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Night-to-night variability of polygraphy in children with sleep disordered breathing symptoms

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Abstract

Introduction: Polygraphy (PG) can be used as an alternative test for the diagnosis of obstructive sleep apnea syndrome (OSAS) in children. Night-to-night variability of PG in children is not known. Our aim was to determine whether a single night PG was reliable for OSAS diagnosis in children with symptoms of sleep-disordered breathing (SDB).

Materials and Methods: Otherwise healthy children who had been evaluated for symptoms of SDB were included. Two nocturnal PGs were performed 2–7 days apart. Demographic and clinical characteristics, Pediatric Sleep Questionnaire, and modified Epworth Sleepiness Scale were recorded. OSAS was diagnosed if obstructive apnea–hypopnea index was (oAHI) $\geqslant$ 1/h and classified as mild (oAHI: 1–4.9/h), moderate (oAHI: 5–9.9/h), and severe (oAHI $\geqslant$ 10/h).

Results: Forty-eight patients were included (37.5% female, age 10.8 ± 3.9 years) to the study. There were no significant differences in oAHI values and other respiratory parameters between the two PGs ($p > 0.05$). Thirty-nine children were diagnosed with OSAS if the highest oAHI over any single night was used for diagnosis. Thirty-three of the 39 children (84.6%) were diagnosed with OSAS with the first PG while 35 of 39 (89.7%) children were diagnosed with OSAS with the second PG. There was an agreement for identifying OSAS and its severity between the two PGs in our study even though there were few individual intra-subject differences in oAHI.

Conclusion: There was no significant first-night effect for PG in this study which suggests that a single night PG is adequate for diagnosis of OSAS in children with SDB- related symptoms.

KEYWORDS

obstructive sleep apnea, polygraphy, variability

Abbreviations: AHI, apnea–hypopnea index; CAI, central apnea index; ESS, Epworth Sleepiness Scale; ESS-CHAD, Epworth Sleepiness Scale for children and adolescents; oAHI, obstructive apnea–hypopnea index; OAI, obstructive apnea index; ODI, oxygen desaturation index; OSAS, obstructive sleep apnea syndrome; PG, polygraphy; PSG, polysomnography; PSQ, Pediatric Sleep Questionnaire; REM, rapid eye movement; SDB, sleep-disordered breathing; TST, total sleep time.

1 | INTRODUCTION

The spectrum of obstructive sleep-disordered breathing (SDB) includes primary snoring, upper airway resistance syndrome, obstructive hypoventilation, and obstructive sleep apnea syndrome (OSAS). Obstructive sleep apnea syndrome is a common SDB in children with a prevalence of 1%–4% and is defined as recurrent, partial, or complete upper airway obstruction with disruption of normal oxygenation, ventilation, and sleep pattern.[1] Significant short and long-term morbidity including neurodevelopmental and cardiovascular consequences may occur if OSAS is not diagnosed and treated timely.[1,2] Overnight in-laboratory polysomnography (PSG) is the gold standard for the diagnosis of OSAS in children. However, the complexity of the procedure, lack of adequate number of pediatric sleep laboratories, and experienced staff led clinicians to seek for simpler methods for diagnosis.[3] Polygraphy (PG) is an alternative method for diagnosing OSAS in children which includes airflow and chest-abdominal wall movement monitoring and pulse oximetry recordings and could be performed in a sleep laboratory, hospital bed, or at home.[1] In-laboratory PG was reported as a reliable method for diagnosis of OSAS in children when compared with PSG.[3] European Respiratory Society guidelines accept in-laboratory PG as an objective method for diagnosis of OSAS in children.[1,4]

Routinely, a single-night sleep study is performed for the diagnosis of OSAS.[5] However, as the patients sleep in an artificial sleep laboratory environment, "night-to-night variability" caused by "the first night effect" is a concern.[6] First night effect may cause a decrease in the duration of rapid eye movement (REM) sleep. As apneic events in children frequently occur in REM sleep, a single night in-laboratory PSG may result in false negative results.[7] Besides, normal night-to-night variances in sleep architecture are also possible.[8] Sleep architecture was affected by the first night effect in several adult studies, which could lead to the underestimation of sleep-related disorders.[9,10] There are conflicting results regarding the variability and first-night effect of PSG from pediatric studies. While some studies reported no significant variability, some studies reported varying degrees of night-to-night variability which could affect the results and management of the disease.[6,11,12]

While there are a number of studies investigating night-to-night variability for PSG, there is only limited data regarding night-to-night variability of PG in children. Even though studies investigating the variability of PG report conflicting results, both of these studies include a special patient population which may affect the results.[5,13] To our knowledge, our study is the first to evaluate the variability of PG in otherwise healthy children with SDB-related symptoms.

