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Original article

Predictive attentional assessment in chess-playing children using the Shulte-Platonov table and the Bootstrap method

[Evaluación atencional predictiva en niños ajedrecistas con la tabla de Shulte-Platonov y el método Bootstrap]

[Avaliação atencional preditiva em crianças enxadristas com a Tabela de Shulte-Platonov e o método Bootstrap]

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ABSTRACT

Introduction: Competitive chess demands high cognitive abilities, such as attention and executive functions. Assessing these in young athletes is often limited by small sample sizes. This pilot study analyzed whether performance on the Shulte-Platonov red-black board (TRNS-P), a task that measures attentional and executive efficiency, predicts performance on the d2 attention test in chess-playing children.

Objective: To validate, using the Bootstrap statistical procedure, the predictive capacity of TRNS-P performance on the results of the d2 test in a small sample of chess-playing children.

Materials and methods: Five chess players (9-13 years old) participated. An efficiency index (accuracy/time) was measured in the TRNS-P and the total score (TR) in the d2 test. To overcome the limitation of n=5, a Bootstrap procedure with 10,000 iterations was used, calculating the Spearman correlation coefficient (rs), 95% non-parametric confidence intervals and an empirical p-value.

Results: The analysis revealed a strong and statistically significant positive correlation between the two measures (observed rs = 0.85). The 95% Bootstrap confidence interval was [0.45, 0.99] (excluding zero), and the empirical p-value was 0.042, confirming the robustness of the finding.

Conclusions: Performance on the TRNS-P is a key predictor of attentional performance as measured by the d2 test in children who play chess. This study demonstrates the usefulness of the Bootstrap method for obtaining valid inferences and quantifying uncertainty in pilot studies with small samples, offering a promising methodological framework for cognitive assessment in high-performance settings.

Keywords: chess, Shulte-Platonov red-black table, Bootstrap procedure, predictive evaluation.

RESUMEN

Introducción: el ajedrez competitivo exige altas capacidades cognitivas, como la atención y las funciones ejecutivas. Evaluarlas en jóvenes deportistas a menudo se ve limitado por muestras pequeñas. Este estudio piloto analizó si el rendimiento en la tabla rojinegra de ShultePlatonov (TRNS-P), una tarea que mide eficiencia atencional y ejecutiva, predice el desempeño en el test de atención d2 en niños ajedrecistas.

Objetivo: validar, mediante el procedimiento estadístico Bootstrap, la capacidad predictiva del rendimiento en la TRNS-P sobre los resultados del test d2 en una muestra reducida de niños ajedrecistas.

Materiales y métodos: participaron cinco ajedrecistas (9-13 años). Se midió un índice de eficiencia (precisión/tiempo) en la TRNS-P y la puntuación total (TR) en el test d2. Para superar la limitación de n=5, se empleó un procedimiento Bootstrap con 10,000 iteraciones, calculando el coeficiente de correlación de Spearman (rs), intervalos de confianza no paramétricos del 95% y un p-valor empírico.

Resultados: el análisis reveló una correlación positiva fuerte y estadísticamente significativa entre ambas medidas (rs observado = 0.85). El intervalo de confianza Bootstrap del 95% fue [0.45, 0.99] (excluyendo el cero) y el p-valor empírico fue de 0.042, lo que confirma la robustez del hallazgo.

Conclusiones: el rendimiento en la TRNS-P es un predictor fundamental del desempeño atencional medido por el test d2 en niños ajedrecistas. El estudio demuestra la utilidad del método Bootstrap para obtener inferencias válidas y cuantificar la incertidumbre en investigaciones piloto con muestras pequeñas, ofreciendo un marco metodológico prometedor para la evaluación cognitiva en entornos de alto rendimiento.

Palabras clave: ajedrez, tabla rojinegra de Shulte-Platonov, procedimiento Bootstrap, evaluación predictiva.

RESUMO

Introdução: O xadrez competitivo exige altas capacidades cognitivas, como atenção e funções executivas. Avaliá-las em jovens atletas é frequentemente limitado por amostras pequenas. Este estudo piloto analisou se o desempenho no Tabuleiro Vermelho-Preto de Shulte-Platonov (TRNS-P), uma tarefa que mede eficiência atencional e executiva, prediz o desempenho no Teste de Atenção d2 em crianças enxadristas.

