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SEX- AND AGE-RELATED DIFFERENCES IN TOOTH ROW LENGTH OF SMALL MAMMALS: SHREWS

Linas BALČIAUSKAS

Vilnius University, The Environmental Studies Centre, M.K.Čiurlionio 21/27, LT-03101 Vilnius, Lithuania. E-mail: linasbal@ekoi.lt

Abstract. The article analyses sex- and age-related differences in tooth row length (TRL) in three shrew species – common shrew (*Sorex araneus*), pygmy shrew (*S. minutus*) and water shrew (*Neomys fodiens*) – found in Lithuania, and the TRL correlation with body weight and length. No age- or sex-related differences were found in TRL. Our sample did not reveal any TRL correlation with body weight or length. The TRL overlap in shrew weight groups was found to be very great. Thus, the TRL being a perfect trait for species identification is not suitable for body weight or length prediction.
Key words: shrews, tooth row length, sex- and age-related differences, body weight and length

Introduction

This article is the last one in the series of our articles that have analysed: (i) the suitability of TRL for identification of small mammal species (Balčiauskienė *et al*. 2002), (ii) sex and age differences in TRL and its suitability for body weight and length prediction in voles (Balčiauskienė *et al*. 2004a), and (iii) the same regularities in mice (Balčiauskienė *et al*. 2004b).

For small mammal species inhabiting Lithuania, we found that the TRL being unmistakably suitable for shrew species identification gave a great overlap between mice and vole species. As a body weight predictor, the TRL was the most indicative in voles of the genus *Microtus* (r = 0.62–0.78). Only root vole (*Microtus oeconomus*) females were significantly heavier, longer and had a greater TRL. The TRL correlation with body weight and length for this species was the strongest. Age-related differences in TRL averages were significant for all vole species (Balčiauskienė *et al*. 2004a). In mice, even in the cases of the highest correlation in wood mouse (*Apodemus sylvaticus*), house mouse (*Mus musculus*) and birch mouse (*Sicista betulina*), the individual's weight could be predicted from the maxillary TRL just in 17–26% of cases. In general, the TRL in mice in comparison with that in voles is less suitable for prediction of the individual's sex, age, body weight and length from the material retrieved from owl pellets (Balčiauskienė *et al*. 2004b). According to Canova *et al*. (1999), the correlation between bone length and body mass in shrews is stronger than in rodents. Thus, we expected to get a more reliable prediction in contrast to our rodent sample.

The article deals with three Lithuanian shrew species – common shrew (*Sorex araneus*), pygmy shrew (*S. minutus*) and water shrew (*Neomys fodiens*). It aimed to test (1) if there are any age- or sex-related differences in the TRL of shrews, (2) if the TRL of shrews can be used as a body weight and length predictor, and also attempted (3) to compare our data with the data already published by other authors.

Material and methods

Shrew skulls were collected in 2001–2003 from animals trapped in different locations of Lithuania: Biržų Giria forest, Kėdainiai district Lipliūnai environs, Zarasai district Antalieptė environs, Žemaitija National Park and Čepkeliai State Strict Nature Reserve. We also used shrew skulls from the collection of the Institute of Ecology acquired from various places of Lithuania in 1977–2000. The majority of individuals were caught in summer and autumn. In total 429 individuals were examined (Table 1).

Measurements of the alveolar length of mandibular and maxillary tooth rows (Fig. 1) were taken under binoculars with a micrometric eyepiece with an accuracy of 0.05 mm. The TRL of the right set of the skull was measured, its left set was measured only if the skull was damaged. The maxillary TRL was measured excluding the first incisor (Fig. 1), as suggested by Turni (1999), Canova *et al*. (1999) and Kryštufek and Vohralik (2001). A standard statistical approach (mean, standard error and limits, *t*-statistics for the comparison of the mean and Pearson correlation) was used. The TRL overlap in males/females or age groups of the same species was presented as bar graphs or box and whisker plots.

Table 1. Number of measured shrew skulls (according to their sex).

