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Effect of a reduced amount of straw bedding on goats' comfort and hygienic characteristics of milk and straw

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ABSTRACT

The present study aims to understand the influence of a reduced amount of straw litter on goats' lying comfort and hygienic characteristics of milk and straw. Lying behaviour (frequency, lying posture, location and social context) of 24 Alpine goats subjected to two different straw treatments (Regular: 2 kg/straw/head + 1 kg straw/head/day, $n = 12$; Scarce: 1 kg straw/head + 0.5 kg straw/head/day, $n = 12$) was observed from video recordings using a scan sampling method at 15-min scan intervals in March 2017. Moreover, straw and milk samples were submitted to microbiological analysis for the detection of total bacteria (SPC) and Enterobacteriaceae count. No significant differences in the duration of lying were observed between treatments, except at the beginning of the experimental period (Day 1: Regular: 26.0%; Scarce: 20.3% of scans; $p < .05$). In both treatments lying behaviour followed the normal lying patterns for goats, with a preference for sternal lying (99.4% of scans), in contact with a pen wall (78.2% of scans) and not in contact with other goats (alone: 79.7% of scans). Milk and straw SPC and Enterobacteriaceae count were not affected by the treatment. This preliminary study suggests the possibility to reduce the amount of straw as bedding material in goat farms, without affecting animal welfare and microbiological characteristics of milk and straw litter. However, further studies are required to confirm these results under different climatic conditions.

HIGHLIGHTS

- Reducing the amount of straw bedding does not affect goats' comfort
- Microbiological characteristics of milk and straw are not affected by the amount of straw bedding
- Provided that a daily addition is guaranteed, it seems possible to reduce management costs by reducing the amount of straw as bedding material

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Introduction

Bedding is one of the main factors that may influence the comfort of farm animals during resting. Preference for difference surfaces is highly species-specific. For example, a recent review highlighted that in dairy cows the total duration of lying time is positively affected by the presence of soft bedding material (Tucker et al. 2021), whereas Bøe et al. (2007) report that goats perceive straw (i.e., a soft bedding) as an unattractive bedding material, probably because they have the same preference of their wild ancestors for lying on hard surfaces (i.e., rocks, that are typically in elevated spaces and hidden, as anti-predatory

strategy; Dwyer 2009; Zobel et al. 2019). Furthermore, Bøe et al. (2007) and Sutherland et al. (2017) suggest that thermal conductivity properties of the lying surface may be more important than softness for goats' comfort, although results are discordant because animals were subjected to different treatments prior to the trial in these studies. In fact, previous experience can influence animals' choice (Bøe et al. 2007).

Total lying time can be considered as an indicator of animals' comfort (Mattiello et al. 2019). Goats sleep during the night, but they also spend some time resting during daytime, approximately 20–25% of time in natural environment (Shi et al. 2003). On farm, the

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duration of daytime lying behaviour may be affected by different environmental conditions, such as ambient temperature, stocking density, flooring material or access to outside enclosure (Loretz et al. 2004; Bøe et al. 2006; Andersen and Bøe 2007; Bøe et al. 2007, 2012; Sutherland et al. 2017).

Goats rest in body contact less than 3% of the total resting time (Andersen et al. 2008) and, when space availability is not a limiting factor, they prefer to lie against a wall rather than in the middle of a pen (Ehrlenbruch et al. 2010; Battini et al. 2014).

Besides affecting goats' comfort, the type and management of the bedding material can also have important hygienic implications. Foschino et al. (2002) observed that the microbiological composition of goat milk was significantly affected by the farm of origin. The importance of farm management conditions on Standard Plate Count (SPC) and Somatic Cell Count (SCC) of goat milk was also described by Goetsch et al. (2011).

At the moment, no information is available on how different amounts of bedding material can influence hygienic characteristics of both bedding and milk. Studies conducted by Lejeune and Kauffman (2005) and van Gastelen et al. (2011) highlighted a higher contamination of organic beddings with a high availability of organic matter, nutrients and water content, compared with inorganic beddings.

As goats seem to prefer lying on hard surfaces, and the amount of straw used as bedding material may affect farm hygiene, the objective of the current study was to present preliminary results on a comparison between the effect of commonly used amounts of straw bedding with a halved amount of straw on goats' comfort and hygienic characteristics of milk and straw.