Objetivo: validar, mediante o robusto procedimento estatístico Bootstrap, a capacidade preditiva do desempenho no TRNS-P sobre os resultados do Teste d2 em uma amostra reduzida de crianças enxadristas.

Métodos: Participaram 5 enxadristas (9-13 años). Foi medido um índice de eficiência (precisão/tempo) no TRNS-P e a pontuação total (TR) no Teste d2. Para superar a limitação de n=5, foi empregado um procedimento Bootstrap com 10.000 iterações, calculando o coeficiente de correlação de Spearman (rs), intervalos de confiança não paramétricos de 95% e um p-valor empírico.

Resultados: a análise revelou uma correlação positiva forte e estatisticamente significativa entre ambas ases medidas (rs observado = 0,85). O intervalo de confiança Bootstrap de 95% foi [0,45, 0,99] (excluindo zero) e o p-valor empírico foi de 0,042, confirmando a robustez do achado.

Conclusões: O desempenho no TRNS-P é um preditor significativo do desempenho atencional medido pelo Teste d2 em crianças enxadristas. O estudo demonstra a utilidade do método Bootstrap para obter inferências válidas e quantificar a incerteza em pesquisas piloto com amostras pequenas, oferecendo uma estrutura metodológica promissora para a avaliação cognitiva em ambientes de alto desempenho.

Palavras-chave: xadrez, tabuleiro vermelho-preto de Shulte-Platonov, teste d2, procedimento Bootstrap, avaliação preditiva.

INTRODUCTION

Competitive chess presents a scenario that demands high-order cognitive functions, including sustained attention, visual processing speed, working memory, and mental flexibility (Ye, 2025). The development of analytical cause-and-effect thinking, inherent in the game regardless of skill level, is supported and enhanced by key cognitive processes. Thus, a player's ability to quickly scan the board, identify patterns, and switch between strategies depends largely on the efficiency of these attentional and executive processes (Szczepańska & Kaźmierczak, 2022; Nanu *et al.,* 2023), which are comprehensively exercised and refined during practice.

Chess is an activity that functions as a natural laboratory for the study of high-performance cognition, intertwining analytical thinking with actions that require tactical and strategic execution, and thus fostering the intellectual and decision-making aspects of those who practice it (Uskoković, 2023; Chowdhary, *et al.,* 2023).

The relevance of chess to cognitive science is still unknown. Chess involves a series of cognitive exercises that challenge the problem-solving abilities, attention, and memory of its players. The game requires players to anticipate opponents' moves, plan several steps in advance, and adapt their strategies based on changing scenarios. This constant mental activity fosters the development of cognitive skills transferable to other aspects of life, critical thinking, and strategic planning (Stegariu) . *et al.,* 2022; Stegariu *et al.,* 2023).

According to the model by Miyake *et al.* (2000), executive functions such as mental flexibility (to change strategies), working memory (to maintain and manipulate positions), and inhibitory control (to suppress impulsive or irrelevant moves) are essential components that determine a chess player's performance. Williams *et al.* (2025), in a meta-analysis, confirmed a strong relationship between these cognitive abilities and chess skill level. Therefore, assessing these functions in young chess players not only describes their cognitive profile but can also predict their performance potential and areas for improvement.

Various tools have been used to evaluate these cognitive constructs. Most studies are based on comparing chess players with non-chess players on various cognitive measures, using univariate analysis. However, regarding cognitive performance on specific functions that demonstrate a measure of the chess player's optimal cognitive state, research involving multiple cognitive domains interactively and closely transferring to the chess player's ability or playing strength is still lacking (González-Burgos *et al.*, 2025).

This perspective requires the adoption of new methodological approaches grounded in statistics and experimentation. Overcoming the limitations of univariate analyses and simple group comparisons demands the use of multivariate and longitudinal models that can examine the dynamic interaction between multiple cognitive domains (such as working memory, inhibitory control, and mental flexibility) and how this synergy correlates with playing strength in chess.

In this regard, ecologically valid experimental designs are needed that use close transfer tasks, that is, cognitive tests that simulate the real demands of the game, in order to more accurately and directly measure the optimal cognitive state of the player during chess performance.

