Analele Universității București. Geografie
Vol. LXXV, p. 125-139
ISSN 1013-4115; e-ISSN 2247-238X
DOI: 10.5719/aub-g/75.1/5

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THE CALORIC STRESS AND TOURISM ON THE ROMANIAN PLAIN AREA

Abstract. This study aims to highlight the impact of thermal/calory stress conditions on tourism activities in southern Romania. A well-known phenomenon in human society, tourism is seen as a refined exporter of specific products (services and goods), ultimately intended to support the development of tourist destinations. The current problem of the modern world, namely climate change, has become a factor that directly influences the decision-making process specific to tourism activities. The need for adaptation actions is imposed against the backdrop of this state of change. The relative strain index is a bioclimatic index that allows the evaluation of bioclimatic conditions of thermal/calory stress, being applicable, at the latitude of our country, only during the summer. The index was calculated for the period 2000-2024, based on temperature (^{0}C) and relative humidity air (%). The calculated values of the index highlight the main areas of bioclimatic stress or not specific to the summer season in southern Romania. The identification of these areas inevitably leads to the need for decision-makers to identify methods of adaptation to new situations in order to ensure the appropriate continuity of tourist activities.

Keywords: relative strain index, bioclimatic comfort, bioclimatic risk, tourist activity, Romanian Plain

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EDITURA UNIVERSITĂȚII DIN BUCUREȘTI
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1. Introduction

In recent times, the adaptation of the tourism sector and recreational activities to climate change has become a necessity. This request is necessary for the specific activities of the Romanian Plain. This region imposes itself in the tourist landscape with a series of tourist activities, such as: urban tourism, fishing tourism, equestrian tourism, balneoclimatic tourism, sports tourism, gastronomic tourism, proximity tourism, etc. Tourist products offer economic benefits to all actors involved, and experiential benefits to the visitor.

The aim of this study is to evaluate the impact of thermal discomfort or comfort on the tourist and those involved in ensuring the quality of the tourism activities. For this purpose, one of the bioclimatic indices was calculated that highlights the state through which the human body tries to adapt. The adaptation of the individual is necessary to successfully complete daily activities. Thus, the bioclimatic factor must be seen as a working tool in scientific research. This factor provides information about the positive or negative potential that the climatic conditions of a region have on: the human health of the locals; the specific activities in the area; the state of comfort of those who have arrived in the area (tourists, visitors, etc.).

A human organism stressed by weather conditions can affect the daily routine of a human society. For example, in Elena Teodoreanu's scientific presentations, we find useful information about how bioclimatological and biometeorological analyses should be viewed and used: "*...two contradictory and complementary aspects... the sanogenic aspect – the elements of the climate in preserving and recovering health and the pathogenic aspect – exceeding natural limits of temperature, humidity, atmospheric pressure, which determines the body's illness or the exacerbation of some disease symptoms...*" (Teodoreanu, 2002).

The increasing appearance of studies referring to tourist comfort has brought back interest in weather forecasts and their importance for tourist activity. In general, these forecasts present weather conditions and everything that involves the assimilation of new knowledge. Scientists such as Peters (1992), Hannah (2002), Hamilton (2004) etc. have presented studies on the emergence of the relational environment developed by

the environment in which man works and the weather. For example, in 2013, Spiridonov said that all the interest in knowing has pushed the individual to identify: "*...the capacity to adapt to sudden changes in weather conditions differs from individual to individual and depends largely on genetic predisposition and specific characteristics...*". Studies have also been published on how the human body suffers under the influence of external factors (de Freitas, 1990; Fiala et. all, 2001; Chen L., 2012; Kantor Noémi, 2012; etc.). Romanian studies are not new, but neither are they very numerous. Among the best-known studies were Ciulache (2004), Ionac (2004, 2007), Bogdan (2010), Teodoreanu (2012), Grigore (2012), Scripca (2019), Ciobotaru (2018), Croitoru (2020), Ichim (2020) etc.

The climatic variability of heat stress, also influenced by global warming, may impose changes reflected both in tourism activity and in any other economic sector with some sensitivity to climate conditions.

2. Study area

Located in southeastern Europe, on the lower course of the Danube, the Romanian Plain is the largest plain located in the southern part of the country (Fig. 1). Currently, it occupies approximately 50.000 km^2, which represents approximately 21,0% of the total area of the country.

