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The use of sheepdogs in sheep production in southeastern Brazil

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Abstract

This study assessed the economic value of using sheepdogs as livestock guardians in southeastern Brazil by implementing a semi-structured interview format divided into four main categories: maintenance costs of sheep production, selling prices of carcasses, annual rate of depredation, and sheepdog acquisition and maintenance costs. According to our results, producers perceive the "unproductive" costs of sheepdogs similarly to the way they view taxes. However, management using sheepdogs as herd guardians tends to be most profitable for herds above 483 head from the fourth year on, being possibly more stable and predictable over time. In contrast, management without sheepdogs shows stochastic dynamics with occasional, though unpredictable, episodes of sheep depredation. This means that sheep farmers follow a cyclical decision strategy, which basically depends on the purchase price of the sheepdog.

Keywords: Ecological management, Livestock depredation, Neotropics, Puma, Sheep industry

Introduction

Livestock predation by mammalian carnivores is one of the most common sources of conflicts between humans and wild animals worldwide (Mech 1981, Cozza et al. 1996, Kaczensky 1996, Pedersen et al. 1999, Mazzolli et al. 2002, Marchini, 2014). Most conflicts come from competition for limited resources. They may become particularly controversial when the resources concerned have economic value and the predators involved are legally protected (Thirgood et al. 2000). In Brazil, pumas (*Puma concolor*) have the greatest economic impact in rural landscapes (Mazzolli et al. 2002, Verdade and Campos 2004, Azevedo and Murray 2007, Palmeira et al. 2008).

Historically, conflicts with predators have resulted in predators' population decline (Weber and Rabinowitz 1996, Estes 1996, Berger et al. 2001, Krebs 2001). One of the main reasons is that most conflicts between humans and predators can be perceived in simple terms, arising from the direct effects of one predator on one prey. This can lead to the idea that a single predator directly reduces the density of prey available to humans, and therefore, the solution can be to remove the predators from the system (Yodzis 2001). Such culling sometimes occurs indiscriminately and affects the food web (Terborgh 1988, Hoogesteijn and Mondolfi 1992).

Depredation is influenced not only by carnivore and herd management practices, but also by habitat characteristics and the local distribution and abundance of natural prey (Polisar et al. 2003, Kolowski and Holekamp 2006). Wildlife damage could be prevented by improving livestock management, implementing alternative strategies such as greater vigilance during grazing, fencing, using sheepdogs, or returning herds to enclosures in daylight (Shivik 2006, Gehring et al. 2010a, b, Gehring et al. 2011). However, as conservation issues increasingly occupy socio-political agendas, and attitudes toward non-lethal approaches to wildlife management evolve, it is clear that a change from decisions based primarily on competition with economic interests to decisions based on the dynamic interaction between the ecosystem and socio-political system is necessary.

In such context, this study assessed the economic value of the use of sheepdogs as livestock guardians in southeastern Brazil. Sheepdogs have been historically used as a decisive strategy for livestock production, significantly reducing depredation (Coppinger and Coppinger 1980, 2007, Coppinger et al. 1987, Coppinger et al. 1988)

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and production cost (Rigg 2001, van Bommel and Johnson 2012).

Material and methods

We carried out a correlational study to determine the qualitative and quantitative effects of using sheepdogs as livestock guardians. We conducted semi-structured interviews with 29 randomly selected Brazilian farmers out of the 41 farmers attending the International Congress of Goat and Sheep Farmers (FEINCO VII), from 9 to 13 March 2010 in São Paulo, Brazil. Interview questions were divided into four main categories, each focusing on a different economic aspect of livestock management: maintenance costs of sheep production, selling price of carcasses, annual rate of depredation, and sheepdog acquisition and maintenance costs. Not all respondents provided answers to each question, and it was not possible to assess the accuracy of information provided by respondents, especially in regard to prices and costs. The participants, however, represent the views of producers themselves. All analyses were performed using the open-source statistical software R (R Core Team 2013).