Our primary aim was to evaluate the night-to-night variability of in-laboratory PG in children with SDB-related symptoms. The secondary aim was to determine whether a single night PG was reliable for OSAS diagnosis in children. We hypothesized that a single night PG will be adequate for the diagnosis of OSAS in children with symptoms of SDB.

2 | MATERIALS AND METHODS

This was a single-center prospective study conducted between May 2020 and January 2021. Children between 4 and 18 years of age with symptoms of SDB who were referred to our center with suspected sleep apnea from general pediatric clinics were included in the study. Symptoms included snoring, mouth breathing, observed apnea, difficulty in waking up, daytime sleepiness, nighttime sweating, hyperactivity, morning headache, and awakening with a dry mouth. Children with underlying chronic diseases and comorbidities known to affect sleep and/or breathing such as chronic pulmonary disease, neuromuscular disease, craniofacial anomalies, and patients receiving medications which might affect the sleep architecture were excluded. In addition, patients with an acute illness such as upper and lower respiratory tract infections were excluded. Demographic and clinical data including sleep related symptoms were recorded and detailed physical examinations were conducted by a pediatric respirologist.

All participants or their parents completed the Modified Epworth Sleepiness Scale for children and adolescents (ESS-CHAD) and Pediatric Sleep Questionnaire (PSQ). ESS-CHAD is a validated, simple scale assessing daytime sleepiness including eight questions with four-point Likert scale answers. ESS-CHAD scores above 10 are indicative of excessive daytime sleepiness which may indicate SDB.[14–16] PSQ is also a validated questionnaire used to evaluate SDB-associated symptoms. It contains 22 symptom items assessing snoring frequency, loud snoring, observed apneas, difficulty in breathing during sleep, daytime sleepiness, inattentive or hyperactive behavior, other obstructive sleep apnea features, and cut-off value for pediatric SDB is defined as 0.33.[17,18] ESS-CHAD and PSQ are valid and reliable tools for use in Turkish children and adolescents.[16,17]

The same type 3 device (Nox T3 portable sleep monitor; ResMed®) was used to perform sleep studies for both nights. Recorded parameters included airflow monitoring by a nasal flow cannula, chest-abdominal movements by respiratory inductance plethysmography belts, oxygen saturation and heart rate by a pulse oximetry, snoring by a microphone, and body position. Two nocturnal PGs were performed in the sleep laboratory to all participants 2–7 days apart. The participants with two successful recordings of PG were included in the study. Successful recording was defined as two nights of sleep containing ≥6 h of sleep each night with an overall signal quality of 90% without artifact.

The scoring and reporting of the PGs were performed blindly by the same experienced pediatric sleep physician and technician. First, scoring and reporting of the PGs were performed blindly by the same experienced sleep technician. The same sleep physician reviewed each PG after the technician. Total sleep/recording time (TST), apnea–hypopnea index (AHI), obstructive apnea–hypopnea index (oAHI), central apnea index (CAI), oxygen desaturation index (ODI 3%), and average and minimum SpO_2 values were recorded. Respiratory parameters, apneas, and hypopneas were scored manually according to the American Academy of Sleep Medicine

scoring rules used for PSG scoring.[19] Obstructive AHI was defined as the sum of the obstructive apnoeic events and hypopnoeic events per hour of sleep/recording and it was used to assess OSAS severity. OAHI ⩾ 1/h together with SDB symptoms was used to diagnose OSAS. OSAS was defined as mild if oAHI was between 1 and 4.9/h, moderate if 5–9.9/h, and severe if ⩾10/h.[2,19,20]

Patients and their families were informed about the study and written informed consents were obtained. The study was approved by the Ethical Committee of Marmara University School of Medicine (12.05.2020, No: 670).