Materials and methods

Animals and treatments

The study was carried out in March–April 2017 at the experimental farm 'Cascina Baciocca', located in Cornaredo (Milan, Italy), section of 'Angelo Menozzi' Experimental Farm of Università degli Studi di Milano. Twenty-four Alpine lactating goats were housed in four pens with six goats each. Each pen had an indoor surface area of 12 m² (2 m²/goat), plus an additional external area of 15 m² (2.5 m²/goat). Throughout the study, goats were milked once a day. The average daily milk production during the experimental period was 2.97 ± 0.06 l/goat (min 1.23, max 4.80), with no significant differences between groups. Goats had access to polyphite hay (3 kg/head/d) and *ad libitum* water, and

Table 1. Means ± standard error of temperature and relative humidity during the observation hours (6.00 a.m.–6.00 p.m.) of the experimental period.

Period	Temperature, °C	Relative humidity, %
27/03/17–02/04/17	18.9 ± 0.3 (11.0–24.5)	52.3 ± 0.8 (35.0–73.0)
07/04/17–13/04/17	20.3 ± 0.2 (14.5–24.5)	56.9 ± 0.6 (40.0–75.5)
Overall	19.6 ± 0.2 (11.0–24.5)	54.6 ± 0.5 (35.0–75.5)

Minimum and maximum values are reported in parenthesis.

were daily supplemented with concentrate (1.2 kg/head/d, twice a day) and mineral supplements (20 gr/head/d), which were consumed with no leftovers. Before the trial, the bedding for all goats consisted of an initial layer of 24 kg of straw/pen, plus a daily addition of 6 kg of straw/pen, i.e., 1 kg of straw/head/day. At the beginning of the trial, two pens were allocated to the usual bedding treatment, defined as 'Regular', and two pens were allocated to a reduced bedding treatment (12 kg of straw/pen as initial layer, plus a daily addition of 3 kg of straw/pen, i.e., 0.5 kg of straw/head), defined as 'Scarce'. Treatments were balanced by age, parity and weight. At the beginning of the trial, the average body weight was 51.87 ± 1.37 and 51.62 ± 2.42 kg and goats' age was 26.50 ± 4.52 (min 12, max 66) and 27.00 ± 5.50 (min 12, max 66) months in the Regular and Scarce treatment, respectively. On average, animals were in their second lactation (Regular: 2.17 ± 0.35; Scarce: 2.17 ± 0.40; min 1, max 5). After the allocation to the treatments, all groups were allowed an adaptation period of four days before starting the first phase of the experimental period, which lasted one week. At the end of the first experimental week, treatments were swapped and each group was again allowed an adaptation period of four days to get used to the new environmental conditions, before starting the second experimental phase, during which data were collected for another week. During the whole experimental period, environmental parameters inside the pens (at goats' level) were monitored every 30 min using a Lascar temperature and relative humidity data logger (Table 1).

Data collection

Before and after the daily addition of new bedding material, the straw depth was measured at five points, equidistant from each other, along the pen diagonal. Before the addition, on day 1 and 7 of each experimental period two straw samples were collected from each point and then submitted to

microbiological analysis at the Institute of Sciences of Food Production – Italian National Research Council, for the determination of total bacteria (SPC) and Enterobacteriaceae count.

Goats' behaviour was recorded continuously during light hours (6:30 a.m.–6:30 p.m.) of the two experimental weeks, using five cameras (Panasonic WV-CP500 Super Dynamic Day/Night) installed above the pens: one camera for each pen in the indoor area, plus one camera for the outdoor area. The videos of day 1, 4 and 7 of each experimental week were analysed by a trained observer using an instantaneous scan sampling observation method (Martin and Bateson 1993), with a 15-min interval, in order to record goats' lying behaviour. Lying behaviour was distinguished between Lateral lying (body on ground, on the left or right side) and Sternal lying. Unfortunately, in about a quarter of scans it was not possible to distinguish between these lying postures, as goats were not completely visible because of their position or to scarce light in some hours of the day. Occasionally, goats were completely hidden in a blind corner, and were then recorded as 'Not visible'. The presence of an operator or other disturbance factors were also recorded, and data collected under these conditions were not considered for behavioural analysis. When goats were lying, their location inside the pen was also recorded as follows: Contact with the pen's wall; Feed trough area; Centre of the pen; Outdoor pen. The social context during lying was also considered: Alone (absence of contact with other goats; distance > 20 cm); Contact (in contact with one or more goats; distance ≤ 20 cm).