The plain was born and evolved through the accumulation of alluvial debris deposited by the Carpathian streams with active slope drainage, in a former large Quaternary lake. It is imposed on the Romanian geographical landscape by an almost flat appearance, with low interfluves, which rarely exceed 300 m (Fig.2 a). These landforms are covered by thick layers of eroded loess with voids and sand dune deposits. We point out the fact that they are interrupted by several widely spaced valley bottoms, bordered by one or two levels of terraces. The low interfluve surfaces are frequently subject to seasonal flooding due to the slope. Another floodplain area is the Danube floodplain and includes numerous side channels and fish lakes, separated by sandbanks, which support the floodplain forests.

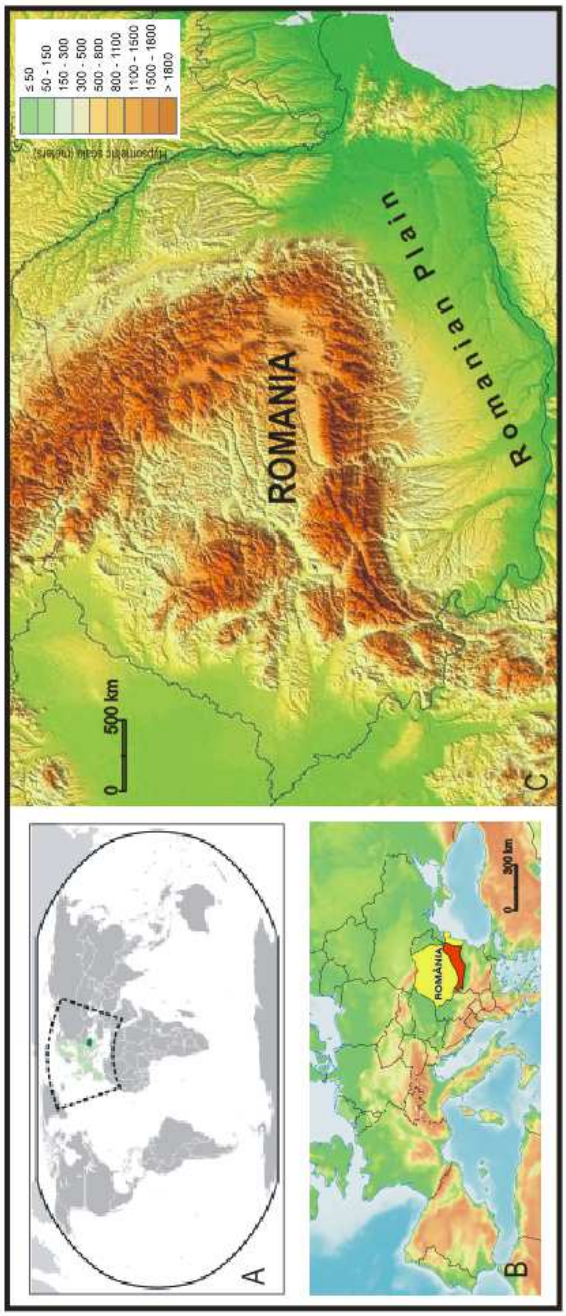

Figure 1. Romanian Plain - geographical position on the Globe (a), in Europe (b) and in Romania (c) *(Source:* processing according to various maps in ArcGis Pro and Corel Draw, 2025*)*