2.1 | Statistical analysis

Statistical analysis was carried out with SPSS for Windows version 20.0. Normality was checked with graphs and normality tests. Continuous variables that were normally distributed were presented as means and standard deviations whereas the data with asymmetrical distribution were presented as medians and percentiles. Categorical variables were presented as proportions. Mann–Whitney *U* test was performed to compare two independent nonparametric variables. Wilcoxon test was performed to compare continuous variables for two repeated samples with asymmetric distribution whereas paired samples *t* test was performed for two repeated samples with normal distribution.

χ^2 test was used to compare categorical variables. McNemar test was performed to compare paired categorical data. Spearman's ρ was used for correlation analysis. OAHI values of the two PGs were demonstrated graphically with scatter plot and Bland–Altman graphs. Results were evaluated with 95% confidence intervals and statistical significance level was set at $p < 0.05$.

We based our sample size estimation on the results of a previous study by Li et al.[7] Assuming an α of 0.05, a β of 0.90, and an effect size of 0.50 by using G*Power software, we calculated that a sample size of 47 participants was needed.

3 | RESULTS

Forty-eight children with a mean age of 10.8 ± 3.9 years were included in the study. The most common presenting symptom was snoring with a frequency of 66.7%. Nine patients (18.8%) were considered as obese as their body mass index was higher than 95th percentile for their age. Table 1 shows the demographic and clinical characteristics of the patients.

According to ESS-CHAD, 10.4% ($n = 5$) of children had daytime sleepiness and according to PSQ, 60.4% ($n = 29$) had SDB.

Table 2 shows the respiratory parameters in the first (PG_1) and the second night (PG_2) PG studies. There were no significant differences in TST, AHI, oAHI, CAI, and ODI 3%, average and minimum SpO_2 values of two PGs ($p > 0.05$ for all).

AHI_1 and AHI_2; $oAHI_1$ and $oAHI_2$; median SpO_2 levels of two nights; CAI_1 and CAI_2; ODI_1 and ODI_2 were positively correlated

TABLE 1 Demographic and clinical characteristics of the patients ($n = 48$).

Age (years, mean ± SD)	10.8 ± 3.9
Sex (F, %)	37.5
Presenting symptoms (*n*, %)	
Snoring	32 (66.7)
Mouth breathing	28 (58.3)
Observed apneas	15 (31.3)
Difficulty in waking up	12 (25.0)
Daytime sleepiness	10 (20.8)
Nighttime sweating	12 (25.0)
Hyperactivity	7 (14.6)
Morning headache	9 (18.8)
Awakening with a dry mouth	11 (22.9)
Family history for SDB (*n*, %)	37 (77.1)
History of prematurity (*n*, %)	4 (8.3)
Adenotonsillectomy (*n*, %)	8 (16.7)
PSQ score (median, 25–75th percentile)	0.38 (0.18–0.55)
ESS-CHAD score (median, 25–75th percentile)	4.00 (1–7.5)

Abbreviations: ESS-CHAD, Epworth Sleepiness Scale for children and adolescents; F, female; PSQ, Pediatric Sleep Questionnaire; SDB; sleep-disordered breathing.

($r = 0.771$; $r = 0.764$; $r = 0.609$; $r = 0.594$; $r = 0.748$, respectively, $p < 0.001$ for all). TST_1 and TST_2 were moderately correlated ($r = 0.402$, $p = 0.005$).

The proportion of OSAS was 81.3% ($n = 39$) in children with SDB-related symptoms if the highest oAHI over any single night was used for diagnosis. While 33 patients (68.8%) had OSAS according to the PG_1, PG_2 revealed that 35 (72.9%) of the patients had OSAS ($p > 0.05$). Thirty-three of the 39 cases (84.6%) were diagnosed with OSAS on PG_1 while 35 of 39 (89.7%) were diagnosed with OSAS with PG_2 if the worst oAHI over any single night was used for the diagnosis. Six participants (12.5%) with normal oAHI in PG_1, had OSAS in the PG_2. The cases missed by the PG_1 had mild OSAS with a maximum oAHI value of 2.6/h. On the other hand, four (8.3%) patients with OSAS on PG_1, had a normal oAHI value on PG_2. Similarly, the cases missed by the PG_2 had mild OSAS with a maximum oAHI value of 3.5/h. Table 3 shows the presence of OSAS in PG_1 and PG_2.