The presence of dirty areas (e.g. wet and yellowish hair, muddy) on both sides of hind quarters, lower legs (front and rear), and udder was also recorded on days 1, 4 and 7 in order to evaluate goats' cleanliness (clean/dirty) (Battini et al. 2016).

On day 1 and 7 of each experimental period individual milk samples were collected using a milk collector, setting the Lactocorder (a mobile electronic flowmeter) on a mean production of 1.5 kg of milk. The milk samples of goats from the same pen were merged and divided into two subsamples that were transported to the laboratory under refrigeration (4 °C), and subjected to microbiological analysis within 12 h from collection.

Bedding material samples were prepared for microbiological analysis according to the procedure described in ISO Standard 8261| IDF 122:2001. One hundred g of straw sample were weighed in sterile manner and then chopped with the blender for one

min. Ten g of sample was later diluted 1:10 with a 2% solution of anhydrous potassium hydrogen phosphate (KH₂PO₄) and homogenised for 3 min at maximum speed using a Stomacher (BagMixer 400, Interscience). Subsequently, the homogenate was serially diluted in sterile quarter-strength Ringer's solution. Milk samples were submitted to 10-fold dilution using quarter-strength Ringer's solution. Both milk and bedding material samples were examined for SPC and Enterobacteriaceae (EB) using Petrifilm (3 M, St. Paul, Minn) and plates were incubated respectively at 30 °C for 72 h and at 37 °C for 24 h.

All analyses were performed in duplicate. Bacterial counts were transformed in base-10 logarithm, for statistical analysis.

Statistical analysis

The percentage of scans dedicated to each behaviour out of the total number of scans in which animals were visible, not in milking and not disturbed by the presence of an operator was calculated. The frequencies of scans between the two treatments were compared by Fisher's exact test using SAS 9.4 software (SAS 2012), focussing exclusively on lying behaviour, intended as indicator of goats' comfort and welfare; microbiological data were analysed by General Linear Model for repeated measures with treatment (Scarce vs Regular) as a fixed factor and the sampling day (Day 1, Day 7) as the repetition, using SPSS Version 27.0 (IBM Corp. Released 2020).

Differences were considered significant when $p < .05$.

Results and discussion

As expected, the average depth of the straw was significantly influenced by the treatment, with higher values observed in the Regular treatment rather than in the Scarce one, both before (8.94 ± 0.18 vs 7.11 ± 0.14 cm, respectively; $p < .05$) and after the addition (10.2 ± 0.17 vs 8.10 ± 0.15 cm, respectively; $p < .05$). In both treatments, the thicker layer was observed at the two extremes of the pen diagonal; in the Regular treatment, the lower thickness was recorded in the middle of the pen (Figure 1).

The percentage of scans dedicated to lying behaviour in the Regular treatment was significantly higher than in the Scarce treatment (29.6% and 25.5%, respectively; $p < .001$). However, the preference for the Regular litter was significantly higher on day 1 of the experimental week ($p < .05$), but then this difference