This principle is precisely linked to the findings of Enke and Graeber (2023), who demonstrate that cognitive uncertainty depends on the complexity of the task being performed and how this can explain various cognitive phenomena. Chess, as a highly complex context, generates cognitive uncertainty that current experimental methodologies are unable to approximate, reinforcing the need to develop new research approaches.

Given this methodological need, specialized tools such as the Shulte-Platonov Red - Black Table (TRNS-P) offer a promising approach. It represents the kind of instrument with close transferability that can begin to address the complex psychological dynamics and cognitive uncertainty inherent in gambling, providing an ecological and specific measurement of the player's optimal state.

The Shulte-Platonov Red and Black Table (TRNS-P), a numerical matrix requiring rapid visual search and sequencing, has proven to be a sensitive instrument for measuring the efficiency of selective and distributed attention, as well as sequential planning ability. Its execution involves frontoparietal networks associated with executive control and visuospatial systems, making it an ideal candidate for evaluating skills directly transferable to the chess context.

In the context of cognitive assessment, the Shulte-Platonov Red -Black Table (TRNS-P) is a test that goes beyond simple visual searching. It requires a systematic and sequential search under time pressure within a matrix (e.g., 5x5) containing randomly distributed numbers. This process mobilizes a neurocognitive network comprised of: a) the frontoparietal attentional network for selecting and directing attention; b) visuospatial working memory to retain the sequence and location of numbers already found; c) cognitive flexibility to switch between search patterns; and d) inhibitory control to resist distraction by irrelevant stimuli. Thus, better performance on the test (high accuracy and low time) reflects greater efficiency of these executive and attentional networks.

However, experimental research with specific populations of child athletes often faces the challenge of small sample sizes, characteristic of pilot or highly specialized studies. This limitation restricts the applicability of traditional parametric statistical tests and the generalizability of the findings.

In this context, the Bootstrap procedure (Efron, 1979), since its inception, has emerged as a robust methodology that facilitates the prediction of outcomes and the identification of patterns and trends in a sport as complex and dynamic as chess. According to authors such as Varmann & Mouriño (2024), this non-parametric resampling technique allows for the estimation of the sampling distribution of statistics of interest and the calculation of reliable confidence intervals without relying on rigid distributional assumptions, thus maximizing the information obtainable from small samples.

The exploratory nature and small sample size (n=5) of this pilot study preclude the use of traditional parametric inferences with guaranteed robustness. The Bootstrap procedure (Efron, 1979) overcomes this limitation by resampling with replacement of the original data. This nonparametric method allows us to: 1) estimate the sampling distribution of statistics such as Spearman's rank correlation coefficient (r) ; 2) calculate robust confidence intervals (CIs) without assuming normality; and 3) obtain empirical p-values through permutation tests. Its application transforms preliminary findings into evidence with a robust quantification of uncertainty, maximizing the information obtainable from small samples.

To validate the predictive capacity of the Shulte-Platonov Red-Black Board (TRNSP) in children chess players, a criterion for measuring attention with established validity and reliability is required. In this case, the d2 attention test (Brickenkamp , 1962) is a classic cancellation test that measures selective and sustained attention, as well as processing speed and performance quality (omissions and commissions). Its total score (TR - Total Rate minus errors) is a robust indicator of attentional capacity. Its use as a criterion variable allows the findings of the Shulte-Platonov Red-Black Board (TRNS-P) test to be anchored in a standardized metric widely accepted in the neuropsychology, chess, and sports psychology literature.

Based on these arguments, the present study proposes the following central hypothesis: that better performance on the Shulte-Platonov Red-Black Table (TRNSP) task, which assesses the efficiency of selective and distributed attention and sequential planning ability, will predict better performance on the d2 attention test in chess-playing children.

It is hypothesized that this relationship will maintain its statistical significance when evaluated using the robust Bootstrap method.

In this sense, the objective of the research is to validate, using the Bootstrap procedure, the predictive capacity of performance in a Shulte-Platonov red-black board task (TRNS-P) on performance in the d2 attention test in a sample of chess-playing children.

MATERIALS AND METHODS

Research Design

A cross-sectional correlational-predictive design was used. The relationship between a predictor variable (Efficiency Index: performance composed of time and accuracy) derived from the Shulte-Platonov red-black table (TRNS-P) and a criterion variable (d2 test score) was measured, with the analytical logic that performance in the TTS can predict the level of attention measured by the d2 in chess-playing children.