The presence and/or severity of OSAS did not differ between the two PG studies in 33 (68.8%) of the patients. The presence/severity of OSAS varied in 15 (31.2%) of the patients. While the severity of OSAS decreased in one patient, it increased in four of the patients. Table 4 shows the comparison of the severity of OSAS in PG_1 and PG_2.

Figure 1 shows the scatter plot of the oAHI measurements of the PG_1 and PG_2. $oAHI_1$ and $oAHI_2$, especially the low values were

TABLE 2 Respiratory parameters in PG_1 and PG_2 studies.

	PG_1 Median (25th–75th percentile)	PG_2 Median (25th–75th percentile)	*p*
Total sleep/recording time, minutes	431.4 (386.3–462.3)	432.7 (386.4–454.7)	>0.05
AHI (/h)	2.8 (1.1–5.0)	2.7 (1.2–6.4)	>0.05
oAHI (/h)	1.6 (0.7–4.0)	1.7 (0.8–4.9)	>0.05
CAI (/h)	0.5 (0.10–1.1)	0.6 (0.15–1.6)	>0.05
ODI 3% (/h)	3.70 (1.55–6.4)	3.85 (1.85–7.7)	>0.05
Minimum SpO_2 (%)	89.5 (83.0–91.5)	87.0 (81.5–90.0)	>0.05
Average SpO_2 (%)	95.7 (94.6–96.2)	95.6 (94.4–96.1)	>0.05

Abbreviations: AHI, apnea–hypopnea index; CAI, central apnea index; oAHI, obstructive apnea–hypopnea index; ODI, oxygen desaturation index; PG, polygraphy.

TABLE 3 OSAS diagnosis with PG_1 and PG_2.

	PG_1		
	Normal oAHI *n* (%)	OSAS *n* (%)	Total
PG_2			
Normal oAHI (*n*, %)	9 (18.8)	4 (8.3)	13 (27.1)
OSAS (*n*, %)	6 (12.5)	29 (60.4)	35 (72.9)
	15 (31.3)	33 (68.7)	48 (100.0)

Abbreviations: PG, polygraphy; oAHI, obstructive apnea–hypopnea index; OSAS, obstructive sleep apnea syndrome.

TABLE 4 Severity of OSAS in PG_1 and PG_2.

	PG_1				
	Normal oAHI	Mild OSAS	Moderate OSAS	Severe OSAS	Total
PG_2					
Normal oAHI	9	6	0	0	15
Mild OSAS	4	17	2	1	24
Moderate OSAS	0	0	3	1	4
Severe OSAS	0	0	1	4	5
Total	13	23	6	6	48

Abbreviations: PG, polygraphy; oAHI, obstructive apnea–hypopnea index; OSAS, obstructive sleep apnea syndrome.

closely correlated. Figure 2 shows the Bland–Altman plot of the oAHI measurements of the PG_1 and PG_2. With higher means of oAHI, there was a tendency toward greater differences between $oAHI_1$ and $oAHI_2$.

There was no significant correlation between the patients' age and night-to-night change in oAHI ($r = -0.217$, $p = 0.139$). Similarly,

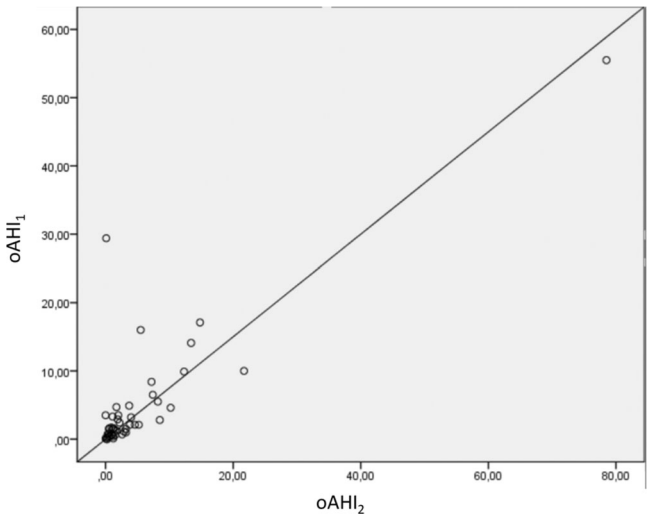

FIGURE 1 Scatter plot showing the measurements of $oAHI_1$ and $oAHI_2$ in 48 children. oAHI, obstructive apnea–hypopnea index.

