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Cognitive Psychophysiological Substrates of Affective Temperaments: A P300 Study

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Abstract

Affective temperaments are the subclinical manifestations or phenotypes of mood states and hypothetically represent one healthy end of the mood disorder spectrum. However, there is a scarcity of studies investigating the neurobiological basis of affective temperaments. One fundamental aspect of temperament is the behavioral reactivity to environmental stimuli, which can be effectively evaluated by use of cognitive event-related potentials (ERPs) reflecting the diversity of information processing. The aim of the present study is to explore the associations between P300 and the affective temperamental traits in healthy individuals. We recorded the P300 ERP waves using an auditory oddball paradigm in 50 medical student volunteers (23 females, 27 males). Participants' affective temperaments were evaluated using the Temperament Evaluation of Memphis, Pisa, Paris, and San Diego–auto questionnaire version (TEMPS-A). In bivariate analyses, depressive temperament score was significantly correlated with P300 latency ($r_s = 0.37$, $P < .01$). In a multiple linear regression analysis, P300 latency showed a significant positive correlation with scores of depressive temperament ($\beta = 0.40$, $P < .01$) and a significant negative one with scores of cyclothymic temperament ($\beta = -0.29$, $P = .03$). Affective temperament scores were not associated with P300 amplitude and reaction times. These results indicate that affective temperaments are related to information processing in the brain. Depressive temperament may be characterized by decreased physiological arousal and slower information processing, while the opposite was observed for cyclothymic temperament.

Keywords

event-related potential, depressive temperament, cyclothymic temperament, personality, arousal

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Introduction

Recent conceptualization of affective temperaments indicates that affective temperamental traits are the subclinical manifestations or phenotypes of mood states and hypothetically represent one healthy end of the mood disorder spectrum.[1,2] Studies have shown that specific affective temperament types (ie, depressive, cyclothymic, hyperthymic, irritable, and anxious) may be the precursors as well as important modifiers of the clinical expression, course, and prognosis of major mood disorders.[2,3] Moreover, a recent surge of research has linked affective temperaments to suicidal behavior,[4-6] alcohol and substance abuse,[7,8] eating disorders,[9,10] female-to-male gender dysphoria,[11] and psychological adjustment to medical disorders[12,13] in a variety of clinical populations; as well as to chronotypes,[14] risk-taking behavior and impulsivity,[15,16] artistic performance,[17,18] and personal choice of profession[19] in nonclinical populations.

Identification of the neurobiological substrates of affective temperaments might help in better understanding of the biological basis of several major psychiatric disorders. However, there have been only few studies investigating this area.[1,20-23] One fundamental aspect of temperament is the individual differences in reactivity, which refers to "the excitability, responsivity or arousability" of the neurobehavioral systems of the organism toward environmental changes.[24] The cognitive event-related potentials (ERPs) reflecting diverse aspects of information processing might be particularly sensitive to detection of the interindividual variations based on reactivity.[25] One commonly studied cognitive ERP component is the P300, a positive parietocentral positivity observed at around 300 ms after presentation of the task-relevant stimuli. P300 has been extensively used as an index of attention activation and information processing both in normality and in various neuropsychiatric disorders,

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including dementia, schizophrenia, and mood and personality disorders, where reductions in amplitudes and increases in latencies have been repeatedly described.[26-29]

Concerning temperament, there have been reports exploring the associations of P300 with introversion/extraversion dimensions of Eysenck's theory and the psychobiological model of personality, as well as other aspects of personality such as impulsivity, anxiety, and anhedonia.[30-34] Among these studies, a fairly consistent finding was higher P300 amplitudes in introverts compared with extroverts.[31] Other studies found associations of greater P300 amplitude with self-directedness, novelty seeking, and reward dependence dimensions of Cloninger's model; while an association of P300 latency with novelty seeking was also reported. Conversely, harm avoidance and persistence were reported to be associated with smaller P300 amplitude and prolonged P300 latency, respectively.[32] Overall, our understanding of the relationship between P300 and temperament is far from clear. Nonetheless, 2 models have been proposed to explain temperament-related differences in P300 characteristics. The first model suggests that subjects with increased physiological arousal levels related to their temperaments tend to allocate more cognitive resources in response to environmental stimuli and they display higher P300 amplitudes and, possibly, shorter P300 latencies compared with low-arousal individuals. An alternative model proposes that different temperaments may be linked to variations in a central control system that actively regulates the amount of effort invested in a specific task, and hence the P300 characteristics.[30]

