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Research

Risk for Endoparasites Among Production Stages of Female Goats With Notes on Sustainable Parasite Control For Smallholder Flocks

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ABSTRACT

The risk of parasitism in different groups of small ruminants depends on intrinsic, environmental, and management factors. Although there are different views regarding the sex-related risk of endoparasites in small ruminants, females are undoubtedly the most affected group in the flock. Moreover, whether the greater sex-specific risk of parasitic infection observed in female goats in field situations is associated with their production or other intrinsic factors is still under scrutiny. In this paper, cross-sectional epidemiological data collected from selected small ruminant flocks were analysed to determine the distribution, risk, and burden of endoparasites in young, nonpregnant, pregnant, and lactating female goats. There was a higher incidence of gastrointestinal parasites (88.4%, 95%CI= 83.01-92.19) than blood protozoa (54.0%, 95%CI= 46.85-60.92), with a significant difference among the groups. A higher risk of gastrointestinal parasites was observed in lactating (OR = 46.667, P = 0.001) and pregnant (OR = 9.167, P = 0.003) groups. A greater risk of blood protozoan infection was also observed in the pregnant (OR = 5.971, P = 0.0104) and lactating (OR = 3.600, P = 0.0528) groups. A significant increase in the mean faecal egg count of the lactating (2.72 ± 0.76) and pregnant (2.34 ± 0.97) groups ($P < 0.05$) was accompanied by a significantly lower mean PCV in the lactating group (23.48 ± 4.838) than the kids (29.44 ± 6.13), or nonpregnant (27.80 ± 5.525) groups ($P < 0.05$). Thus, the pregnant and lactating female goats may experience a greater exposure risk and burden of endoparasites. Therefore, female goats may be selectively targeted for implementing nutritional management, controlled grazing, and selective anthelmintic treatment during pregnancy and lactation to save cost and minimise excessive use of anthelmintic.

Key words: Blood protozoa, gastrointestinal parasites, goats, sex-specific risk, sustainable control

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INTRODUCTION

Goat farming is an alternative to crop production for smallholders and marginal farmers living in rural communities (Ghimire & Bhattarai, 2019). In Malaysia, goat production is a smallholder enterprise involving rural farmers with 10-50 animals per head kept on semi-intensive management, which is often integrated with plantations, orchards, or paddy farming (Melissa *et al*., 2016). Goats and other ruminants only contribute a meagre 29% of the domestic demand for meat and milk products, failing to achieve the desired self-sufficiency level (DVS, 2022). Although the net contribution of goats to livestock gross domestic product (GDP) is expected to increase annually, production losses caused by chronic parasitic diseases may slow the desired progress in the industry.

Parasitism in small ruminants can affect production factors such as weight gain, milk yield, reproductive performance, and herd health (Singh *et al*., 2017). Although parasitic diseases, especially parasitic gastroenteritis complex (PGE) and piroplasmosis, are widespread problems in the tropics due to suitable ecological factors for parasite epidemiology (Emiru *et al*., 2013; Zainalabidin *et al*., 2015; Mat Yusof & Md Isa, 2016; Zvinorova *et al*., 2016), the risk of infection can vary depending on host and management factors (Paul *et al*., 2020a). For instance, under the traditional open grazing system, young male goats were more susceptible to gastrointestinal parasitic infections than were their adult and female counterparts (Zvinorova *et al*., 2016). In contrast, other investigators observed and reported higher rates of parasitic infection among females than among male sheep and goats (Emiru *et al*., 2013; Islam *et al*., 2017). Moreover, parasitic nematodes, especially *Haemonchus contortus*, significantly affect the packed cell volume (PCV) due to anaemia caused by hematophagy, haemorrhagic gastroenteritis, and protein-losing enteropathy (Mpofu *et al*., 2022). Additionally, blood protozoa such as *Babesia*, *Theileria*, and haemotropic *Mycoplasma ovis* cause anaemia by destroying red blood cells and affect the PCV in small ruminants (Glaji *et al*., 2014; Paul *et al*., 2021, 2023). Thus, the haematological profile, especially PCV, is used for health evaluation, diagnosis, and monitoring treatment (Fanta *et al*., 2024). The nematode faecal egg count and coccidia faecal oocyst count are also important parameters for determining the severity of gastrointestinal parasites and monitoring the progress of treatment (Paul *et al*., 2020a). Therefore, the PCV, FEC, and FOC can be used as important analytes for gaining insights into the effects of parasitism on herd health and productivity.