Maintenance costs of sheep production were furnished by the "Associação de Caprino-Ovinocultores da Região de Piracicaba" (ACOPI), considering six months as the commercial cycle of sheep production in the central-southern state of São Paulo, Brazil. The price of carcasses was obtained by consulting the latest sales, as prices tend to fluctuate rapidly over time (Firetti et al. 2013). Two breeders of Maremma sheepdogs attending the Congress were consulted in regard to sheepdog purchase prices. Annual maintenance costs were estimated using information provided by breeders and users of this same breed. Provided that herds were classified into lots, each reaching the stipulated maximum of 300 head, and based on ACOPI (Grisotto 2010,[1] personal communication), we assumed the use of a pair of sheepdogs per lot was sufficient, even though this number may vary depending on other factors such as the rate of depredation (Andelt 2004). To determine the importance producers assigned to depredation, in economic terms, we conducted a principal component analysis using data obtained from Question 7, which asked the respondent to classify a list of items at levels 1 to 5, with 1 being the most important, and generated a biplot.

Depredation rates vary because it depends on several factors acting in concert, such as amount of wild versus domestic prey available (Azevedo and Murray 2007), breed and species of livestock, time of the year, species of predators in the area, location and size of the property, type of management used by the producer, presence of forest fragments nearby (Palmeira et al. 2008), and presence and abundance of predators in these areas (Polisar et al. 2003, Breck and Meier 2004).

We proposed two management models: with and without sheepdogs (respectively, Management Models I and II). Comparing both, using sheepdogs has the advantage of not losing sheep to depredation due to pumas and feral dogs, or to theft. However, there are expenses to acquiring and maintaining sheepdogs. The Management Model II does not incur these expenses, but there is a risk of depredation by wildlife and domestic dogs, and theft.

Linear correlations were established with respect to the magnitude of annual production (ranging from 15 to 2200 head) and also with respect to time, to check for patterns of stability in the economic dynamics of the producer when using different types of management. We assumed that maintenance cost were 75 % of all production costs, since the maintenance cost of a sheep was estimated as USD$ 101.18 and its selling price as USD$ 134.91 (assuming slaughter at 40 kg, with a carcass utilization of 50 % of weight). When fitting two regression lines (1 and 2) with different slopes, we may test for differences on estimated values $\hat{Y}_1$ and $\hat{Y}_2$, on regression lines 1 and 2, respectively, as proposed by Zar (2010, p. 353 to 369) to compare estimated sheep herder annual revenues, which defines the test statistic

$$t_c = \frac{\hat{Y}_1 - \hat{Y}_2}{s_{Y_1-Y_2}} \sim t_{n_1+n_2-4},$$

where

$$s_{Y_1-Y_2} = \sqrt{s^2_{Y.X}\left[\frac{1}{n_1} + \frac{1}{n_2} + \frac{(X-\overline{X}_1)^2}{\left(\sum x^2\right)_1} + \frac{(X-\overline{X}_2)^2}{\left(\sum x^2\right)_2}\right]},$$

with

$$s^2_{Y.X} = \frac{(\text{residual sum of squares})_1 + (\text{residual sum of squares})_2}{(\text{residual degrees of freedom})_1 + (\text{residual degrees of freedom})_2}.$$

Results

Interviews

We conducted interviews with 29 producers (Table 1). Sheepdog acquisition price *per capita*, obtained from Maremma sheepdog breeders, was USD$ 1124.23. Maintenance costs for a six-month commercial cycle for sheep production *per capita* in southeastern Brazil, obtained from ACOPI, was USD$ 101.18.

Using information from the interviews, we assumed an average of 30 head lost (ranging from 18 to 84) to depredation per year, or 2.5 head lost per month. This value was calculated taking into account the wide variability in the records of these losses, which may vary from months with no depredation to months with losses of up to 30 head on a single night. Given this variability and the

Table 1 Mean, standard deviation, range, and sample size for number of rams and breeding ewes, annual production of lambs, ram price, carcass kilogramme price, number of sheepdogs in the farm, and annual cost of a sheepdog obtained from Questions 2, 6, 12, and 13 asked to Brazilian sheep herders during the International Congress of Goat and Sheep Farmers (FEINCO VII), held in São Paulo, Brazil, from 9 to 13 March, 2010

Category	Mean	Standard deviation	Minimum	Maximum	Sample size
Number of rams and breeding ewes	503.4	597.4	15	2000	28
Annual production of lambs (head)	432.6	554.7	15	2200	27
Ram price (USD$)	1872.67	1896.12	112.42	8431.70	27
Meat/carcass purchase price (USD$/kg)	5.17	1.25	3.93	8.43	23
Number of sheepdogs	3.1	1.4	2	5	14
Annual cost of each sheepdog (USD$)	536.35	332.43	281.06	1236.65	12

The answers were given in Brazilian Real, and the date of currency conversion to US Dollars was 9-3-2010 (BRL 1.00 = USD$ 1.78)

discrete nature of the random variable, a reasonable assumption is that the number of head lost annually as a consequence of depredation follows a Poisson distribution with a mean and variance of 30 per lot, as they are independent from each other.