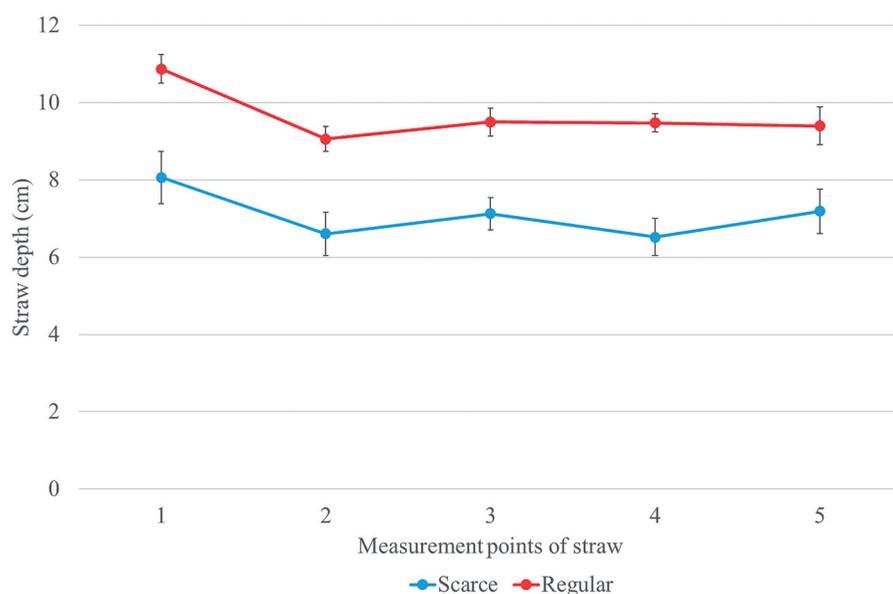


Figure 1. Average (\pm standard error) straw depth measured at the five points along the pen diagonal (where 1 and 5 are at the extremes and 3 is in the middle of the diagonal) in the two treatments during the experimental period.

decreased and it was not significant on day 4 ($p = .0531$), nor at the end of the experimental week, when the percentage of scans dedicated to lying behaviour was almost the same in the two treatments (Figure 2). Although goats generally prefer to rest on hard surfaces (Dwyer 2009), all goats involved in the present experiment were used to the Regular straw treatment before the start of the trial, and this previous experience may have influenced their choice in the first days (Bøe et al. 2007). Therefore, it is probable that the 4-day adaptation period was not enough for goats to adapt to the new condition in the Scarce treatment. However, within one week they seemed to adapt to the new treatment in terms of duration of lying time.

Table 2 reports goats' lying behaviour in terms of posture, location and social context depending on the straw treatment. Sternal lying was by far the most adopted lying posture in both treatments, with significantly higher frequencies in the Scarce treatment than in the Regular one (respectively 100% and 98.83%; $p < .01$). It is likely to assume that sternal lying is the preferred lying posture for goats; however, it is interesting that lateral lying was observed only in the Regular treatment, although at low frequencies (1.17%). This can be probably explained by a need for heat dispersion, due to the higher thermal insulation provided by the thicker layer of straw (Figure 1). This hypothesis is supported by the fact that, in spite of the generally mild climatic conditions recorded during the study period (Table 1), the highest percentage of lateral lying corresponded to one of the moments in

which the highest environmental temperature was recorded (24.3 °C), exceeding the optimal temperature range (10–18 °C) suggested by Toussaint (1997), and close to the suggested upper value (27 °C) for dairy goats kept indoors.

No significant differences between treatments were observed in terms of social context during lying. In both treatments, goats spent only about 20% of their time lying in contact with other conspecifics, in agreement with findings by Andersen and Bøe (2007), who reported that goats spend most of their time lying alone, and only a small percentage of time in body contact with other animals, regardless of the size of the resting area.

In both treatments, goats mainly rested in contact with the pen wall, with no significant differences between treatments (Regular: 78.5% of scans; Scarce: 77.9% of scans). This preference had already been observed in goats (Andersen and Bøe 2007; Ehrlenbruch et al. 2010), in sheep (Bøe et al. 2006) and in calves (Stefanowska et al. 2002), maybe as an antipredatory strategy. In fact, animals probably feel safer by a wall than in an open area. Therefore, it seems that goats maintained their normal preference for lying against a wall in both treatments. However, some differences in space use were recorded between treatments: goats in the Regular treatment spent a higher proportion of time lying in the middle of the pen than goats in the Scarce treatment (9.84% vs 6.02%, respectively; $p < .01$). This may be due to the fact that, in spite of their natural preference for protected areas by the walls, in the Regular treatment