Despite the contrasting views regarding the sex-linked risk of infection in small ruminants, females are undoubtedly the most affected group due to vulnerabilities associated with production demands such as pregnancy and lactation (Paul *et al*., 2020a). Moreover, under a smallholder system, female goats are usually maintained for a few years for breeding and production, which can cause cumulative exposure to both gastrointestinal parasites and blood protozoa (Paul *et al*., 2016). In our experience, a remarkably greater risk of infection was observed among female and adult smallholder goat flocks in Malaysia, which is consistent with the findings of other reports (Paul *et al*., 2020a). We have also observed and reported strong associations between single Strongyle and Strongyle-blood protozoan coinfection and the female gender in goats in Malaysia (Paul *et al*., 2023). However, whether the greater sex-linked risk of parasitic infection observed in female goats under field conditions is associated with their production stage, specifically that of kids (3-5 months of age) and adults: nonpregnant, pregnant, or lactating, has not been reported. Understanding the source of the sex-linked risk of endoparasites is crucial for proper goat management and health improvement towards sustainable production (Mohamed *et al*., 2023). Hence, this study was conducted to investigate whether the higher risk of parasitism observed in female goats is linked to production demand, as widely reported in the literature. According to the null hypothesis, we postulated that there was no difference in the distribution, risk, or burden of parasitic infection between female goat kids and adults: nonpregnant, pregnant, or lactating. In this paper, cross-sectional epidemiological data collected from selected small ruminant flocks were analysed to elucidate the sex-specific distribution, risk, and burden of parasitic infection in various production stages of semi-intensively managed female smallholder goats.

MATERIALS AND METHODS

Study area

The study area, Negeri Sembilan, is located on the southwest coast of Peninsular Malaysia (2.8 2.7258°N, 101.9424°E). There are approximately 16,094 individual goats reared by smallholder farmers throughout the 7 Districts of the state (DVS, 2022). Data and samples collected from four accessible flocks in the state were included in this study. The study animals were smallholder goats owned and managed by the local farmers for their subsistence. The smallholder practised a semi-intensive management system that prioritises grazing or cut-and-carry grass feeding and housing without a defined herd health programme for controlling endoparasites.

Study design

The total number of goats included in this study was calculated based on the 88.9% expected incidence (p) of parasitic infection among female goats in Negeri Sembilan (Paul *et al*., 2020a), 5% absolute precision (d), and $Z_{1-\alpha/2}$ (standard normal variate at 5% type 1 error, *P*<0.05) (Charan & Biswas, 2013). Thus, $n = Z_{1-\alpha/2}^{2}.\ p\ (1 - p)/d2 = 152$, but 189 females were sampled to increase the precision of the estimates. Briefly, 5 mL of whole blood was collected from the jugular vein into EDTA-coated vacutainer tubes, and 5 g of faecal material was withdrawn from the rectum using gloves into labelled plastic containers and stored in a cold box maintained at 4°C until processing immediately after sample collection at the Clinical Research Laboratory, Faculty of Veterinary Medicine, Universiti Putra Malaysia.

Laboratory examinations

The saturated sodium chloride (400 g NaCl in 1000 mL of water; specific gravity 1.200) flotation technique was used for the detection of gastrointestinal parasites in faeces, while the simple McMaster technique, with a sensitivity of 50 eggs/oocysts per gram of faeces, was used to determine the faecal egg count (FEC) and faecal oocyst count (FOC) (Urquhart *et al.*, 1996). Thin blood smears fixed in absolute methanol and stained in 10% Giemsa solution (pH 7.2) were examined under an oil immersion (100x) objective of a compound microscope to detect blood protozoa. The smears were considered negative for blood protozoa if no intraerythrocytic, exoerythrocytic or free organism(s) were detected in 10 oil-immersion fields. Blood protozoa were identified morphologically based on colour, size, shape, and position in the erythrocytes or background of the slide (Soulsby, 1982). The packed cell volume (PCV) was determined by microhaematocrit centrifugation, and the height of the haematocrit was read on a microhaematocrit reader and recorded as the value of PCV (%) (Grindem, 2011).