Species	Males	Females	Total*
Common shrew (*Sorex araneus*)	147	113	272
Pygmy shrew (*S. minutus*)	62	39	105
Water shrew (*Neomys fodiens*)	18	21	52

* – data on sex were missing in some animals

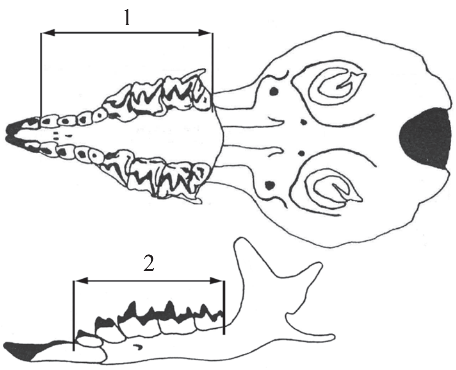

Figure 1. Cranial measurements used: 1 – alveolar length of the maxillary tooth row, 2 – alveolar length of the mandibular tooth row.

According to the reproductive condition of animals and the presence of the thymus gland we tried to single out the same age groups as for mice and voles. Over-wintered or reproducing individuals with an involuted thymus gland were regarded as adults, those with a disappearing thymus gland and inactive reproductive organs – as subadults, and those with a functioning thymus gland and still developing reproductive organs – as juveniles. Unfortunately, this was not always possible for the animals from the collection, when only the presence of the thymus gland was recorded (present, absent or partly present). It should be noted that determination of shrews' age may be questionable, if caught animals stay in the snap-traps for a longer time under hot air condition.
We also used body length and weight groups (the sample did not include pregnant females). For *S. araneus* and *N. fodiens,* body weight groups were distinguished every 2 g (i.e., ≤7, 7.1–9, 9.1–11 and >11 g for *S. araneus*, and ≤12, 12.1–14, 14.1–16 and >16 g for *N. fodiens*). For a smaller species, *S. minutus*, body weight groups were: ≤2, 2.1–3, 3.1–4 and >4 g. According to body length, shrews were classified into length groups at 10 mm intervals. For *S. araneus* and *S. minutus,* the first group included individuals with a body length ≤45 mm, then 45.1–55, 55.1–65 and ≥65.1 mm. For *N. fodiens*, the first group was ≤70 mm.
Raw data published by Niethammer and Krapp (1990) – weight, body length, maxillary and mandibular TRLs of the same shrew species – were used for comparison.

Results

Data on the body weight, length and TRLs of shrews in our sample are presented in Table 2. Inter-species differences in TRL are highly significant and unmistakably suitable for identification of shrew species (Balčiauskienė *et al.* 2002).

1. Sex-related differences

No statistically significant differences in body weight, length and TRLs were found between male and female shrews from our sample (Table 3). Unfortunately, the only source for shrew morphometrics from Lithuania is 'Fauna of Lithuania. Mammals' (Prūsaitė *et al.* 1988). In our sample, the body weight and length of shrews were within the limits of the published data, with the exception of some young animals of *S. araneus*. Absence of differences in male and female body and in cranial measurements was pointed out in the above source, but we cannot compare our TRL data with the source data based on a differently performed TRL measurements, i.e., with the first incisor included (Prūsaitė *et al.* 1988).
Distribution of TRL in males and females is presented in Figure 2. In our sample, males of both *Sorex* species had minimum and maximum maxillary TRL values, whereas mandibular TRL values completely overlapped. In *N. fodiens*, the mandibular TRL ≤ 6.0 mm was characteristic only of females, while ≥6.6 mm – of males.

2. Age-related differences

In *S. araneus*, we found significant differences between body weight and length in age categories described as adults (n = 27), subadults (n = 84) and juveniles (n = 9). Body weights were 9.3 ± 0.2, 7.5 ± 0.1 and 6.6 ± 0.2 g; body lengths – 66.9 ± 0.8, 64.2 ± 0.4 and 58.3 ± 3.0 mm, respectively (differences between groups significant at $p < 0.001$). However, no significant age-related differences in maxillary and mandibular TRLs were observed. The maxillary TRL in adult *S. araneus* was

Table 2. Morphometrics of the investigated shrew species.

Species	Parameters	N	Mean ± SE	Minimum	Maximum
Sorex araneus	Body weight	264	7.57 ± 0.07	5.1	13.0
	Body length	250	65.0 ± 0.25	38.2	75.3
	Maxillary TRL	261	7.14 ± 0.01	6.7	7.6
	Mandibular TRL	267	5.30 ± 0.01	5.0	5.6
Sorex minutus	Body weight	103	2.98 ± 0.05	1.7	5.4
	Body length	100	48.6 ± 0.35	38.4	57.9
	Maxillary TRL	90	5.57 ± 0.01	5.2	5.9
	Mandibular TRL	103	4.14 ± 0.01	4.0	4.3
Neomys fodiens	Body weight	39	14.17 ± 0.36	9.7	19.7
	Body length	33	79.1 ± 0.98	65.2	94.3
	Maxillary TRL	52	8.95 ± 0.05	7.8	9.6
	Mandibular TRL	52	6.32 ± 0.02	5.9	6.7

Table 3. Sex-related differences in body weight and length, mandibular and maxillary TRLs of shrews (mean ± SE).