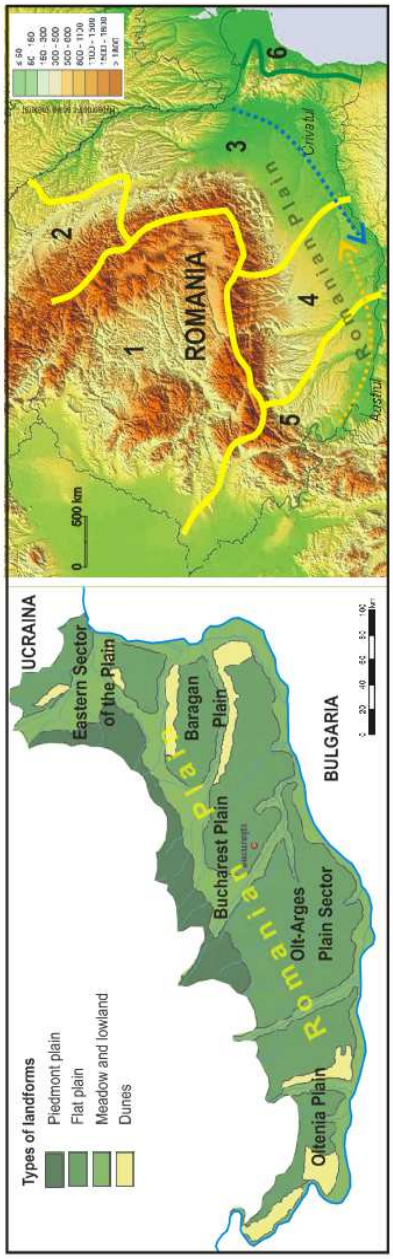

Figure 2. Romanian Plain – representation of the main landforms (a) and the climatic influences felt (b). Legend climate influences: 1 – oceanic influences; 2 – scandinavian-baltic influences; 3 – continental (aridity) influences; 4 – transitional influences; 5 – sub-mediterranean influences; 6 – pontic influences)
(Source: processing in ArcGis Pro and Corel Draw, 2025*)*

Regarding the climatic characteristics of the Romanian Plain, they vary from Mediterranean influences (in the west) to dry continental influences (in the east) (Fig. 2 b). The average annual atmospheric precipitation decreases steadily towards the east from 550 mm to 450 mm, while the air temperature remains relatively constant at average annual values of 10,0°C – 11,0°C. However, the influence of the relief forms gives the climate considerable variations in the plain area. Thus, extreme climatic conditions can develop, especially in summer, when the stability of tropical air masses from Africa produces high air temperatures. For this reason, the Romanian Plain not only produced the absolute maximum air temperature (44,5°C at the Ion Sion/Râmnicelu meteorological station, located near Brăila, on August 10, 1951), but also currently records the highest temperature amplitude in the country (25,0°C – 26,0°C °C).

3. Methodology

The present study aims to show the reader and outline, at the same time, through specific analyses of the relative strain index – RSI, the main areas of bioclimatic stress or not, specific to the hot season in southern Romania, respectively in the Romanian Plain. The relative strain index is a relevant bioclimatic index used to evaluate the bioclimatic stress due to overheating conditions during the summer. Its values can be quantitatively derived from the air-temperature (°C) and the real/effective vapor pressure (hPa) according to the formula: **RSI = (Ta – 21) / (58 – e).** The mathematical calculation of this index was proposed and published in the year 1992 by Kyle W.J., in the article "*Summer and Winter patterns of human stress in Hong Kong*".

The relative strain index was initially developed by Shapiro, in the year 1982, taking into account "*…a healthy person dressed in a business suit in a place not acclimatized to direct heat to take into account the insulation of clothing…*". Kyle mentions that at a value of 0,30 units of the comfort index, the comfort decreases and raises problems for the elderly and those with health problems, becoming dangerous at values above 0,50 units (for example: it can affect the cardiovascular system; it can cause an increase in the mortality rate, especially for children and the elderly). Between 0,10 and 0,20 we have a comfortable state for all people, while between

0,20 and 0,30 we identify a state of moderate comfort by approaching the upper limit of the comfort state.

This study analyzes the relative strain index values, over a period of 25 years (2000-2024), using the monthly average of air-temperature (°C) and mean values of relative humidity (%), obtained from 16 reference meteorological stations located in the Romanian Plain (Fig. 3).