Participants

The sample consisted of 5 children (n=5, 4 boys, 1 girl) aged between 9 and 13 years (M=11.2, SD=1.3). All were active chess players in competitive training, with a minimum of two years of practical experience at the ISLA Chess Study Center. Participants were selected using non-probability purposive sampling. Inclusion criteria were: a) basic-competitive level in chess, b) informed consent signed by parents/guardians, and c) absence of diagnosed neurodevelopmental or neurological disorders.

Instruments and Procedure

The experimental session consisted of two sequential stations in a controlled environment.

Station 1: Shulte-Platonov red-black board test (TRNS-P). It allows the determination of concentration, stability and alternation of attention using the Schulte-Platonov method (Figure 1).

Fig. 1. *- Performance of a participant during completion of the Shulte Platonov red and black board task at the ISLA Chess Study Center*

Material: Shulte-Platonov red-black board (TRNS-P) of 5x5 (numbers 1-25 in black and 24-1 in red, randomly distributed).

Task: The participant had to sequentially match the numbers according to the rule: black number in ascending order (1,2,3...) with its corresponding red number in descending order (24,23,22...), following the sequence 1-24, 2-23, etc. The black number 25 had no pair.

Measurement: The total time (in seconds) to complete the sequence and the percentage of accuracy (hits/total pairs) were recorded. The predictor variable was a composite efficiency index: (accuracy %) / (time in seconds). A higher value indicates greater efficiency (more accurate and faster).

Station 2: d2 attention test.

Material: Standard form of the d2 test.

Task: On a sheet with rows of the letters 'd' and 'p' with 1-4 apostrophes, the participant had to cross out, in a limited time (4 minutes 40 seconds per section, according to standard protocol), only the characters 'd' with 2 apostrophes ('d2').

Measurement: The total performance score (TR) was calculated according to the manual: TR = (total responses) - (errors by omission + commission). This score constituted the criterion variable.

Mathematical statistical processing of data

To address the limitations of the small sample size and validate the robustness of the findings, a bootstrap resampling procedure (10,000 iterations) was implemented, allowing for the calculation of non-parametric confidence intervals and the estimation of the empirical significance of the correlation. This combined methodological approach enabled the evaluation of both the association between the two measures and the predictive capacity of the Shulte-Platonov red-black table (TRNS-P) on the d2 attention test, with implications for the personalization of neuro -training protocols based on robust statistical evidence. The statistical procedures followed this order:

Descriptive statistics: Means and standard deviations (SD) were calculated for time and accuracy on the Shulte-Platonov red-black board task (TRNS-P), and for TR on d2.

Bootstrap procedure: To overcome the limitation of n=5, a Bootstrap procedure with 10,000 iterations was implemented in R (v4.3.1, boot package).

Resampling with replacement, n=5) were generated from the data pairs (Efficiency Index (time and accuracy), TR d2).

For each sample, Spearman's correlation coefficient (r_s) was calculated.

A non-parametric 95% confidence interval (CI) was constructed using the percentile method (2.5 and 97.5 percentiles).

An empirical p-value was obtained using Bootstrap permutation test (proportion of Bootstrap $r_s \geq |$ observed $r_s|$).

The same procedure was used to calculate 95% Bootstrap CIs for the means of all variables.

For the implementation of all the statistical procedures described, including descriptive analysis, calculation of Spearman's correlation coefficient and, fundamentally, execution of the Bootstrap resampling procedure with 10,000 iterations, the statistical programming environment R (version 4.3.1) was used, operated through the integrated development interface RStudio.

Resampling analyses were performed using the boot package, widely recognized for its robustness in implementing resampling- based inference techniques. This open-source software environment was selected for its ability to perform advanced and reproducible statistical calculations, which is especially valuable for validating results in studies with small sample sizes.

RESULTS AND DISCUSSION

Descriptive statistics with Bootstrap intervals

The Bootstrap procedure, by generating multiple replications of the data through resampling, allows for more robust estimates of population parameters and quantifies their uncertainty using non-parametric confidence intervals, which is particularly valuable in studies with small samples such as this one.

Table 1 presents the key descriptive measures with their 95% Bootstrap CIs. The intervals, although wide due to n=5, provide robust estimates of the population parameters and fall within psychologically plausible ranges (Table 1).