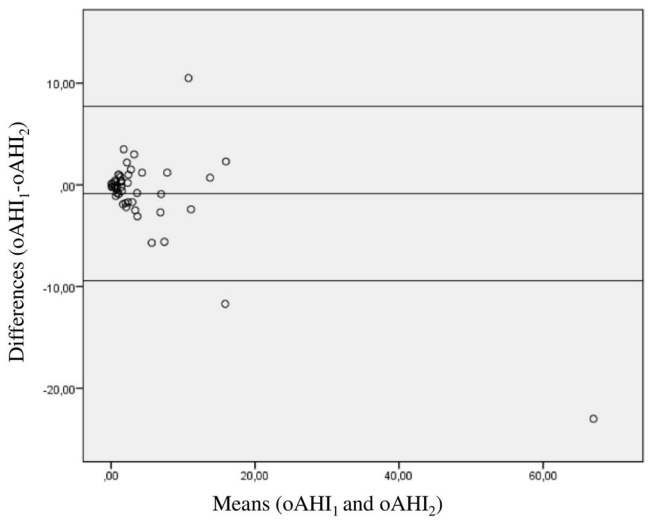

FIGURE 2 Bland–Altman plot demonstrating $oAHI_1$ and $oAHI_2$ in 48 children. oAHI, obstructive apnea–hypopnea index.

there was no significant difference in terms of average oAHI values of two nights' PG results between obese and nonobese patients ($p > 0.05$). However, while the median difference in oAHI values of two nights was 2.2/h in obese patients, it was 0.8/h in nonobese patients ($p = 0.015$).

We also compared patients with high variability (difference in OAHI ≥ 3/h, $n = 8$) and low variability (difference of OAHI < 3/h, $n = 40$) between two nights according to oAHI. There was no significant difference in terms of age, sex, BMI, and BMI percentiles of the groups with high and low variability ($p > 0.05$ for all).

4 | DISCUSSION

Several studies evaluated the night-to-night variability of sleep and respiratory parameters in PSG and reported wide variety of results. However, there is only limited data regarding the variability of PG. The current study evaluated in-laboratory PG results of two different nights in children with suspected OSAS. To our knowledge, the present study is the first to assess the night-to-night variability of in-laboratory PGs with largest scale of otherwise healthy children with SDB- related symptoms. We did not observe a first-night effect and did not find a significant difference in oAHI values and other respiratory parameters between the two PGs in the present study.

One of the major concerns of in-laboratory sleep studies is the first-night effect. A recent meta-analysis regarding the first-night effect of PSG reported decreased TST, greater frequency of awakening, decreased sleep efficiency, and REM sleep in the first night.[21] First night effect may be due to an unfamiliar sleep environment, discomfort from the electrodes, and limited mobility. In addition, night-to-night variability may occur due to physiological, biological, and patient-related factors.[5] As a result of the first night effect; there is a concern that decreased REM sleep duration may lead to underestimation of respiratory events. In this study, we did not observe a first-night effect and did not find a significant difference in terms of respiratory parameters of two different nights. There are pediatric studies with PSG that support[11,12] and that do not support[6] the first-night effect phenomenon. In addition, most of the pediatric studies reporting first-night effect did not report a variability in respiratory parameters with PSG.[11,12] Similarly, Ding et al. also reported no significant variability regarding AHI in their meta-analysis including 1422 healthy subjects aged between 9.2 and 85.5 years.[21]

The overall rate of OSAS was 81.3% ($n = 39$) in our study in children with SDB symptoms if the highest oAHI over any single night was used as the criterion. First-night PG would have correctly diagnosed 33 of the 39 cases (84.6%) while the diagnosis rate with the second-night PG was 89.7%. The missed cases of both nights were only the mild cases, so the clinical importance of this finding is not very significant.