Species	Sex	Body weight, g	Body length, mm	Maxillary TRL, mm	Mandibular TRL, mm
Sorex araneus	m	7.67 ± 0.10	64.86 ± 0.34	7.13 ± 0.01	5.29 ± 0.01
	f	7.45 ± 0.10	65.31 ± 0.37	7.16 ± 0.01	5.31 ± 0.01
Sorex minutus	m	3.00 ± 0.06	48.37 ± 0.45*	5.57 ± 0.02	4.14 ± 0.01
	f	3.01 ± 0.10	49.53 ± 0.51	5.59 ± 0.02	4.15 ± 0.01
Neomys fodiens	m	14.12 ± 0.42	78.11 ± 1.44	8.95 ± 0.08	6.34 ± 0.04
	f	14.13 ± 0.58	80.04 ± 1.43	8.95 ± 0.10	6.33 ± 0.04

*Note: significance of male–female differences is expressed as: * – $p < 0.10$*

7.09 ± 0.02 mm, subadult – 7.15 ± 0.02 mm, juvenile – 7.14 ± 0.04 mm; the mandibular TRL – 5.25 ± 0.03, 5.28 ± 0.02 and 5.20 ± 0.05 mm, respectively.

In *S. minutus*, only a few individuals had a clear age identification as adults (n = 3), subadults (n = 16) and juveniles (n = 5). Significant differences were found in the average body weight of these groups. Adult *S. minutus* weighed 4.2 ± 0.6, subadult – 3.2 ± 0.1 ($p < 0.005$), juvenile – 2.6 ± 0.2 g ($p < 0.002$ from subadult). The body length of these age categories did not differ significantly, as well as the TRL. The average lengths of maxillary and mandibular TRLs in adults were 5.60 ± 0.06 and 4.2 ± 0.00, in subadults – 5.56 ± 0.03 and 4.12 ± 0.02, in juveniles – 5.58 ± 0.04 and 4.13 ± 0.03 mm, respectively.

In *N. fodiens,* our sample of known-age animals was even smaller – five individuals in each adult and subadult group. No significant differences in body dimensions and in TRL were observed. For adults and subadults the average maxillary TRL was 8.96 ± 0.17 and 9.02 ± 0.09 mm, the average mandibular TRL – 6.50 ± 0.05 and 6.36 ± 0.10 mm, respectively.

3. Correlation between TRL, body mass and body length

Our data show that body dimensions (weight and length) in shrews do not correlate with maxillary or mandibular TRLs. The only exception was *S. minutus*, in which the mandibular TRL correlated with body length, but even in this case prognosis is not possible, as correlation is too weak (Table 4).

The TRL distribution in shrews across weight groups showed two patterns (Fig. 3). In the first one, the longest TRL was in the 2nd or 3rd weight groups (i.e., in older animals); in the 4th group the TRL was even shorter than in the 1st group. This pattern was characteristic of both maxillary and mandibular TRLs in *S. araneus*, the maxillary TRL in *S. minutus* and the mandibular TRL in *N. fodiens*. The other pattern was observed in the maxillary TRL in *N. fodiens* and the mandibular TRL in *S. minutus*. The shortest TRL was in the 2nd weight group, then it was increasing and reached the highest values in the 4th group (presumably, in the oldest animals). Not all of these differences were significant, and even if so, they hardly may have a prognostic value (Figs 3, 4).