Because of the frequently documented P300 abnormalities in psychiatric disorders and the significance of affective temperaments in a variety of clinical settings as precursors as well as modifiers of psychopathology, we undertook to explore the potential associations between auditory P300 and the affective temperamental traits. We hypothesized that even in normalcy, various affective temperamental traits might be related with distinct cognitive strategies and this could be effectively revealed by the classical auditory oddball paradigm, extensively used in the clinical and healthy populations. Additionally, identification of the relationship between affective temperaments and P300 could provide valuable data for better interpretation of P300 abnormalities described in patients with psychiatric disorders.

Methods

Study Design and Participants

The experiment was conducted at Rahmi Sakallıoğlu Psychophysiology Laboratory, Department of Psychiatry, Cerrahpaşa Medical Faculty at Istanbul, Turkey. Participants were 62 medical student volunteers (26 females, 36 males) aged 22 to 29 years. ERP recordings of participants were conducted at late morning on the same day with the clinical and psychometric assessments. All participants provided written informed consent before the study and the study protocol was approved by Cerrahpaşa Medical Faculty's Ethics Committee.

A clinical interview was performed by an experienced psychiatrist to ensure that participants had no history of *DSM-IV* axis I psychiatric disorders, neurological diseases (eg, epilepsy), brain surgery, head injury (ie, loss of consciousness greater than 5 minutes), major medical diseases (including hypertension, diabetes, renal and cardiac diseases, presence of an acute infection, etc), regular psychoactive medication use, alcohol or other drug abuse (excluding nicotine), and hearing impairment.

A subset of participants was excluded from analysis due to presence of exclusion criteria (1 female, 2 males), excessive artefacts in the EEG recordings (2 females, 3 males), device failure (2 males) and incomplete questionnaires (2 males). Ultimately, a total of 50 participants with complete data sets (23 females, 27 males) were included in the analysis.

Psychometrics

Affective temperaments of the participants were assessed by Temperament Evaluation of Memphis, Pisa, Paris, and San Diego–auto questionnaire version (TEMPS-A). TEMPS-A was developed as a self-report yes-or-no type questionnaire by Akiskal et al[35] and consists of items questioning one's lifelong emotional, cognitive, psychomotor, circadian, and socially adaptive traits. The Turkish version of TEMPS-A consist of 100 items that pertain depressive (19 items), cyclothymic (19 items), hyperthymic (20 items), irritable (18 items), and anxious (24 items) temperaments. This version is shorter compared with the original 110-item questionnaire due to omission of redundant items according to a former reliability and validity analysis in the Turkish population.[36] TEMPS-A is thought to be a suitable representation of affective temperaments in both clinical and nonclinical samples.[37]

Electrophysiological Recording

The ERP recording was carried out in a sound-proof, electrically shielded room while the participant sat in a high-backed chair. An oddball 2-tone discrimination task was used for elicitation of auditory P300 potentials. The oddball sequence consisted of 4 blocks of 190 standard tones (500 Hz; 70 dB pure tones; 50 ms; 5 ms rise and fall time) and 30 target tones (1000 Hz; all other parameters identical to standard tones) presented binaurally (via headphones) in a quasi-random pattern. Each block was separated by brief rest periods. The inter-stimulus interval was 1.2 second. Participants were instructed to press a response key on a set only to the target tones while fixating their eyes on a cross on the wall in front of them. Speed and accuracy of response were both equally stressed in the instructions. Participants' accuracy rates and reaction times to targets were also recorded.

NeuronSpectrum 4/P amplifier (Neurosoft Inc, Ivanova, Russia) was used to record electroencephalographic (EEG) and electro-oculographic (EOG) data at a sampling rate of 512 Hz using 0.05 Hz hardware highpass and 100 Hz hardware lowpass filtering. Active electrodes were placed at frontal (F3, F4,

Table 1. Age, Affective Temperament Scores, Reaction Time, and P300 Amplitude and Latency of Participants According to Gender.