Statistical analysis

The distribution of gastrointestinal parasites and blood protozoa among the different production stages of the female goats was calculated using EpiTools® calculators (Sergeant, 2018). Univariate binary logistic regression analysis was performed in SPSS® to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) for the associations between parasitic infection and the various production stages of female goats. One-way analysis of variance (ANOVA) and Tukey's HSD test in SPSS® were used to determine the mean differences in the PCV, faecal egg count (FEC) and coccidia faecal oocyst count (FOC) (dependent variables) among the different production stages of female goats (independent variables). The odds ratios were transformed into probabilities in the Microsoft Excel® spreadsheet program using the formula P = OR / (1 + OR) and converted into percentage odds by multiplying P × 100 (%). The non-normally distributed FEC and FOC data were log-transformed [log10 (EPG) and log10 (OPG)] before analysis. In all analyses, a P<0.05 was considered to indicate statistical significance.

RESULTS

Distribution of parasitic infection among different production stages of female goats

In this study, the term gastrointestinal parasite was used to describe either single or mixed infections involving coccidia and strongyle nematodes in goats, while blood protozoa represent either single or mixed infections involving various species of haemoparasites, mainly hemotropic *Mycoplasma ovis*, and a few cases of *Anaplasma* and *Babesia*. The overall incidence of gastrointestinal parasites (88.4%, CI = 83.01-92.19) was greater than that of blood protozoa (54.0%, CI = 46.85-60.92). The distribution of gastrointestinal parasites according to production stage was significantly greater (χ2=46.224, P<0.001) in the lactating group (96.6%, CI = 82.82-99.39), followed by the nonpregnant group (94.1%, 88.26-79.10), pregnant group (84.6%, 66.47-93.85), and young group (37.5%, 18.48-61.36). However, the distribution of blood protozoa was greater (χ2=8.374, P=0.039) in the pregnant group (73.1%, 53.92-86.30), lactating group (62.1%, 44.00-77.31), nonpregnant group (50.8%, 41.94-59.70), and kids (31.3%, 14.16-55.60) (Table 1).

Table 1. Distribution of parasitic infection among female goats at different production stages

Production stage	Examined	Gastrointestinal parasite		Blood protozoa	
		Positive (%)	95% CI	Positive (%)	95% CI
Overall	189	167 (88.4)	83.01 - 92.19	102 (54.0)	46.85 - 60.92
Kids	16	6 (37.5)	18.48 - 61.36	5 (31.3)	14.16 -55.60
Nonpregnant	118	111 (94.1)	88.26 - 79.10	60 (50.8)	41.94 - 59.70
Pregnant	26	22 (84.6)	66.47 - 93.85	19 (73.1)	53.92 - 86.30
Lactating	29	28 (96.6)	82.82 - 99.39	18 (62.1)	44.00 - 77.31
		χ2=46.224	P<0.001	χ2=8.374	P=0.039

Univariate association between parasitic infection and the production stage of female goats

Compared to that of the kids, the risk of infection with gastrointestinal parasites was significantly greater (97.9%) (OR=46.667, 95% CI = 4.984, 436.932, P=0.001), 96.4% (OR=26.429, 95% CI =

7.437, 93.918, $P<0.001$), and 90.2% (OR=9.167, 95% CI = 2.109, 39.847, $P=0.003$) in the lactating, nonpregnant, and pregnant does, respectively. Similarly, the risk of infection with blood protozoa was 85.7% (OR=5.971, 95% CI = 1.522, 23.427, $P=0.0104$) and 78.3% (OR=3.600, 95% CI = 0.985, 13.159, $P=0.0528$) greater in the pregnant and lactating does, respectively, than in the kids (Table 2).