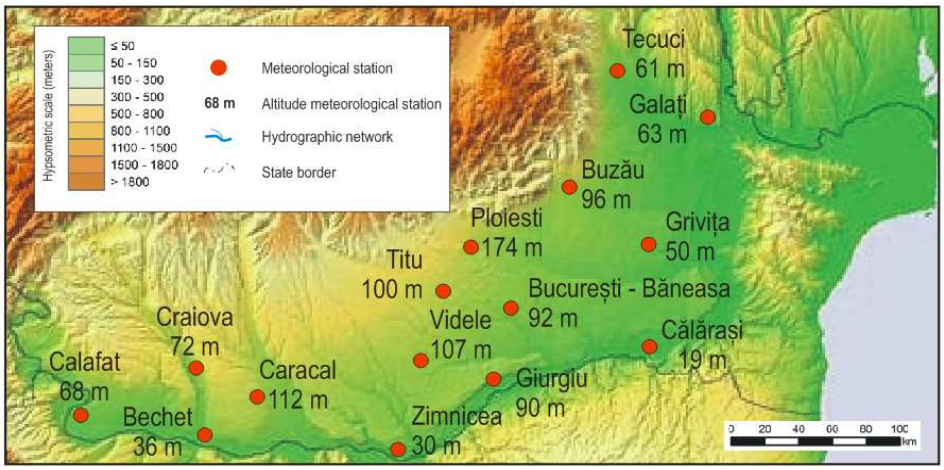

Figure 3. Romanian Plain - the geographical position and altitude of the meteorological stations used in the analysis
(Source: processing in ArcGis Pro and Corel Draw, 2025*)*

The calculations were based on the mathematical formula launched by Kyle W.J., but also on mathematical formulas used by Ionac Nicoleta and Ciulache Sterie, in the creation of the Bioclimatic Atlas of Romania (2008). The data used to calculate the index values, mentioned above, are for the summer season (June-August). In this way, we consider that the reader's perspective on the level of bioclimatic risk in the respective territory has been completed. In general, the detailed evaluation of bioclimatic indices is interesting and useful in studying the variation in time and space. Diagnostic analysis is useful in the efficient adoption of mitigation strategies and adaptation to variable bioclimatic conditions. We point out that currently, it has become a necessity to describe comfort conditions or bioclimatic risk related to climate along with the presentation of the weather.

4. Findings and discussion

In general, the bioclimatic factor should be seen as a tool in scientific research. This analysis offers a wide range of possible assessments of the climatic potential. This, whether positive or negative, indicates how a region imprints these characteristics on human health and the activities performed. These factors are seen as an important component in the treatment of climate on the human body.

The explanation is based, in the case of the present analysis, on the relationship established between elements such as temperature and humidity of the air. We also recall that the bioclimatic factor is not entirely "guilty" for human comfort. In the equation of human comfort, individual reactions to a banal heat exchange also intervene, that is, subjective elements that vary from individual to individual. This entire process is called the caloric exchange of the human body.

The bioclimatic risk due to warming depends both on the variation of radiative and dynamic climatogenic factors, but also on the variation of local physical-geographic factors. Thus, they become factors that play an essential role in the diversification of the climatic and, implicitly, bioclimatic conditions of the Romanian Plain area. Therefore, the detailed analysis of the different bioclimatic indices is interesting (they can also be adapted to the climate of Romania) and useful in studying their spatio-temporal variation on a single reference scale (being possible to best describe the meteorological conditions for tourists and local people, physiological comfort or the risk related to the local climate). Using the meteorological database created for this purpose, the values obtained through mathematical calculations and taking into account the applicability limits of the index (Ionac, 2008; Grigore, 2012) it was possible to create a synthetic and suggestive image of the degree of spatial and temporal extension of the heat stress specific to the Romanian Plain (Table 1).

Table 1

Applicability limit and threshold values of RSI (units) corresponding to different types of bioclimates

Applicability limit: air-temperature less than or equal to + 35^{0}C		
Relative Strain Index (RSI) - units -	**Type of bioclimate**	**Type of bioclimatic comfort/discomfort**
RSI ≤ 0.15	Bioclimatic comfort	Bioclimatic comfort
0.15 ≤ RSI ≤ 0.25	Bioclimatic discomfort for more sensitive persons	Bioclimatic discomfort
0.25 ≤ RSI ≤ 0.35	Bioclimatic discomfort for all persons	
0.35 ≤ RSI ≤ 0.45	Overheating risk for more than 50% of the population	
RSI ≥ 0.45	Heat-stroke risk for all population	

(*Source:* Grigore, 2012)

As we specified in the data and methods used, this index was calculated strictly for the summer period, namely the three months – June, July and August. Knowing the regime of this index allows the identification of specific methods of personal adjustments to deal with heat stress. For example, by reading different specialized writings we can learn how to make a realistic planning of the vacation or the recreation area (De Freitas, 2003), we can improve the conditions within the health facilities and we can opt for different daily activities (World Health Organisation, 2011), etc. These assessments are useful in adopting adaptation and mitigation strategies to bioclimatic conditions in vulnerable regions.