	Females (n = 23)	Males (n = 27)
Age, years, mean (SD)	23.3 (0.8)	24.3 (1.1)
Temperament, median (interquartile range)		
Depressive	3 (2-4)	3 (2-4)
Cyclothymic	5 (3-8)	3 (2-5)
Hyperthymic	8 (5-10)	9 (7-13)
Irritable	1 (0-3)	2 (0-3)
Anxious	4 (2-8)	2 (1-4)
P300, mean (SD)		
Amplitude (μV)	16.1 (5.2)	12.1 (4.9)
Latency (ms)	286 (31)	295 (35)
Reaction time (ms), mean (SD)	278 (52)	286 (36)

Fz), central (C3, C4, Cz) and parietal (P3, P4, Pz) locations according to 10/20 International System. Linked electrodes placed on left and right mastoid processes served as reference and a mid-forehead electrode as ground. Blinks and eye movements were recorded with bipolar electrodes located above and below the left eye. Sintered Ag/AgCl electrodes were used for recordings and impedances were kept <10 kohm.

ERP Reduction and Analyses

EEGLab (version 13) and ERPlab (version 5) Matlab packages were used for the analysis of EEG signals. Briefly, data were filtered offline with a 0.2- to 20-Hz band-pass filter. The filtered data were segmented into epochs starting 100 ms before stimulus onset to 900 ms after stimulus onset. Epochs containing ocular, muscle and motion artefacts were removed initially with a ±70 μV simple voltage method, then visually by an experienced technician. Data were baseline-corrected using the average of 100 ms prestimulus epoch and averaged for the target stimuli. Only stimuli with a correct target response were included in the target average. The peak amplitude and latency for the P300 were measured using an automated peak detection routine within a window of 250 to 450 ms after onset of the stimulus and later confirmed visually. Average percent of epochs excluded were 18%. Overall error rate of participants was less than 1%. We used P300 amplitude and latency at Pz for the statistical analyses in this study, as largest P300 waveforms in our sample were measured at this location, and evidence indicates that Pz and Cz are the more suitable sites to obtain P300 endophenotypes.[38]

Statistical Analysis

Summary results are presented as means (SDs) or medians (interquartile range [25th%, 75th%]). Dichotomous variables were compared using Student's *t* tests or Mann-Whitney *U* tests, where appropriate. Spearman correlation coefficients were used to measure the relationship between continuous variables. Multiple linear regression models were developed to predict P300 latency and amplitude (dependent variables) from scores of the affective temperaments (independent variables) which were included if they had at least a trend-level relation with the dependent variable in the correlational analysis ($P <$ 10%). These models were controlled for the effects of gender if indicated by a significant association between gender and the dependent variable in univariate analysis. SPSS 20.0 (IBM SPSS) was used for the statistical analysis. $P < .05$ was considered statistically significant.

Results

Participant Characteristics and Affective Temperaments

Table 1 summarizes the age and affective temperament characteristics of participants according to gender. Females were significantly younger than males in our sample ($t = 3.4$, $P < .05$); however, the difference was slight. We found prominent difference between genders only in the anxious subscale of TEMPS-A, on which female participants scored significantly higher than males ($U = 424.5$, $P = .02$).

Additionally, we investigated the bivariate correlations among affective temperaments in our sample. The significant correlations relate irritable temperament with cyclothymic temperament ($r_s = 0.37$, $P < .01$); and anxious temperament with irritable temperament on one hand ($r_s = 0.53$, $P < .01$) and cyclothymic temperament on the other hand ($r_s = 0.48$, $P < .01$). Also, hyperthymic temperament was weakly correlated with irritable temperament ($r_s = 0.28$, $P = .04$).

Psychophysiological Data and Affective Temperaments

Gender Comparisons and Bivariate Correlations. Table 1 summarizes the psychophysiological data of participants according to gender. In our sample, females had significantly greater P300 amplitudes compared with males ($t = 2.8$, $P < .05$). The correlations between the psychophysiological data and affective temperament scores are presented in Table 2. P300 amplitude and reaction time were not significantly correlated with either of

Table 2. Correlation Matrix of Affective Temperament Scores of TEMPS-A With Reaction Time and P300 Amplitude and Latency.[a]

	Depressive	Cyclothymic	Hyperthymic	Irritable	Anxious
P300					
Amplitude	0.01	0.03	–0.02	0.11	0.24*
Latency	0.37**	–0.23*	0.14	0.03	–0.19
Reaction time	0.14	–0.15	0.08	0.14	0.12

Abbreviation: TEMPS-A, Temperament Evaluation of Memphis, Pisa, Paris, and San Diego–auto questionnaire.
[a]The values are Spearman correlation coefficients.
*$P < .1$; **$P < .01$.