***Table 1.** - Descriptive statistics with Bootstrap confidence intervals (95%)*

Variable	Average	IC Bootstrap 95%	OF
Time(s)	145.2	[125.8, 164.1]	18.7
Accuracy (%)	88.4	[80.1, 94.9]	6.3
Efficiency Index	0.61	[0.50, 0.72]	0.09
Total Score Test d2 (TR)	185.6	[155.8, 215.0]	22.4

***Source:** Database derived from the experiment.*

These preliminary results, obtained and validated using the Bootstrap procedure, not only quantitatively describe the attentional and executive efficiency profile of the sample of chess-playing children, but also establish a statistically sound basis for subsequent predictive analysis.

The confidence intervals, despite reflecting the uncertainty inherent in a small sample size, confirm that the estimates of key variables, such as the Shulte-Platonov red-black board task efficiency index (TRNS-P) and the Total score on the d2 test, are within ranges compatible with efficient attentional performance and promising cognitive ability in this specialized population.

This directional consistency and the robustness of the estimates fully justify the continuation and validation of the correlational-predictive analysis between performance on the Shulte-Platonov red-black board task (TRNS-P) and attentional performance as measured by the d2 test.

Bootstrap-validated correlation analysis

The analysis revealed a strong and significant positive correlation between the Shulte-Platonov red-black board task efficiency index (TRNS-P) and the total score (TR) on the d2 test.

- Observed Spearman coefficient: $r_s = 0.85$.
- Bootstrap 95% confidence interval: [0.45, 0.99] (excluding 0).
- Empirical p-value (Bootstrap): $p = 0.042$.

As can be seen in Figure 2, the Bootstrap distribution of the 10,000 Spearman correlation coefficients is concentrated in positive values, mostly between 0.65 and 0.80 (Figure 2).

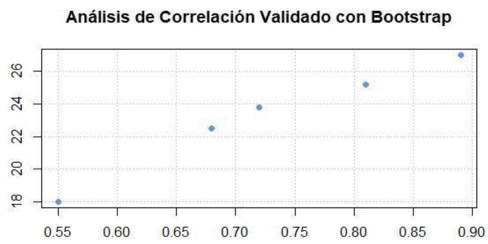

Fig. 2. *- Bootstrap distribution of Spearman's correlation coefficient*

The value observed in the original sample ($r_s = 0.85$, vertical line) is located at the upper end of this distribution, but within the range of plausible values. Notably, none of the Bootstrap replicates produced a negative or zero correlation, providing further visual evidence of the strength of the positive relationship between the variables. The area to the right of the observed value (approximately 4.2% of the distribution) corresponds directly to the p-value of 0.042.

These results indicate that, with 95% confidence, the population correlation is between 0.45 and 0.99, and the probability of obtaining such an extreme result by chance is less than 5%.

This triply robust result (strong in magnitude, accurate in estimation, and significant in probability) statistically validates that the Shulte-Platonov red-black board task (TRNS-P) is a valid predictor of attentional performance in children who play chess. Furthermore, despite the small sample size, the use of the bootstrap procedure allows for a robust quantification of uncertainty, which is especially valuable in pilot studies with specialized populations where obtaining large samples is difficult.

Discussion of the results

The application of the Bootstrap procedure allowed for robust conclusions to be drawn from a very small pilot sample. The central finding showed a strong and significant correlation (r = 0.85, p = 0.042) between performance on the Shulte-Platonov red-black table (TRNS-P) and the d2 test. This result is supported by a rigorous, non-parametric statistical evaluation, which yielded a Bootstrap CI [0.45, 0.99], demonstrating a legitimate positive relationship.

This suggests that chess-playing children with greater efficiency in attentional and executive networks, as measured by time and accuracy on the ShultePlatonov red-black table (TRNS-P), also show better performance on a standardized sustained and selective attention task such as the d2 test.

The use of the Bootstrap procedure in this study to validate the relationship between the TRNS-P and the d2 test aligns with a growing methodological trend in cognitive research with small samples. Previous research, such as that by Zou (2007), presents Bootstrap as a robust and recommendable alternative, especially when the assumptions of bivariate normality are not met. In this sense, it provides the statistical framework for the Bootstrap comparison of two correlation coefficients as estimators of the relationship between constructs.