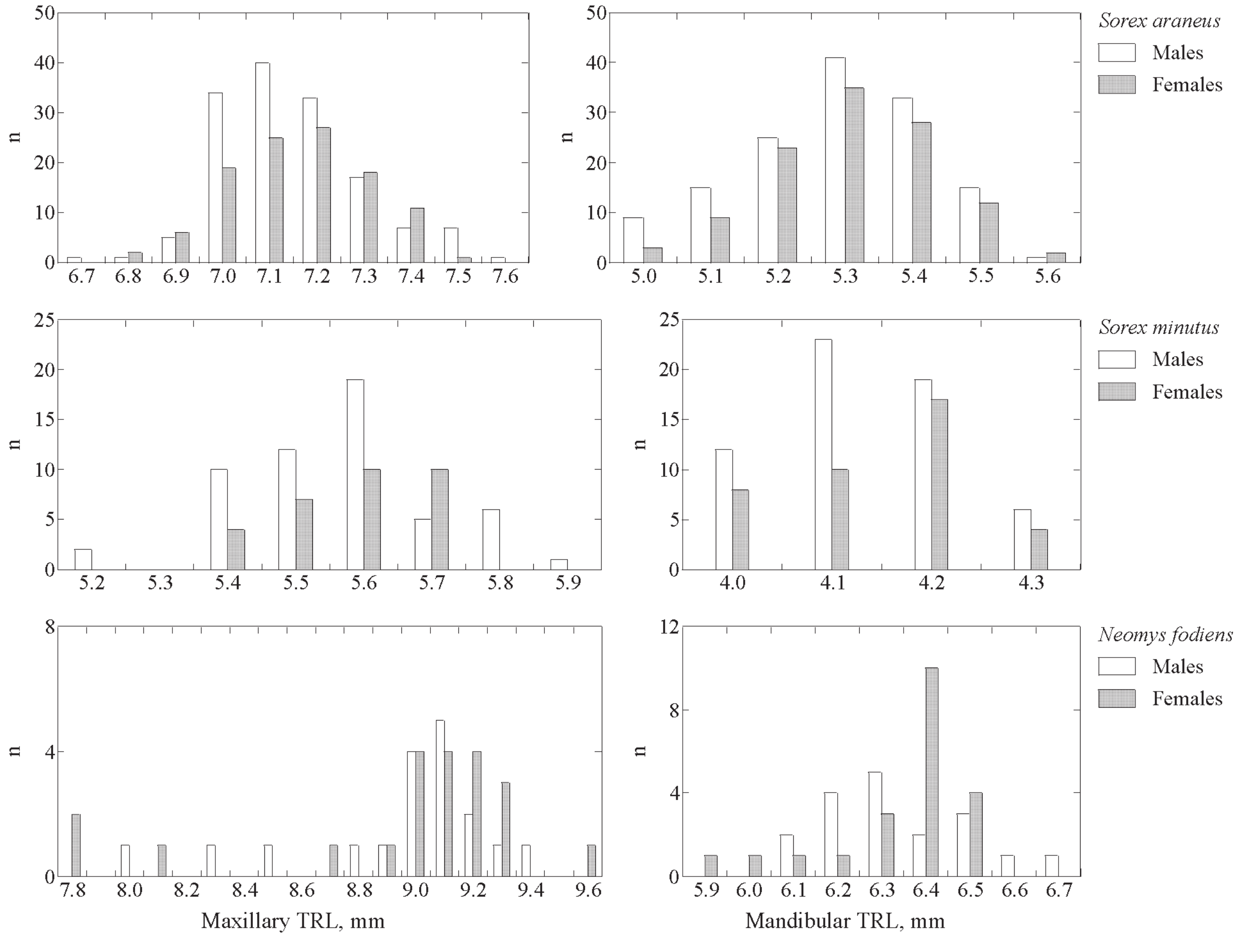

Figure 2. Sex-related distribution of maxillary and mandibular TRLs in shrews.

Table 4. Correlation coefficients between body weight, length, and maxillary and mandibular TRLs in shrews.

Species		Maxillary TRL	Mandibular TRL
Sorex araneus	weight	-0.013	0.001
	length	-0.001	0.087
Sorex minutus	weight	0.059	0.018
	length	0.028	0.220*
Neomys fodiens	weight	0.164	0.027
	length	-0.080	0.279

*Note: significance of correlation is expressed as * – p < 0.05*

The overlap of maxillary and mandibular TRLs across body weight and length groups in shrews is so great and chaotic, that any prediction is impossible. The correlation analysis also suggests that the TRL in shrew species is practically not associated with animal age (consequently, its body weight and length; Table 4). This assumption is illustrated by the TRL distribution pattern in *S. araneus* (Fig. 4). The TRL of the two other shrew species is distributed in the same overlapping manner.