Relative Strain Index allows the evaluation of bioclimatic conditions of heat stress, highlighting areas of potential discomfort and even bioclimatic risk (due to hyperthermia). For this purpose, a series of graphic and cartographic representations were made (Table 2), which highlight the heat stress situation in the Romanian Plain.

Table 2

Average Relative Stress Index (units) on the Romanian Plain, in the warm season

Stația meteorologica	luna		
	VI	VII	VIII
Eastern Sector of the Romanian Plain and the Baragan Plain			
Tecuci	0,14	0,23	0,21
Galați	0,15	0,24	0,23
Buzău	0,16	0,26	0,24
Grivița	0,27	0,30	0,28
Călărași	0,20	0,30	0,29
Bucharest Plain			
Ploiesti	0,15	0,24	0,23
Bucuresti	0,19	0,29	0,28
Târgovişte	0,14	0,26	0,23
Titu	0,17	0,27	0,25
The plain sector between Olt - Arges			
Giurgiu	0,21	0,33	0,32
Videle	0,23	0,35	0,31
Zimnicea	0,23	0,36	0,35
Oltenia Plain			
Craiova	0,22	0,36	0,31
Caracal	0,21	0,35	0,31
Calafat	0,20	0,36	0,32
Bechet	0,22	0,36	0,35

(Source: own research, 2025)

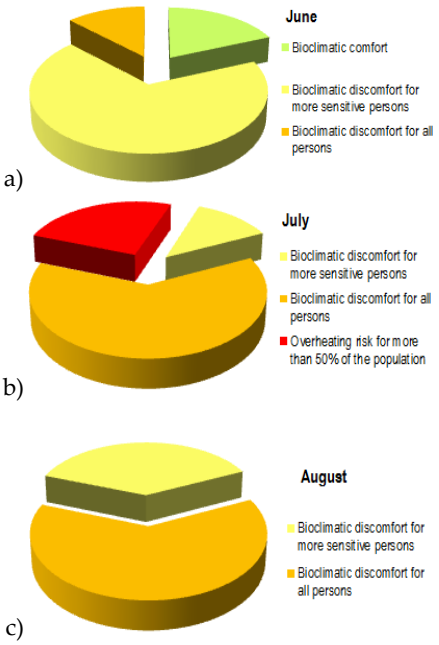

Figure 4. Monthly frequency (%) of bioclimate changes *(Source: own research, 2025)*

The corresponding RSI values that we obtained for the summer season clearly delimit several typical areas of bioclimatic risk. By visualizing and analyzing centralized data and graphic and cartographic achievements, we can identify three monthly situations.

The month of June is highlighted by two bioclimatic trends. We find the bioclimatic comfort area in the northern area of the plain, representing only 30.0% of the total area of the plain. The area of mild bioclimatic discomfort, on the other hand, dominates in most of the plain (70.0% of the total area). In this month, the vulnerable population is exposed to the danger of warming (Fig. 4a).

In July, we find that bioclimatic comfort appears insular in the north of the plain, in proportion to 5.0% of the total area of the Romanian Plain. The bioclimatic area of discomfort due to heating covers most of the plain, respectively 85.0% of the total area. This expansion of the risk area due to overheating by increasing the area also leads to an increase in the number of those affected. The calculated values indicate a physiological discomfort for all people alike, with chances of overheating risk for more than 50.0% of the population present in the identified area. In the southwest and south, representing about 10.0% of the total area of the plain, an insular area also appears with a very intense risk of overheating for the entire exposed population. These islands appear as a result of the predisposition to extremely hot and dry advections of tropical and continental air masses from North Africa (Fig.4b).

For the month of August, on the other hand, the area of bioclimatic discomfort due to heating decreases to 30.0% of the total area of the plain. Only one area with insolation can be identified, in the southern part of the Plain, representing about 4.0% of the total area. The area with moderate risk is identified in the area of the Craiova - Bechet localities. By viewing the centralization of the results and the graphical representations, we can see that the rest of the analyzed region is characterized by moderate and mild discomfort. Thus, in the case of moderate bioclimatic discomfort, over 50.0% of the population is exposed to a risk of illness or exacerbation of certain health conditions. In a proportion of 20.0% of the total area of the plain, we also find an area with mild bioclimatic discomfort. In this case, only sensitive people are exposed to a mild risk due to overheating. Regarding the area with moderate bioclimate, the discomfort decreases and is distributed evenly over the total area of the plain (Fig.4c).