A further point in assessing the economic consequences of livestock depredation was addressed in Question 7. From 1 (most important) to 5 (least important), according to the sheep herders, the investment required for "Food" was first (1.46), followed by "Labour" (2.07), "Veterinary/Medicine" (2.85), and "Depredation/Other", which averaged just below "Taxes", at 4.21 and 4.33, respectively. The biplot of the principal component analysis (PCA) confirmed the order of importance obtained from these means, and indicated a strong correlation between "Taxes" and "Depredation/Other" (Figure 1). PC1 explained 57.8 % of the total variance and PC2 explained 28.2 %. It was also clear that PC1 divided, in the view of the interviewees, "productive" (i.e. food, labour, and veterinary/medicine) costs from "unproductive" (i.e. damage and taxes) costs. PCA loadings are shown in Table 2.

Twenty-two out of 29 farmers reported damage caused by pumas (eight), feral dogs (four), theft (one), and undetermined causes (nine). Fourteen out of 29 farmers

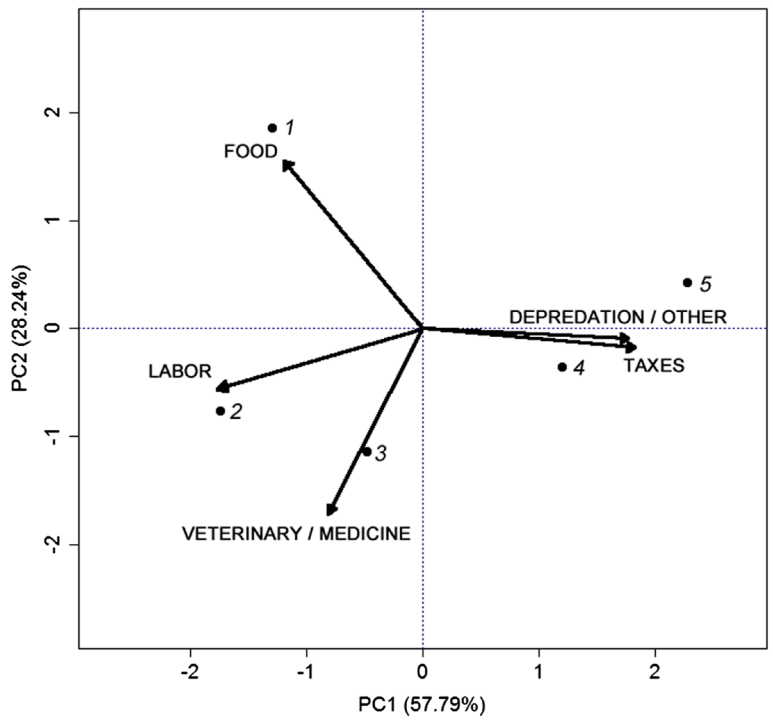

Fig. 1 Biplot of principal component analysis with correlations between items and categorizations made by interviewees from Question 7 asked to Brazilian farmers during the International Congress of Goat and Sheep Farmers (FEINCO VII), held in São Paulo, Brazil, from 9 to 13 March, 2010. This question asked the respondent to classify a list of items (food, labour, veterinary/medicine, taxes, and depredation/other) at levels 1 to 5, with 1 being the most expensive item

Table 2 Principal component loadings for the principal component analysis performed for the data obtained from Question 7 asked to Brazilian sheep herders during the International Congress of Goat and Sheep Farmers (FEINCO VII), held in São Paulo, Brazil, from 9 to 13 March, 2010