Table 2. Univariable association between parasitic infection and production stage

Production stages	B	S.E.	Wald	Sig.	OR	95% CI (L - U)
Gastrointestinal parasites						
Kids					Ref.	
Nonpregnant	3.274	0.647	25.618	0.0000*	26.429	7.437, 93.918
Pregnant	2.216	0.75	8.733	0.0030*	9.167	2.109, 39.847
Lactating	3.843	1.141	11.34	0.0010*	46.667	4.984, 436.932
Constant	1.822	0.331	30.371	0	6.187	-
Blood protozoa						
Kids					Ref.	
Nonpregnant	0.822	0.57	2.082	0.149	2.276	0.745, 6.955
Pregnant	1.787	0.697	6.565	0.0104*	5.971	1.522, 23.427
Lactating	1.281	0.661	3.751	0.0528*	3.6	0.985, 13.159
Constant	0.184	0.204	0.813	0.3671	1.202	-

B = regression coefficient; S.E. = standard error; Wald = chi-square; Sig. = p values for Wald's chi square test; * denotes statistical significance; OR = odds ratio; CI = confidence intervals.

Effect of parasitic burden on the production stages of female goats

One-way between-subjects ANOVA was conducted to compare the effects of parasitic infection on the packed cell volume, coccidia FOC, and nematode FEC of female goats at different production stages. The parasitic infection had a significant effect on the mean FOC of female goats at different production stages [F (3, 185) = 7.200, $P<0.001$], FEC [F (3, 185) = 10.677, $P<0.001$], and PCV [F (3, 185) = 7.077, $P<0.001$] at the $P<0.05$ level. Post hoc comparisons using the Tukey HSD test showed that the mean A significantly lower FOC was recorded in kids (0.60 ± 1.31) than in lactating (2.13 ± 1.13), nonpregnant (2.08 ± 1.25), and pregnant goats (1.97 ± 1.09). The mean FEC was significantly higher in the lactating group (2.72 ± 0.76) than in the pregnant group (2.34 ± 0.97), mating stock (2.12 ± 1.11) and young (0.87 ± 1.35) (Figure 1). On the other hand, the mean PCV was significantly lower in lactating females (23.48 ± 4.838) than in kids (29.44 ± 6.13) and nonpregnant (27.80 ± 5.525) or pregnant females (29.54 ± 5.805). The FEC of pregnant females was also significantly different ($P<0.05$) from the kids, nonpregnant and lactating (Figure 2).

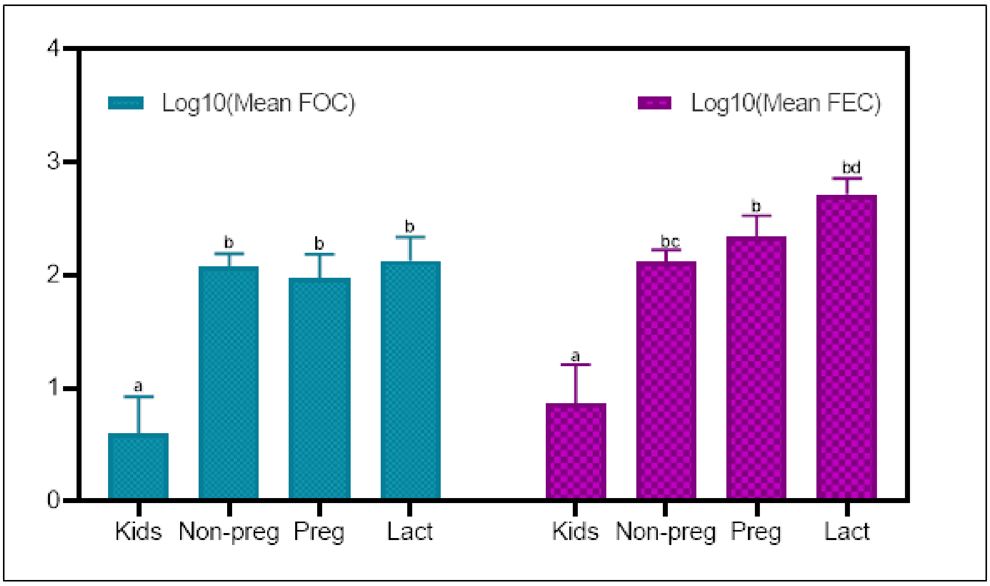

Fig. 1. Burden of gastrointestinal parasites based on FOC/FEC at different production stages in female goats. Bars with different superscripts (a b/c, d) are significantly different at $p<0.05$.