Looking at the whole, it is found that only two areas in the Romanian Plain raise serious problems. These are Craiova-Bechet (in the southwest) and Zimnicea (in the south) and are individualized as two areas of real risk of heat shock. The moments of bioclimatic discomfort are due to the summer, especially, to the hot and humid days, when the human body loses heat (for example through transpiration at the skin level, upper respiratory tract, etc.), when the body fails physiologically and allows the manifestation of sensations of overheating.

The intensity and spatial extension of the bioclimatic stress due to overheating in the Romanian Plain, expressed in this case by the relative strange index, specific to the hot summer season, are related to the distribution of the main landforms and the circulation pattern of air masses. The bioclimatic stress due to overheating increases from the northwest to the southeast. In the Romanian Plain we identify a danger to human health, only in three areas. These are identified in the southwest and south of the plain. In the south of the Oltenia Plain (the area with sand dunes in the south), some local topoclimatic conditions can cause the intensification of bioclimatic stress and the islands in the area of the Băileşti-Craiova-Bechet and Zimnicea localities, which are exposed to frequent advections of warm, tropical air masses from North Africa.

In general, the bioclimatic risk due to heating depends primarily, as the results obtained indicate, on the variation of radiative and dynamic climatogenic factors, but also on the variation of local physical-geographic factors. These factors play an essential role in the diversification of the climatic and, implicitly, bioclimatic conditions of the Romanian Plain. The state of bioclimatic comfort or discomfort that the human body feels directly depends on the manifestation of its caloric exchange processes. This exchange is influenced by the regime of air temperatures and relative humidity of the air. Through the combined or opposing action of the elements, it is possible to determine the amplification or diminution of the sensations of comfort or discomfort due to heating felt by the human body, at different times. The regime of sensations depends in turn on the succession of weather types and the various local influences in the Romanian Plain.

As we learn from scientific studies, presented over time, climate change is seen as a direct influence on tourism. The most affected segment of the tourist activity being the decision-making process. Weather and climate influence decisions both in the destination or receiving area, and in the region from where the tourist departs or is supplied. The need to adapt to change means increased attention to increasing resilience, reducing vulnerability, but also to appropriately handling the opportunities created by this climate change. Taking these aspects into account, decision-makers must assume a faster and more efficient adaptation. Tourism demand is affected, in addition to heat stress, by: seasonality, the tendency to

desertification, the increase in the frequency of fires (which mainly threaten infrastructure), high costs of cooling rooms in accommodation units and means of transport, the emergence of infectious diseases, the loss of natural or anthropogenic attractions, the deterioration of cultural heritage and tourism infrastructure, business interruption costs, etc.

Conclusions

Taking into account the warnings reported following the analysis, we can say that during the summer there are no prohibitions regarding tourist activity in the south of the country. The thermal condition and the adequate understanding of the concept of developing a complex relational system. The new system is as important as the one developed by the environments used by planners and decision-makers. The caloric stress on the human body becomes, in itself, a significant threat to life. Among the most well-known causes is inadequate infrastructure. In this context, the results obtained in this new segment of studying the climate and assessing the impact on tourist activities imprint a great responsibility in everyday life. Today, this responsibility consists in the generation and rapid and efficient transfer of the information obtained. Information becomes a useful tool between decision-makers and citizens. Thus, it helps to plan and assume the development of the life of the human community, in general, by respecting its requests.

The response of human society to the inevitable impact of different types of influences will be significantly different from the present one. The assessment of present and future risks already requires interdisciplinary and transdisciplinary approaches in order to couple climate modeling with socio-economic modeling. Therefore, the detailed analysis of such bioclimatic indices is not only interesting, because they have also been adapted to the Romanian climate, but also useful in studying their spatio-temporal variation on a single reference scale to best describe people's meteorological conditions or physiological comfort or climate-related risks.

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DECLARATION OF CONFLICTING INTERESTS
The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING
The authors received no financial support for the research, authorship, and/or publication of this article.