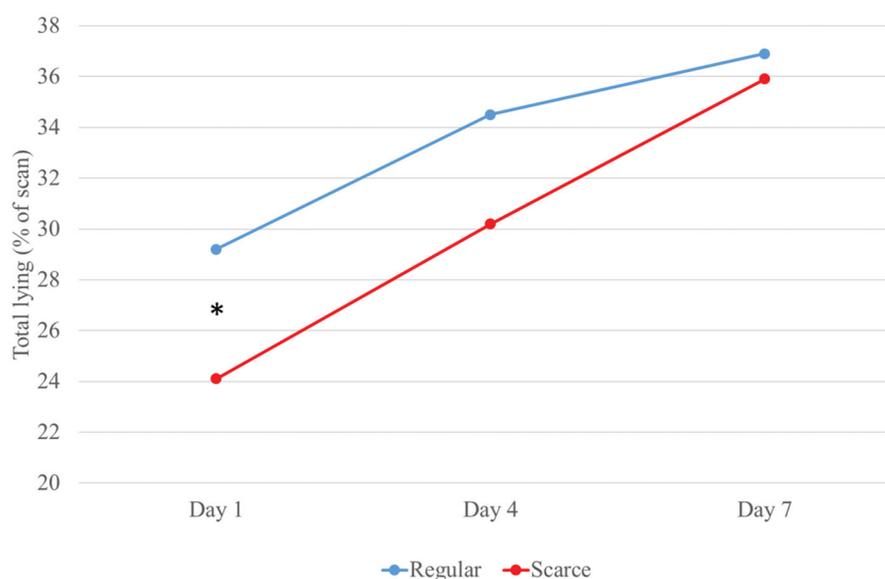


Figure 2. Total lying time at the beginning (day 1), in the middle (day 4) and at the end (day 7) of the experimental period in the two treatments. Significant differences are highlighted by an asterisk ($*p < .05$).

Table 2. Absolute number (and percentage) of scans for each lying posture, location and social context of goats during lying in the two treatments, with related significance levels of the difference between treatments.

	Lying posture		Lying location				Social context	
	Sternal lying	Lateral lying	Side	Centre	Feed trough	Outdoor	Alone	Contact
Scarce	628 (100%)	0 (0%)	686 (77.87%)	53 (6.02%)	88 (9.99%)	54 (6.13%)	631 (79.57%)	162 (20.43)
Regular	675 (98.83%)	8 (1.17%)	686 (78.49%)	86 (9.84%)	57 (6.52%)	45 (5.15%)	690 (79.86%)	174 (20.14%)
p^a	0.008**	0.008**	0.773	0.003**	0.009**	0.408	0.903	0.903

^aSignificance level: $*p < .05$; $**p < .01$; $***p < .001$.

goats looked for a harder surface, that could be found in the middle of the pen, when straw depth was lower (Figure 1), confirming goats' preference for resting on hard surfaces (Dwyer 2009; Zobel et al. 2019). Unexpectedly, goats occasionally rested also in the feed trough area, with significant differences between the two treatments (Regular: 9.99%; Scarce 6.52%; $p < .01$). Although this is a suboptimal area for resting, goats probably rested there in search for a hard surface, due to the absence of bedding, and this may explain the significantly higher proportion of goats of the Regular treatment that chose to rest there. Furthermore, the feeding area is also slightly elevated from the floor surface and the feed trough is made of solid material that can serve to the goats for hiding from the outside of the pen: these two characteristics are in line with findings of Zobel et al. (2019) on goats' preference during resting.

A low percentage of goats was observed lying in the outdoor pen in both treatments (Regular: 5.15%; Scarce: 6.13%; n.s.). Also, Bøe et al. (2012) observed that goats spent a low percentage of time lying in an

external area (<3% of observations). This is probably due to the fact that this area is mainly used for physical exercise and not for resting.

We never observed the presence of dirty areas on animals, therefore all goats were considered to be clean in both treatments, probably due to the fact that new bedding was added daily, and that no diarrhoea episode occurred during the trial.

Table 3 shows the effect of the amount of straw bedding on milk and straw microbiological quality. Milk SPC and Enterobacteriaceae, although with high average values as a result of sampling operations that did not allow immediate refrigeration, were not significantly influenced by straw treatment. These results are in agreement with those observed by Rowbotham and Ruegg (2015), in a study on dairy cows in Wisconsin, where no effect on milk bacterial contamination was observed in response to bedding addition, replacement and grooming. This underlines how the microbiological characteristics of milk are the result of a multifactorial and complex system, including the interaction between individual characteristics, health and

Table 3. Least square means (\pm standard error) of Standard Plate Count (SPC) and Enterobacteriaceae count (\log_{10} ufc/mL) in milk and bedding depending on straw treatment, sampling day and their interaction.