On the other hand, the work of Ratcliff & Childers (2015), in the comparison of cognitive model parameters between conditions, have used Bootstrap in bivariate contexts to estimate robust correlations and confidence intervals in the face of limitations of normality or reduced sample sizes.

As in these studies, our approach allowed us to overcome the limitations of a small sample size (n=5), obtaining a stable, non-parametric estimate of the correlation between variables. However, while many of these studies have focused on general or clinical populations, the present research extends the applicability of the Bootstrap to a high-performance cognitive context—children's chess—thus demonstrating its versatility for the specific assessment of attentional and executive domains in child athletes. This methodological consistency reinforces the validity of the Bootstrap as a fundamental tool for statistical inference in the early stages of cognitive neuroscience applied to sport.

These findings, while robust within the bivariate and low-dimensional context, open the door to future research that could benefit from more advanced and scalable resampling techniques. In particular, methodologies such as that proposed by Shi *et al.* (2025), which refine the Bootstrap for high-dimensional factor-augmented regression models, would offer a powerful framework for integrating multiple cognitive variables (e.g., working memory, inhibitory control, mental flexibility) and contextual predictors, typical of chess, into a single model. Adopting such approaches would not only allow for a more comprehensive validation of the predictive capacity of TRNS-P but also enable the examination of interactions between cognitive domains and their relationship with chess variables, thereby optimizing cognitive assessment and training in high-performance environments.

The Shulte-Platonov red-black board (TRNS-P), therefore, would not only be a visual search task, but an integrated behavioral reflection of key executive components (flexibility, working memory, inhibitory control) that are derived from timing, accuracy and sequential planning, and that are essential both for chess (Williams, *et al.*, 2025) and for attentional performance in general.

These findings align with the literature linking chess to higher executive functions and support the usefulness of specific assessment tools in sports settings. The methodological strength provided by the bootstrap design transforms a potentially fragile preliminary result into robust evidence to guide future research. It demonstrates that valid inferences can be drawn and uncertainty quantified even with small sample groups, provided appropriate statistical techniques are employed.

In light of the findings and their inherent limitations due to the sample size, although mitigated by the use of bootstrap analysis, clear avenues for future research emerge. Therefore, it is necessary to replicate this study with a larger and more representative sample of young chess players. This approach would not only allow for narrower confidence intervals and increased statistical power, but would also enable multivariate analyses, such as regression models, to discern the specific contribution of other individual cognitive subcomponents of the Shulte-Platonov Red-Black Board Task (TRNS-P), such as search time versus accuracy, in predicting attentional performance.

Resampling techniques, such as the bootstrap procedure, is recommended in the pilot phases of cognitive neuroscience research applied to sport. This methodological practice would allow for more reliable estimates to be obtained from small samples, thus providing a more solid foundation for the design and justification of subsequent, larger-scale studies.

On a more ambitious note, future designs should adopt a longitudinal approach. This would allow for the examination not only of the predictive capacity of the Shulte-Platonov red-black table (TRNS-P), but also its potential to forecast the rate of improvement or learning curve of athletes throughout a structured cognitive training program in the chess context.

The dual assessment protocol validated here (TRNS-P + d2 test) has the potential to be transferred and integrated into real-world training environments for talented young chess players. Training coaches in its application could transform it into an agile and objective tool for identifying attentional profiles, personalizing mental training loads, and objectively monitoring cognitive progress, thereby optimizing the athlete's overall development.

CONCLUSIONS

Performance on the Shulte-Platonov red-black board task (TRNS-P), operationalized as an efficiency index (accuracy/time), proved to be a strong and significant behavioral predictor of performance on the d2 attention test in a sample of chess-playing children.

The application of the Bootstrap procedure confirmed the statistical robustness of this relationship (r_s = 0.85, 95% CI [0.45, 0.99], p=0.042), validating the usefulness of resampling methods for inference with small samples in pilot studies.

The combination of a specific cognitive assessment (TRNS-P) with a standardized criterion (d2) and a robust statistical validation (Bootstrap) constitutes a promising methodological framework for the assessment and prediction of attentional performance in high cognitive performance contexts such as youth chess.

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Conflict of interest:

The authors declare no conflicts of interest.

Authors' contribution:

The authors have participated in the writing of the work and analysis of the documents.