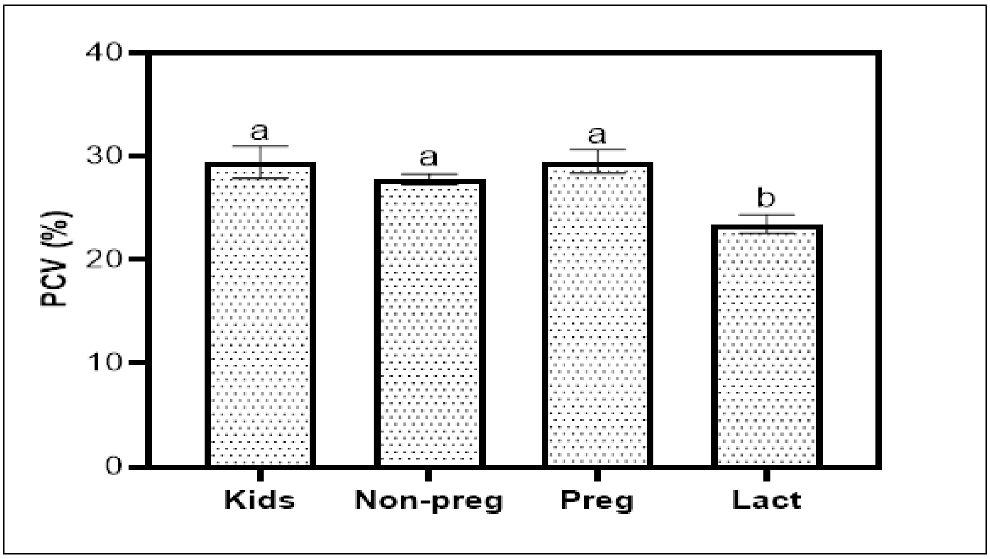

Fig. 2. Packed cell volume at different production stages in female goats with parasitic infection. Bars with different superscripts (a, b) are significantly different at $p<0.05$.

DISCUSSION

The prevalence rate of gastrointestinal parasites observed among the different groups of female goats in this study is consistent with previous reports from Malaysia (Zainalabidin *et al*., 2015; Hashim & Yusof, 2016; Tan *et al*., 2017; Paul *et al*., 2020a, 2023). Although there were several studies on the epidemiology of gastrointestinal parasites and blood protozoa among small ruminants in Malaysia (Sani *et al*., 2004; Nor-Azlina *et al*., 2011; Zainalabidin *et al*., 2015; Hashim & Yusof, 2016; Nur Hazirah *et al*., 2016; Nur *et al*., 2018; Paul *et al*., 2020a, 2023), these studies are limited in their scope, area of coverage, sample size, and risk factors. In terms of the distribution, a significantly greater prevalence of gastrointestinal parasites was observed in the adult lactating goats than in the nonpregnant and pregnant female goats. Compared to that of kids, the risk of blood protozoan infection was increased by 6.0 and 3.6 times, while the risk of gastrointestinal parasites was increased by 9.2 and 46.7 times in pregnant and lactating does, respectively. This finding suggests a higher risk of gastrointestinal parasites than blood protozoa among the smallholder flocks in the study area. Additionally, this study has revealed that pregnant and lactating female goats were the most vulnerable to endoparasites in the herd. Although there are several reports in the literature regarding the risk factors of endoparasites in small ruminants, this study is, to the best of our knowledge, the first attempt to explain the gender-specific susceptibility among different production stages of female small ruminants. Generally, adult female sheep and goats (>6 months) are thought to be more susceptible, with a significantly higher risk of parasitic infection (Emiru *et al*., 2013; Islam *et al*., 2017; Singh *et al*., 2017; Bhowmik *et al*., 2020; Paul *et al*., 2020a, 2023). The influence of sex on the prevalence and vulnerability of female animals to endoparasites has been ascribed to decreased immunity due to reproductive events such as cycling, pregnancy, parturition, lactation, and poor nutrition owing to higher demands associated with production in females (Zvinorova *et al*., 2016; Mbong *et al*., 2023). However, some authors who observed and reported similar frequencies of parasitic infection among male and female goats have attributed their findings to the fact that both sexes are often kept under similar management conditions (Hassan *et al*., 2019; Mpofu *et al*., 2020, 2022). Other researchers who observed and reported a greater frequency of parasitism among male than female animals ascribed their findings to genetic factors and differential susceptibility due to hormonal dynamics (Thrusfield, 2005; Zvinorova *et al*., 2016; Singh *et al*., 2017). The discrepancies in the reports on the prevalence of GIPs in goats of different sexes could be related to genetic variations within and among goat breeds, geographical location and size of sampling sites, and the management system in place (Mpofu *et al*., 2020). Other important factors, including geographical location, season, age, and gender, were reported to have significant influences on the occurrence and severity of gastrointestinal parasites among sheep and goats under an extensive management system (Zvinorova *et al*., 2016).