	Straw treatment			Sampling day			Treatment \times Sampling day	
	Scarce	Regular	p^a	Day 1	Day 7	p^a	p^a	
Milk SPC	6.446 \pm 0.621	6.343 \pm 0.621	.910	6.274 \pm 0.428	6.515 \pm 0.454	.037*	.902	
Milk Enterobacteriaceae	5.397 \pm 0.972	5.407 \pm 0.972	.995	5.361 \pm 0.755	5.443 \pm 0.635	.741	.924	
Bedding SPC	9.151 \pm 0.146	9.242 \pm 0.146	.675	9.136 \pm 0.169	9.256 \pm 0.152	.645	.835	
Bedding Enterobacteriaceae	6.091 \pm 0.841	4.838 \pm 0.841	.332	5.488 \pm 0.574	5.440 \pm 0.755	.940	.981	

^aSignificance level: * $p < .05$; ** $p < .01$; *** $p < .001$.

well-being status of the animals and farm management. In fact, it is also worth considering that hygiene at milking is a further key factor influencing the microbiological quality of milk. Finally, treatments had no significant influence on straw bedding samples in terms of SPC and Enterobacteriaceae content, in spite of the different amount of organic matter, nutrients and water content that was supposed to affect bacterial contamination (Lejeune and Kauffman 2005). This suggests that under the mild climatic conditions recorded during the study period (Table 1) the amounts of organic matter provided in both treatments did not elicit an excessive bacterial proliferation. However, it is interesting to notice that preliminary data collected in the same farm in full summer highlighted a statistically higher concentration of Enterobacteriaceae in the bedding of the Regular straw treatment (Regular: 5.86 ± 0.14 ; Scarce: $5.09 \pm 0.14 \log_{10}$ ufc/g; $p < .05$; unpublished data). Therefore, further investigations are required to understand the implications of different amounts of straw on the hygienic characteristics of the litter under different climatic conditions.

Conclusions

In conclusion, goats in both straw treatments generally showed a normal lying behaviour in terms of lying time, lying posture, social context and spatial behaviour, in line with the results reported by other authors (e.g. Shi et al. 2003; Andersen et al. 2008; Ehrlenbruch et al. 2010; Battini et al. 2014). A reduced amount of straw bedding had a limited and apparently only transitory effect on goats' lying behaviour, which disappeared at the end of the experimental period. It is possible to hypothesise that, after a longer adaptation period, no differences between treatments in lying behaviour would be observed. Unfortunately, very scarce information is available on lying behaviour in goats, and therefore it is not always possible to make comparisons with other studies. In this sense, the present investigation is particularly interesting, as it adds new information on these neglected aspects.

Microbiological quality of milk and bedding were not affected by the straw treatment; however, based on our preliminary findings (Mattiello et al., unpublished data), we may hypothesise that a reduced amount of straw litter might have a positive effect on bedding hygiene, especially in warmer climatic conditions. Of course, from this preliminary investigation it is not possible to draw definitive conclusions. However, our results are interesting and new and open up new perspectives for investigations on the optimal bedding to be used in goat farms. Further research is therefore required in order to confirm these results, especially in different seasons, possibly allowing for longer adaptation periods and taking into account additional important parameters, such as the effects on dust, ammonia emission or microbiological quality of air. In case our preliminary results are confirmed, it will be possible to advice a reduction of the amount of straw as bedding material, provided that a daily addition is guaranteed. This would be particularly important in contexts where straw supply is difficult, such as Italian goat farms located in mountain areas, where straw is not produced and where transport costs of this by-product can be high. Considering an average price of wheat straw of 70 euros/tons, farmers may save about 12.8 euros/head/year by using 0.5 kg of straw/head/day instead of 1 kg of straw/head/day, without affecting goats' welfare and possibly improving the hygiene of the litter.

Ethical approval

Animals were raised in line with all fundamental ethical principles and with national and EU legislation, and their care was undertaken by personnel who had received appropriate instruction on goats' maintenance and handling. According to the national Italian law (D.L. 26/2014), no specific ethical approval was required, as no pain, suffering, distress or prolonged damage equivalent to or greater than that caused by the insertion of a needle was applied.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data that support the findings of this study are available from the corresponding author, [S.M.], upon reasonable request.

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