Item	PC1	PC2	PC3	PC4	PC5
Food	−0.3480	0.6523	−0.2228	0.3217	0.5481
Veterinary/medicine	−0.2354	−0.7180	−0.3291	0.4903	0.2835
Taxes	0.5374	−0.0737	−0.4813	−0.4661	0.5068
Labour	−0.5136	−0.2284	0.4473	−0.5368	0.4426
Depredation/other	0.5205	−0.0379	0.6406	0.3883	0.4081

This question asked the respondent to classify a list of items (food, labour, veterinary/medicine, taxes, and depredation/other) at levels 1 to 5, with 1 being the most expensive item

had sheepdogs (eight Maremma, three Kuvasz, and three other breeds) with no depredation after sheepdogs' acquisition. A similar pattern has been described by Ciucci and Boitani (1998) in Italy. Among respondents who did not have sheepdogs, the main reasons for not doing so were "difficulty of training" and "high cost". In addition, one respondent reported that he had lost about 200 head in about two years (to pumas and feral dogs), and had solved the problem by installing an electric fence.

Sheep management models

Although both management models generate revenues in excess of maintenance costs of production, the costs of acquiring, maintaining, and training sheepdogs eventually generate an income approximately equivalent to losses by depredation in management systems without sheepdogs (Figure 2). The t test showed that for a herd size of 483 lambs or more, revenues estimated by the linear regression curves differed significantly ($t_{30} = 2.07$, $p = 0.05$). Thus, management using sheepdogs as herd guardians is the most profitable for herds of 483 head or more.

On the other hand, net profits from management with the use of sheepdogs (Figure 3) gradually come to exceed profits gained from management without sheepdogs. Testing differences between net revenues estimated by linear regressions showed that from the fourth year on, earnings obtained by managing the herd with the use of sheepdogs become significantly larger than earnings obtained by using the other management system ($t_{74} = 2.70$, $p = 0.01$).

Concerning projected annual revenues for the two types of management, management with the use of sheepdogs is possibly more stable and predictable (Figure 4) and can be considered deterministic over time. In contrast, management without sheepdogs shows stochastic dynamics. This means that sheep farmers follow a cyclical decision strategy, which basically depends on the purchase price of the sheepdog. If the price is too high, then buying and maintaining them is not worth the potential costs from the loss of livestock. However, when this price drops, buying a sheepdog does compensate for potential losses.

Since the amount of losses due to depredation is not fixed and follows a Poisson distribution, and is

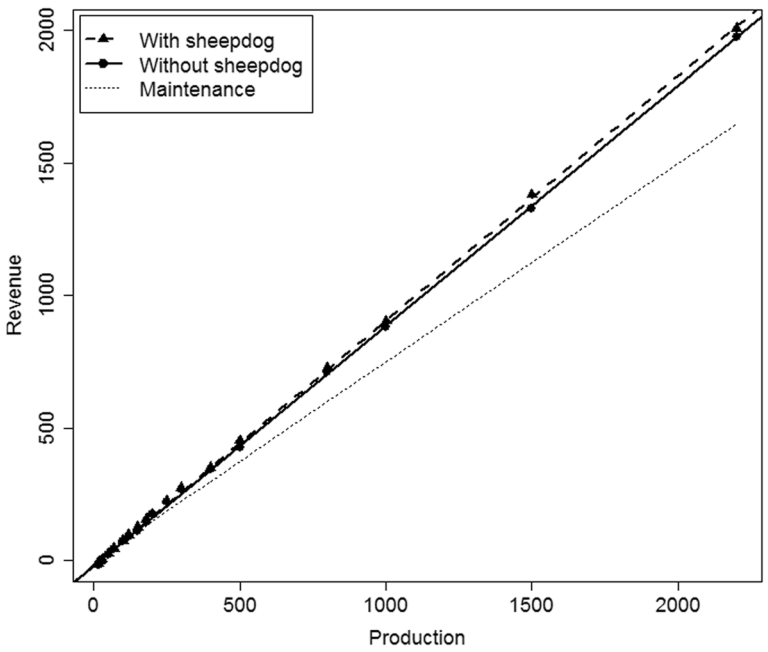

Fig. 2 Annual revenue and regression lines for the two management strategies (with and without sheepdogs) in relation to densities of production for the year of acquisition of sheepdogs. Values are given in terms of lamb production