Discussion

Shrews undoubtedly are the most variable group of small mammals in respect of body parameters. Even body size is not constant for shrew species. Young animals may be bigger than adults. In most species, sex-related dimorphism is not expressed, and definitely this is not characteristic of Lithuanian shrews (Prūsaitė *et al.* 1988; our data).
In *S. caecutiens*, (a shrew species expected to live in Lithuania, but still not found) sex-related dimorphism in body size is not

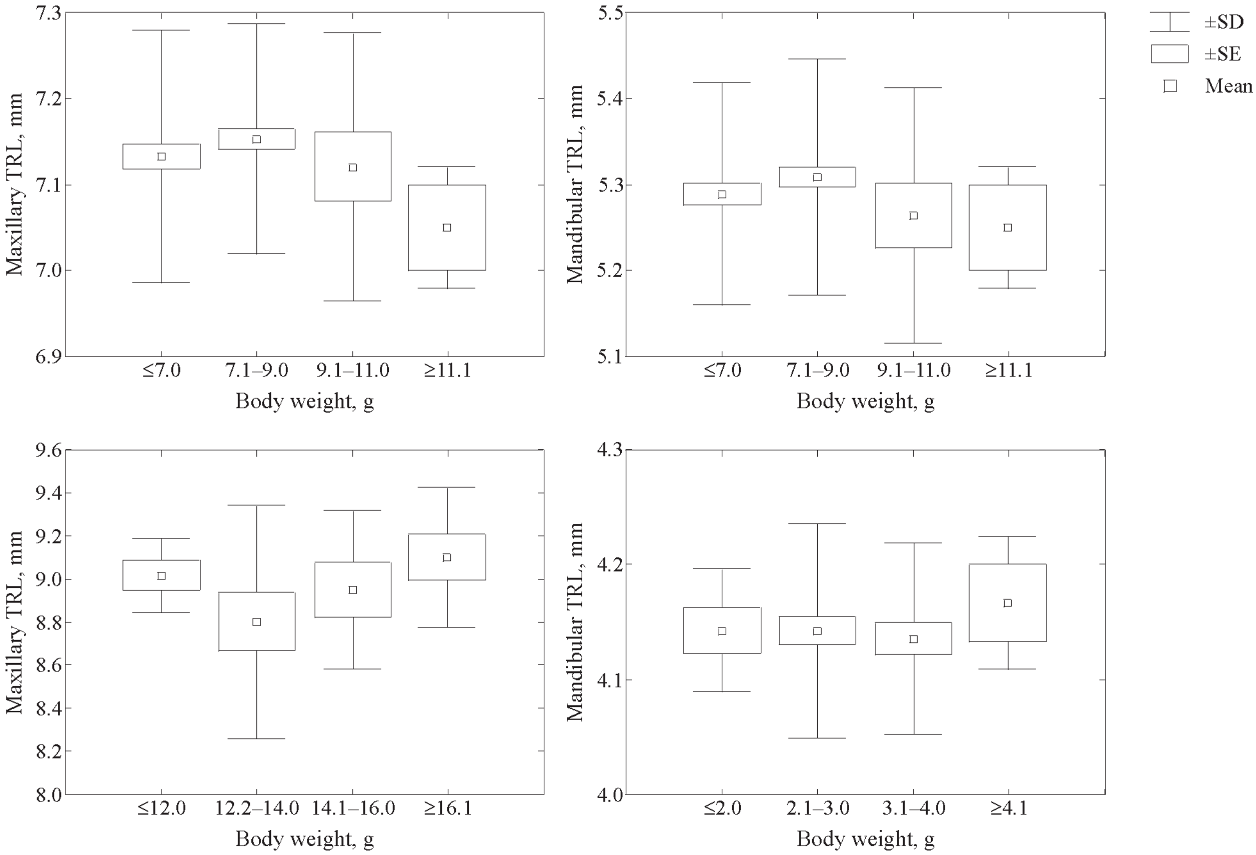

Figure 3. Distribution of maxillary and mandibular TRLs in shrews depending on body weight groups.

