
Phyllotis xanthopygus	600	Chile, Putre	Present study
Akodon albiventer	683.3	Chile, Putre	Present study

associated with *Cerradomys goytaca* (Langguth and Bonvicino) and *Cerradomys scott* (Wagner) collected from Restinga de Jurubatiba and Distrito Federal, respectively. They detected morphometric differences in mites between hosts and between localities. Similar results were found in *Laelaps manguinhosi* Fonseca, where PCA separated two groups of mites morphologically different among their hosts *Nectomys squamipes* (Brants) collected from Distrito Federal and *Nectomys rattus* (Peter) collected from Restinga de Jurabatiba and Praia de Neves, demonstrating morphological variation between their hosts and localities. The same authors further analyzed *Laelaps differens* (Fonseca) showing the presence of two groups, one associated to the host *C. scotti* from Distrito Federal and the other associated with *C. goytaca* from Restinga de Jurubatiba (Brazil). More recently, Lareschi and Gallieri (2014) studied *A. rotundus* through PCA identifying four groups of mites, each host specific and without geographical variation. Each group corresponded to a new species that differed by group means of particular measurements. Lareschi and Gallieri (2014) propose that these different morphs exist because mites change hosts, followed by a process of speciation, based mainly in the fact that Laelapideae inhabit the nests of their hosts and may colonize new hosts by nest sharing and/or by overlap of geographic host ranges. The same thing could be happening in *A. fahrenholzi*, a species associated with nests of its hosts (Strandtmann and Wharton 1958; Radovsky 1994; Krantz and Walter 2009).

The morphometric variation found in some structures (setae and shields) of *A. fahrenholzi* would help these mite 'morphs' to adapt in a better way to hosts and their environment, gradually generating speciation and host specialization.

This research comprises the first statistical analysis of morphometric characters of *A. fahrenholzi*. Morphometric variation could be related to its hosts and collection sites. It would be valid to conduct subsequent molecular analyses and establish whether the morphs are subspecies or can be truly considered different species, belonging to the *fahrenholzi* complex.

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