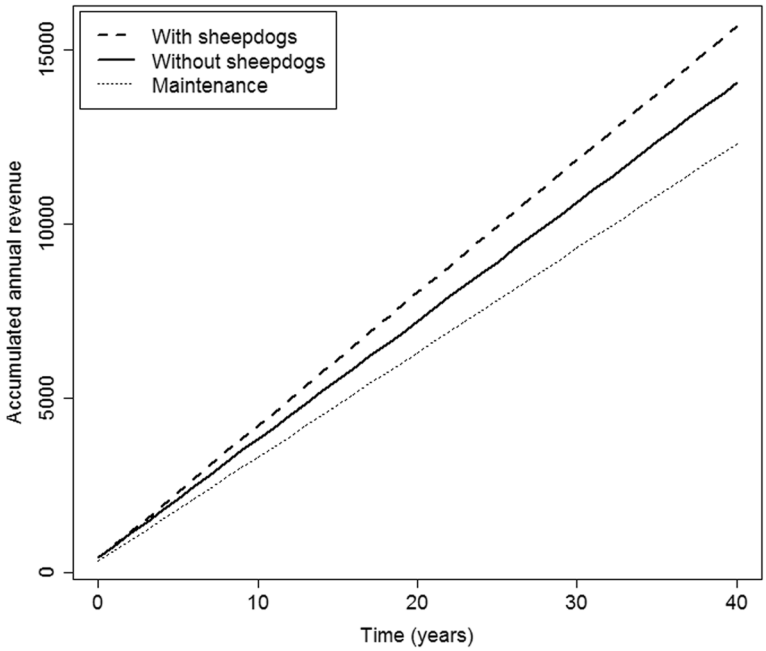

Fig. 3 Projections of cumulative annual revenues for a production of 400 head per year for 40 years after the acquisition of sheepdogs, for the two management strategies (with and without sheepdogs). Values are given in terms of lamb production

characterized as the distribution of rare events, it is possible that the model underestimates losses from management without sheepdogs. This would outweigh revenues obtained by the other strategy. It might also overestimate losses, leading to revenue levels below the break-even point. We derived the probability, obtained by the Poisson distribution, that the revenue from management without sheepdogs which will exceed the revenue from management with sheepdogs is 2.04×10^{-6}. The probability of being in the same range

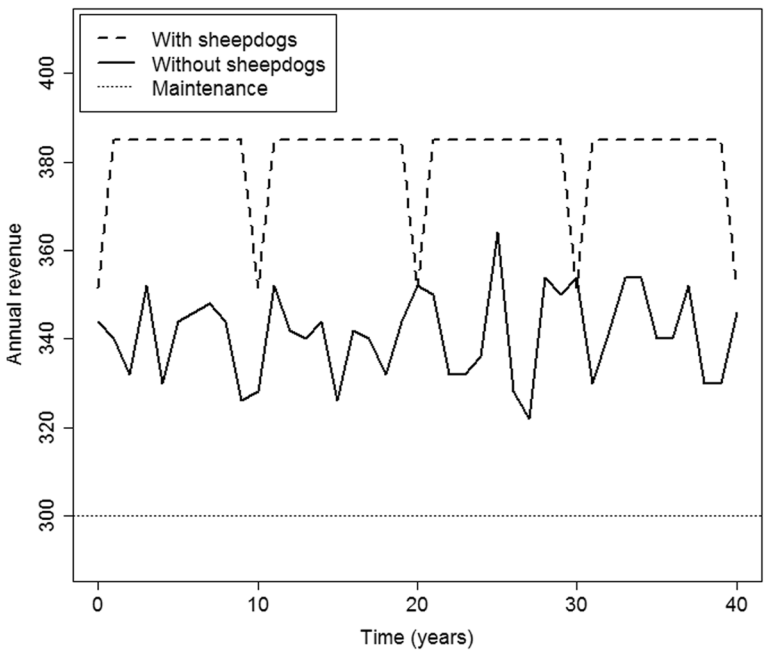

Fig. 4 Projections of annual revenues for an annual production of 400 head for 40 years after the acquisition of sheepdogs, for the two management strategies. The values are given in terms of lamb production

as the revenue from management with sheepdogs is 0.208, and the chance of being lower (revenue below maintenance) is 5.19×10^{-4}.