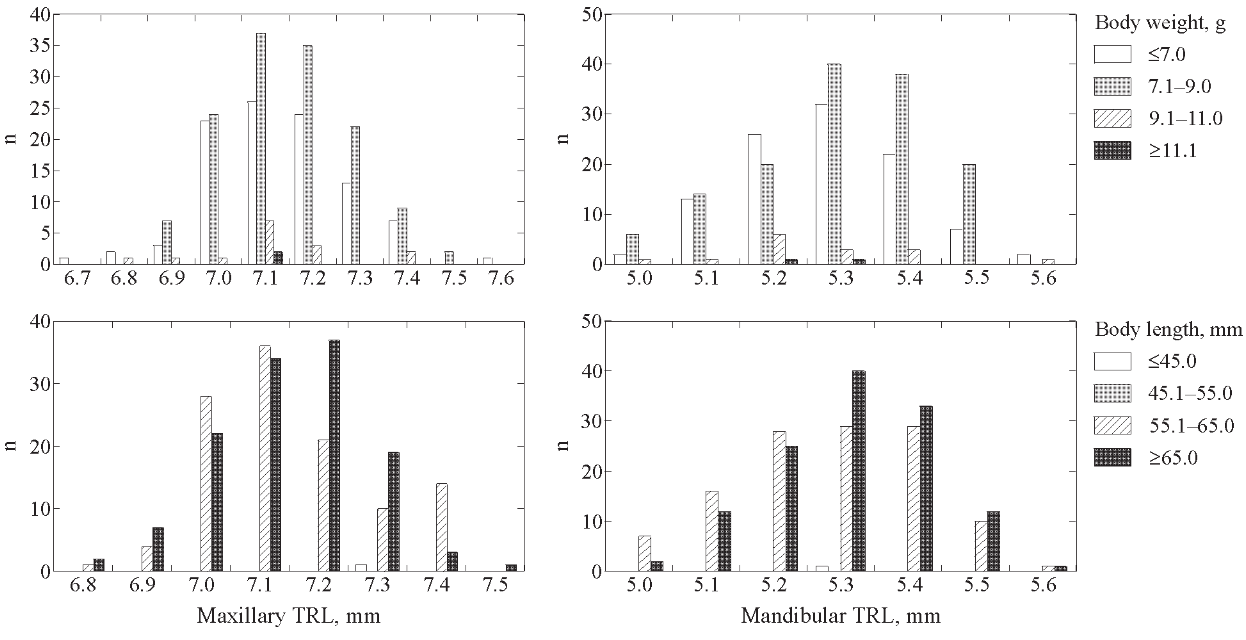

Figure 4. Distribution of maxillary and mandibular TRLs in *S. araneus* depending on body weight and length groups.

marked. Some cranial characters, including the maxillary TRL, condylobasal length of the skull and rostral length are longer in young males. The maxillary TRL is longer in young animals comparing to adults (Cherniavsky *et al.* 1978). According to Dolgov (1985), the maxillary TRL is significantly longer in young *S. araneus* – 8.58 ± 0.01 (limits are 7.8–9.4) in comparison with adults – 8.34 ± 0.01 (7.6–9.3) mm. Unfortunately, we cannot compare

Dolgov's data on TRL with ours, as his TRL measurements were performed in a different way – the first incisor tooth included. In his shrew-devoted monograph, the author claims that the body size in *S. araneus* depends on the habitat and varies in different years and seasons (cit. in Dolgov 1985). Sex-related dimorphism of craniological traits is not evident. The condylobasal length of the skull in some years is longer in the young, while in other years – in adult animals. Favourable years (seasons) result in bigger animals. The maxillary TRL is shorter in adult shrews. This depends upon tooth wearing, a mechanism explained in the example with *Neomys fodiens* (Dolgov 1971). High geographical variability in TRL was also indicated (Dolgov 1985; Niethammer & Krapp 1990).

In Austria, according to Spitzenberger's (2001) data from three localities, the TRL in *S. araneus* males from one locality was significantly longer: the maxillary TRL 7.19–7.20 vs. 7.78 ($p < 0.001$); the mandibular TRL 5.30 vs. 5.70 mm ($p < 0.001$). Data from the two other localities are in agreement with our sample (maxillary TRL of males in our sample was 7.13 ± 0.01, mandibular TRL – 5.29 ± 0.01 mm). According to Spitzenberger (2001), the maxillary TRL ranged between 6.70–7.60, and the mandibular TRL – 5.00–5.50 mm, which is also in full agreement with our data (6.70–7.60 and 5.00–5.60 mm, respectively). According to the same source, no significant differences were found in TRL between males and females and between different age groups of *S. minutus* (Spitzenberger 2001). Our sample suggests the same pattern.