Table 3. Results of Multiple Linear Regression Analyses for Dependent Variables P300 Latency and Amplitude.

	Regression			
Variables	*b* (SE)	β	*t*	*P*[a]
P300 latency				
Depressive	7.15 (2.39)	.40	2.98	**<.01**
Cyclothymic	–2.21 (1.03)	–.29	–2.14	**.03**
Adjusted R^2 = .15; $P < .01$				
P300 amplitude				
Anxious	0.33 (0.25)	0.18	1.3	.20
Male	–3.38 (1.52)	–.31	–2.22	**.03**
Adjusted R^2 = .14; $P = .01$				

[a]Significant values are presented in boldface.

the five affective temperaments. On the other hand, P300 latency was positively correlated with depressive temperament scores ($r_s = 0.37$, $P < .01$). Partitioning the participants by gender revealed a moderate positive correlation between the 2 variables in males ($r_s = 0.51$, $P < .01$), and a positive nonsignificant one in females ($r_s = 0.22$, $P > .05$).

Regression Analyses. A multiple linear regression model for prediction of P300 latency (dependent) using depressive and cyclothymic temperament scores as independent variables was developed, as the former temperament had a significant ($P < .01$) and the latter had a trend-level correlation ($P < .1$) with P300 latency in bivariate analyses. Results of this analysis revealed that depressive and, to a lesser extent, cyclothymic temperament scores were the independent variables associated with P300 latency. Another model which explored the association of anxious temperament scores with P300 amplitude (dependent) revealed that this temperament was not associated with P300 amplitude after adjustment for the significant effects of gender. Table 3 presents the results of the multiple linear regression analyses for P300 latency and amplitude. Partial residual plots (Figure 1) reveal the independent associations of P300 latency with depressive and cyclothymic temperament scores.

Since only one participant in our sample had a dominant temperament based on temperament scores (a TEMPS-A subscore 2 SD above the previously published normative data mean), we did not attempt to analyze participants' psychophysiological data based on dominant temperaments. Grand average P300 ERP waveforms of extreme scorers on depressive and cyclothymic temperaments (the approximate highest vs the lowest thirds based on the temperament scores) are depicted in Figure 2.

Discussion

We examined whether affective temperaments were distinguishable on an electrocortical index of information processing, the P300 component, during an auditory oddball task in healthy adult volunteers. First, we have shown a relation between the depressive temperament and the prolonged P300 latency. Second, we detected a relatively weaker association between the cyclothymic temperament and the shorter P300 latency. These findings were more prominent for the male participants compared to females. To our knowledge, no study to date evaluated relationship between P300 and affective temperaments.

P300 latency represents the time required to detect and evaluate a target stimulus; thus, it is conceived as an index of cognitive efficiency.[29,39,40] Accordingly, we may link the depressive temperament to an inefficient behavioral strategy in the information processing. In contrast, the finding of shorter P300 latency for the cyclothymic temperament suggests that high scorers in this temperament might have a strategy connected with prompt and efficient evaluation of the stimuli.

As mentioned before, earlier studies investigating the individual differences in the P300 characteristics based on diverse personality models (ie, introversion-extraversion, the