Katz et al. performed PSG on two different nights for 30 children with snoring 1–4 weeks apart and reported that clinical diagnosis remained the same for all children and concluded that a single night PSG is sufficient for the diagnosis of OSAS in otherwise normal, snoring children. The study also did not find any difference between respiratory parameters and sleep parameters except for the percentage of stage 2 sleep.[6] Even though we were not able to compare sleep parameters since the current study was performed with PG, the results are compatible with the study of Katz et al. Another study by Li et al. included 44 obese children and 43 control subjects. They performed PSG on two consecutive nights and reported that the first night PSG would have correctly identified 84.6% of the OSAS cases if the worst obstructive apnea index (OAI) over any single night was used as the criterion and the missed cases were the ones with borderline OAI values, similar to our study. Even though this study supported the first-night effect according to changes in sleep stages especially in the control group, it also concluded that a single-night sleep study is adequate and cost-effective for OSAS diagnosis in children.[7]

A recent study by Ørntoft et al. assessed the variability of home PG (type 3 sleep monitor) in children with obesity/overweight and showed no significant difference in terms of respiratory parameters between two consecutive nights. Similar to our results, the first night identified 83% of OSAS cases while only four cases with mild OSAS were missed.[5] In addition, it was also reported that if the first-night PG was normal, second-night PG might diagnose OSAS with 40% probability.[5] In the current study, first-night PG would have correctly diagnosed 84.6% of the cases and similar to this recent study, 40% of the patients with normal oAHI in the first night were diagnosed with OSAS in the second night.

The presence/severity of OSAS varied in 31.2% of the patients in the current study. This ratio was reported to be 50% by Ørntoft et al. while Katz et al. reported it as 6.6%.[5,6] Ørntoft et al. suggested the presence of clinically relevant night-to-night variability of OSAS severity between two nights. These results might be due to the first night effect as the PGs were performed consecutively. REM sleep deprivation theory is defined as the effect of the first-night sleep study on the next night which is supposed to be observed on consecutive nights.[12] In our study, the second night PG was performed 2–7 days after the first PG, which excludes the REM deprivation theory. Therefore longer time intervals between two sleep studies can be the reason for the lower variability and the lack of a first-night effect in our study similar to the study performed by Katz et al.[6] In addition, patient characteristics such as underlying obesity might also affect the variability.[5] The median difference in oAHI values of two nights was significantly higher in obese patients in the current study, which shows the possible effect of obesity on variability. Greater night-to-night differences and variability in sleep studies were reported in patients with obesity in previous studies.[22,23] Even though the exact reason is not known, it is suggested that high sleep variability in obese patients may be associated with insufficient sleep time and compensation on other nights. In addition, obese patients may have an affected synchronization in eating patterns as a result of variation in sleep.[22,23]

Previous studies reported that older children have a more pronounced first-night effect.[11,12] However, we did not find a

significant difference in terms of age of the patients within the low and high variability groups. In 16.6% of the patients, there was a difference in oAHI greater than 3/h in our study. The graphical analysis showed that with higher oAHI values, there was a tendency of increasing differences in oAHI values between the two nights. Katz and Ørntoft also found a similar pattern.[5,6] The reason of this finding is not known but higher OSAS severity and increased variability may be directly related.[6]

The present study has several limitations. First, we only included otherwise healthy children older than 4 years of age with SDB-related symptoms. Variability may differ between special patient groups such as patients with underlying disorders. In the present study, the number of patients with severe OSAS is low which may affect the results. Variability may be higher in patients with severe OSAS. The number of the patients included in the study was limited as the PGs were performed in sleep laboratory and required extra resources. Also, we did not perform PSG which is the gold standard method for confirming the diagnosis of OSAS due to limited resources. Diagnosis of mild to moderate OSAS may be underestimated with PG compared to PSG, which may affect the management decision.[24] Lastly, studies were not performed in the patients' homes and they cannot be generalized to home PG studies. Even though home sleep apnea tests are not routinely recommended,[25] home PGs may be useful when the probability of OSAS is high in otherwise healthy children with SDB-related symptoms.[26]

In conclusion, we did not find a significant first-night effect and variability in two PGs performed in the hospital on two different nights in our study. The current study suggests that if the PG results are consistent with OSAS in the first night, the diagnosis is reliable. However, if the first PG is normal and the patient has significant history and symptoms suggesting OSAS, it would be prudent to perform a second night sleep study preferably with PSG to prevent long-term consequences related to OSAS.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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