In *N. fodiens*, sex-related dimorphism was characteristic neither of animals from Austria (Spitzenberger 2001), nor of our sample. Data from Austria confirm a significantly shorter maxillary TRL in adult females ($p < 0.01$) compared to subadults/juveniles and in adult males compared to juveniles ($p < 0.01$). As for the mandibular TRL, these differences were not significant (Spitzenberger 2001). In our sample, juvenile *N. fodiens* were not presented. The maxillary TRL was shorter in adult animals compared to subadults, but the sample size was not big enough to ensure significance. In our sample, the mandibular TRL had a tendency to be greater in adults, while in Austria, a shorter mandibular TRL of adult animals was reported (though, in both cases sample sizes were limited).

For Lithuania, it was reported that the maxillary TRL in *S. araneus* is 8.3 (7.3–8.8), in *S. minutus* – 6.5 (6.2–6.9) and in *N. fodiens* – 10.8 (10.3–11.3) mm, including the first incisor (Prūsaitė *et al*. 1988).

According to the key for identification of German mammal skulls from owl pellets (Turni 1999), maxillary TRLs in *S. minutus* are less than 6.0 mm, whereas mandibular TRLs are less than 5.0 mm. These measurements agree with our data.

We compared our results with the data on the same shrew species reported from Switzerland (*Sorex araneus*, n = 24), Germany and France (*S. minutus*, n = 20) and Austria (*Neomys fodiens*, n = 14) by Niethammer and Krapp (1990). The TRL was measured including the first tooth, therefore it cannot be compared with our data. In *S. araneus*, the maxillary TRL equalled 8.72 ± 0.08 (8.1 ÷ 10.1) mm and was significantly longer in young animals (8.87 vs. 8.45 mm, $p < 0.01$). In *S. minutus*, the maxillary TRL was 6.60 ± 0.08 (6.1 ÷ 7.3) and the mandibular TRL – 5.70 ± 0.07 (5.7 ÷ 6.9) mm. TRLs in adult and young animals did not differ. In *N. fodiens*, the maxillary TRL was 10.22 ± 0.07 (9.7 ÷ 10.6) mm; as there was only one adult animal in the sample, age comparison is not available. For all three shrew species there were no sex-related differences in TRL. Correlation coefficients between body measurements and the TRL were higher than in our sample, but in most cases the relation was not significant (Table 5). Thus, our data are in accordance with the reported by Niethammer and Krapp (1990).

Consequently, neither our sample, nor Niethammer and Krapp's (1990) data support Canova's *et al.* (1999) estimates of strong relation between shrew fresh body mass and cranial measurements. Double regression estimates in his sample were based on a small number of shrew individuals (n = 12–22). Even with determination coefficients

Table 5. Correlation coefficients between body weight, length and maxillary and mandibular TRLs in shrews, calculated from data by Niethammer and Krapp (1990).

Species		Maxillary TRL	Mandibular TRL
Sorex araneus	weight	-0.34	
	length	-0.45*	
Sorex minutus	weight	0.44	0.32
	length	0.01	0.03
Neomys fodiens	weight	-0.50	
	length	-0.36	

*Note: * – $p < 0.05$*

being equal ca. 70%, Canova *et al.* (1999) warn that 'the mass values obtained from our equations are the estimate of the probable body mass that can fluctuate widely…'. Therefore, TRL values in shrews are useful only for species identification.

Conclusions

1. Sex-related differences in body weight, length and TRL were not found for the three investigated shrew species.
2. Age-related differences in TRL were also not observed in our sample.
3. No correlation was found between the TRL (maxillary or mandibular) and body measurements (weight and length) in shrews.
4. The TRL of shrews is unsuitable for prediction of their body length or weight.

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Smulkiųjų žinduolių dantų eilės ilgio amžiniai ir lytiniai skirtumai: Kirstukai

L. Balčiauskas

Santrauka

Straipsnyje analizuojama 3 Lietuvoje aptinkamų kirstukų rūšių (*Sorex araneus*, *S. minutus* ir *Neomys fodiens*) dantų eilės ilgio (DEI) priklausomybė nuo individo lyties ir amžiaus, o taip pat kūno masės, kūno ilgio ir dantų eilės ilgio koreliacija. Su lytimi ar amžiumi susijusių DEI skirtumų nerasta. Su kirstukų kūno svoriu ar ilgiu DEI taip pat nekoreliavo, o DEI reikšmių persidengimas kirstukų svorio grupėse buvo labai didelis. Taigi, nors DEI yra tinkamas požymis rūšies apibūdinimui, kūno masės ar ilgio prognozė pagal šį požymį tirtoms Lietuvoje gyvenančių kirstukų rūšims negalima.

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