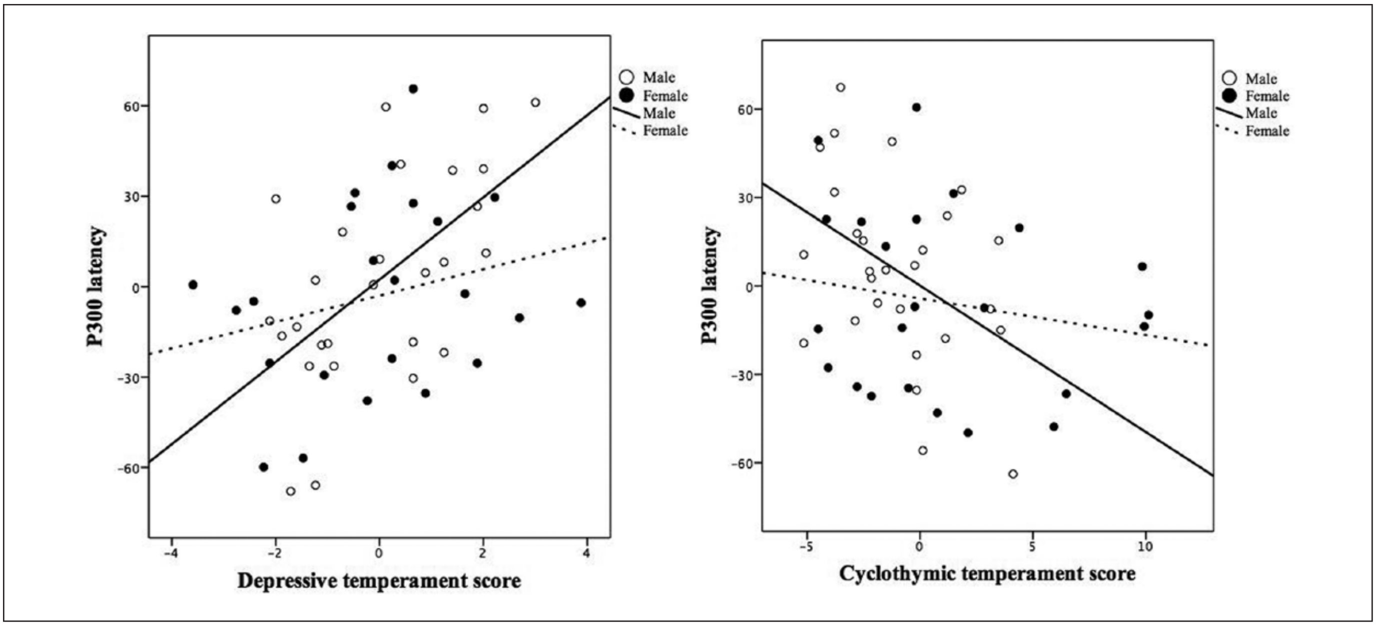

Figure 1. Partial residual plots between P300 latency and (left) depressive temperament and (right) cyclothymic temperament score by gender.

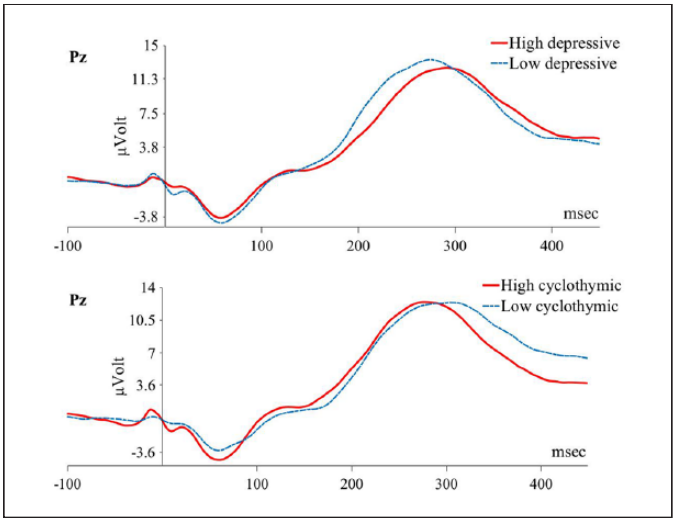

Figure 2. Grand average P300 waveforms of the highest versus the lowest thirds based on (above) depressive (23 versus 17 subjects) and (below) cyclothymic temperament scores (21 versus 15 subjects).

psychobiological model of temperament and further aspects of personality) have provided some inconsistent results. However, as concluded by Polich,[29] a correlation between individual differences for personality-related arousal levels and P300 can generally be identified across these studies. This view shares similar theoretical underpinnings with the resource allocation model of P300 generation[41] and indicates that *physiological arousal* governs the amount of processing capacity that can be allocated as attentional resources to a given task. In other words, low-arousal individuals orient their attentional resources to novel stimulations of the environment in a less efficient way, and consequently generate attenuated or prolonged P300 waveforms compared with high-arousal individuals. Based on our findings, we hypothesize that individuals with depressive temperament are more likely to have low levels of arousal, and they use an inefficient resource allocation strategy; while in contrast individuals with cyclothymic temperament can be characterized by increased arousal and an efficient resource allocation. Alternatively, these 2 temperaments might be associated with distinct characteristics in a central control system that regulates the amount of *effort invested* and attentional resources used during the task. The assumption of a central control system implies that the attentional resources are actively allocated, depending on the subject's baseline arousal level and required arousal during the task, as well as his/her motivational status.[30]