Discussion

Due to the lack of a specific public policy about wildlife damage over livestock production in Brazil, depredation often leads to retaliatory responses by producers, including persecution of carnivores, opposition to the presence of wildlife sanctuaries close to farms, or resistance to the reintroduction of extirpated predators to protected areas (Verdade 2004, Verdade and Campos 2004, Marchini et al. 2010, Marchini, 2014). Most of these retaliatory responses contravene public and political aims of large carnivore management (Graham et al. 2004).

According to our interview results, predation on the herd is less expensive than maintenance costs of the production system itself, although predators might occasionally cause serious damage (Mazzolli et al. 2002). In addition, "Depredation/Other" and "Taxes" were negatively correlated with the other factors (Figure 1) (i.e. there was a clear division between production-related costs such as food, labour, and veterinary/medicine and costs not related to production such as damage and taxes). The similarity of the factors "Depredation/Other" and "Taxes" (Figure 1) shows that, in the opinion of the interviewees, these "unproductive" costs are considered as equivalent deductions from the producer's income.

This study suggests that the revenue from the two types of management is similar (Figure 2), with a proportional increase in the amount of income earned by managing with sheepdogs over managing without them. Therefore, the use of sheepdogs to care for the herd is a cost-effective strategy as suggested by previous studies (Green and Woodruff 1980, Green et al. 1984, Andelt and Hopper 2000, Gehring et al. 2010b, Vercauteren et al. 2008, van Bommel and Johnson 2012, Rust et al. 2013). In Australia, the cost of acquiring a sheepdog is returned in up to three years (van Bommel and Johnson 2012).

Although depredation due to pumas means an instant loss for the producer (Hoogesteijn 2001), losses were not large enough to decrease overall revenues to a level below maintenance costs. Thus, both strategies can be profitable, but only one is satisfactory from the standpoint of conservation. Stability found in simulations for the scenario with the use of sheepdogs was expected, given that additional investments will be needed only for sheepdog replacement, training, and maintenance (Andelt 2004). This context was shown as sharp declines (Figure 4), but following a general pattern. This generated predictable income for the producer who includes sheepdogs in their management system.

We observed the opposite outcome for annual revenues regarding the strategy which does not use sheepdogs where peaks and valleys do not form a consistent pattern and consequently cannot be predicted as disturbances in the system (e.g. loss of a sheepdog) may occur (Marker et al. 2003, Andelt 2004). Thus, the prediction of income in these cases is merely probabilistic, and the chance that the two management schemes will provide the same income is 20.8 %. Deterministic processes are characterized by being predictable, so identifying and determining patterns may be, at times, easier to accomplish. On the contrary, stochastic mechanisms are governed by probabilistic processes and are, therefore, difficult to predict (Roughgarden 1998).

Two management alternatives in the present study may generate net revenues to the producer, and differ primarily in the predictability and temporal stability of income. Producers perceive the "unproductive" costs of sheepdogs similarly to their view of how taxes diminish their revenue. In being so, producers are risk takers when choosing one strategy over the other, such that the lower risk is placed on the strategy that generates a higher payoff, as they perceive it. Therefore, they tend to choose between a deterministic strategy (i.e. with the use of sheepdogs) and a stochastic strategy (i.e. without sheepdogs) which may or may not result in herd losses. A comparable behaviour has been described for tax evasion (Laffer 2004).

With respect to long-term estimates, revenue generated by the management strategy with the use of sheepdogs increases over time, in contrast to the other alternatives. Therefore, the cumulative net revenues over time increases more in the system in which sheepdogs are used (Figure 3) confirming that the benefits of using sheepdogs exceed the costs (after 40 years, the revenues are 11.57 % higher than for the management without sheepdogs and 27.37 % higher than maintenance costs). However, other measures (e.g. subsidies to partially fund purchase, breeding, and sheepdog sale promotions between producers, as well as non-governmental organizations actions) could be implemented to encourage farmers to use sheepdogs (e.g. Marker et al. 2003).

The use of sheepdogs by farmers should be stimulated by public policy as a least impacting livestock production management practice for wild predators as well as for benefitting the sheep production system. However, further studies regarding the longevity of sheepdogs and rates of sheep depredation by pumas and other carnivore species should be encouraged.

Endnotes

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Authors' contributions
All authors participated in all steps of this article, from planning to data collection and analyses, and writing. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

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