The observations of a significantly greater mean FOC and FEC with a concurrently greater prevalence of blood protozoa in lactating and pregnant females in the present study suggest that females are exposed to more stress, which lowers immunity and favours the egg output of nematodes during pregnancy and lactation (Emiru *et al*., 2013). Increased levels of the female hormones progesterone and prolactin are also known to cause immunosuppression and decreased natural resistance of females to parasites, increasing their susceptibility to any infection during pregnancy and lactation (Mpofu *et al*., 2020). Regarding the reduction of PCV in lactation, anaemia is frequently encountered in small ruminants during pregnancy or lactation due to increased metabolic demands, negative energy balance, and nutrient deficiencies, especially iron, which is essential for red blood cell production. Therefore, parasitic infections may complicate the course of pregnancy and lactation in endemic areas due to hematophagy, gastrointestinal bleeding, and protein-losing enteropathy (Paul *et al*., 2020a). Additionally, the presence of haemoparasites causes haemolytic anaemia due to the direct destruction of red blood cells by the parasites (Paul *et al*., 2020b). Moreover, GIP coinfection with blood protozoa is known to increase the severity of infection due to synergy in the pathogenesis of anaemia (Paul *et al*., 2023), which further explains the observation of a significantly lower mean PCV among lactating females in this study.

Regardless of the production stage, there was a significantly greater risk of gastrointestinal parasitism among adult females than among kids. Ageing, which is associated with production and secondary demands, appears to play a key role in the vulnerability of older female goats to a greater risk of parasitism. One of the key economic growth activities (KEGAs) for the livestock industry proposed in the Malaysian National Agrofood Policy (NAP) 2.0 (2021-2030) is the adoption of innovative livestock farming approaches to enhance production and reduce the environmental footprint of animal production (MAFI, 2021). Understanding the sex-specific risk of endoparasites among does is a crucial step for implementing sustainable parasite control strategies in smallholder goat flocks. Sustainable strategies now rely on epidemiological information such as prevalence, risk factors, infection burden, geographical location, and management systems to implement farm-tailored parasite control strategies (Leathwick & Besier, 2014; Maurizio *et al*., 2021). Since the result of this study showed that pregnant and lactating goats under the present system of management were more vulnerable to parasitism, smallholders can save costs while preventing indiscriminate anthelmintic application by selectively targeting these groups for anthelmintic dosing and nutritional management instead of deworming the whole flock. This method, known as targeted selective anthelmintic treatment (TST) or targeted treatment (TT), is widely used to slow the development of anthelmintic resistance in grazing animals (Berk *et al*., 2016). The goal is to maintain refugia within nematode populations and reduce the development of resistance by preserving sensitive nematode genotypes through strategic selective anthelmintic treatments of individuals (TSTs) or groups (TTs) of ruminants based on specific criteria to optimise treatment effectiveness and maintain performance while minimising the risk of developing anthelmintic resistance in the population (Baltrušis *et al*., 2018; Höglund & Gustafsson, 2023).

CONCLUSION

In conclusion, pregnant and lactating female goats had a greater risk of exposure and burden of parasitic infection. Proper nutritional management, controlled grazing, and targeted selective anthelmintic treatment are recommended to reduce the risk and severity of parasitic risk in pregnant and lactating females. However, further studies are needed to elucidate the potential mechanism of vulnerability to endoparasites during pregnancy and lactation, especially the potential roles of hormones and the likely molecular crosstalk between the endocrine and immune systems.

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ETHICAL STATEMENT

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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