Individuals with depressive temperament are traditionally described as quiet, gloomy, self-reproachful and apathetic; and this temperament has been related with a low level of novelty seeking,[42,43] a trait toward excitement, impulsive decision making and behavioral activation in response to novelty.[44] Conversely, cyclothymic temperament, which is characterized by intense emotionality and a tendency to rapid changes in the level of energy and mood, has been related with increased novelty seeking.[42,43] It is of note that there is now a substantial amount of evidence that supports the involvement of dopaminergic system in novelty-seeking behavior.[45-47] Arguably, our findings of altered P300 latency with the depressive and cyclothymic temperaments might suggest an indirect evidence of the dopaminergic basis for these affective traits. This is in line with the findings from the clinical, genetic, and in vivo studies that show an important contribution of dopaminergic activity to the generation of P300,[28] and fits well with the aforementioned associations that relate novelty seeking (behavioral activation) with depressive and cyclothymic temperaments in opposite directions. Fairly consistent with our findings, in the 2 previous studies with healthy adults, novelty seeking was linked to increased P300 amplitude[31] and shorter P300 latency.[32]

Our findings are in partial agreement with the findings of a recent study that showed a strong negative correlation between the depressive temperament and processing speed in a combined sample of healthy controls and bipolar patients.[21] The authors of the same study also reported associations between the cyclothymic temperament and better performance on a range of executive tests in bipolar patients and in the combined sample. As P300 is often correlated with cognitive functioning, these findings are generally consistent with the results of our study.

We did not detect associations between reaction time and the affective temperaments in our sample. Also, the correlations of reaction time with P300 amplitude and latency was at best moderate (Spearman coefficients <0.4). These findings may be basically due to simplicity of the behavioral task (ie, ceiling effect) or the greater sensitivity of ERP measures to detect differences in information processing compared with behavioral measures.

There are some limitations to our study. For one thing, our analyses were of exploratory nature and we did not perform correction for multiple testing. This calls for confirmation of our findings by future studies. Second, the use of a highly educated sample may limit the generalizability of our findings. However, the use of a homogenous sample with respect to education and age helped us control for the effects of these confounding factors. Third, almost none of the individuals in our sample had a predominant affective temperament as defined by the previous normative data. This may represent a selection effect in our sample, or alternatively the lack of sensitivity of current cutoff scores for certain populations. The fact that participants were low scorers on affective temperaments raises the possibility of restriction of range (floor effects), which could have hindered detection of significant correlations between these traits and the P300 measures. Fourth, the use of more complex ERP tasks (possibly with inclusion of emotional stimuli) could arguably help detecting significant associations for other affective temperaments. Finally, a topographical analysis of the multichannel ERP data as opposed to a single electrode analysis could allow investigation of local or hemispheric differences in the P300.

In conclusion, this is the first study that demonstrates an association between affective temperaments (as measured by TEMPS-A) and P300. We propose that our findings can be better understood in the light of the personality theories that emphasize individual differences in arousal levels and behavioral activation/effort investment. Furthermore, we hypothesize that dopaminergic system may play a major role in neurobiology of depressive and cyclothymic temperaments. Future studies examining the cognitive ERPs across levels of affective as well as alternative temperament dimensions in the clinically well individuals and in those with psychiatric disorders are required for a better interpretation of our findings.

Author Contributions

BCP contributed to conception and design; contributed to acquisition, analysis, and interpretation; drafted manuscript; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy. ASK contributed to conception and design; contributed to acquisition; drafted manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy. CAP contributed to conception and design; contributed to analysis; drafted manuscript; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy. TÖB contributed to conception and design; contributed to acquisition; drafted manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy. MKA contributed to conception and design; contributed to acquisition, analysis, and interpretation; drafted manuscript; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of Conflicting Interests

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