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Relationship of Anaerobic Running Performance, Physiological And Psychological Characteristics Among Police Students - Proof of Concept

Miloš Milošević[1], Nenad Koropanovski[2], Filip Kukić[3], Milivoj Dopsaj[4]

[1]Faculty of Physical Education and Sports Management, Singidunum University, Belgrade 11000, Serbia, [2]Department of Criminalistics, University of Criminal Investigation and Police Studies, Belgrade 11000, Serbia, [3]Faculty of Physical Education and Sports, University of Banja Luka, Banja Luka 78000, Bosnia and Herzegovina, [4]Faculty of Sport and Physical Education, University in Belgrade, Belgrade 11000, Serbia

Abstract

Anaerobic Running Performance (AP) is critical for police field operations, yet biological markers alone do not fully explain performance variance. Grounded in the Central Governor Model and trait theories, this proof-of-concept study examined the relationship between AP, physiological recovery, and psychological characteristics in police cadets. Thirty-two cadets (20 males, 12 females; age 19.7+/-0.5 years) completed the 300-yard shuttle run test (SR300y). Capillary blood lactate (La3min) and heart rate recovery (HRend, HRmin1-3) were measured. Psychological profiles were assessed using validated inventories (Big Five Plus Two Questionnaire, Interpersonal Reactivity Index, Mental Toughness Inventory and Dark Triad Dirty Dozen). Sex-standardized T-scores were analyzed using backward multiple linear regression. Sex differences were significant for SR300y time ($p<0.001$). The exploratory regression model explained 56.3% of AP variance ($R2=0.563$, adjusted $R2=0.44$, $p<0.01$). Superior performance (shorter time) was predicted by higher trait Aggression (Beta=-0.70), Mental Toughness (Beta=0.48), and Fantasy (Beta=-0.33), alongside lower Perspective Taking (Beta=0.37), lower Narcissism (Beta=0.29), higher lactate (Beta=-0.75), and lower 3-minute recovery heart rate (Beta=0.41). These preliminary results suggest that anaerobic running performance may be influenced by central personality traits alongside physiological markers, offering tentative support for the Central Governor Model in tactical populations.

Keywords: *tactical athletes, central governor model, blood lactate, mental toughness, personality traits, 300-yard shuttle run*

Introduction

Anaerobic Running Performance (AP) is a fundamental performance component essential for high-intensity sports as well as physically demanding occupations, including firefighting, law enforcement, and emergency tactical services (Skinner et al., 2020). AP represents the physiological and bioenergetic capacity for rapid muscle activation during short bursts of maximal effort (typically up to 30 seconds), metabolically relying heavily on anaerobic glycolysis (Driss & Vandewalle, 2013). Given the unpredictable nature, high intensity, and critical duration of police field interventions, which are often compounded by heavy occupational loads, AP plays a decisive role in operational success. For instance, during suspect pursuits or urgent physical interventions, police officers perform activities at maximal or submaximal intensity where their level of AP directly dictates performance outcome (Arble et al., 2019).

Carrying occupational load significantly decreases movement speed, particularly when switching from linear to curvilinear trajectories. Furthermore, both maximal and submaximal anaerobic running induce acute fatigue that negatively impacts subsequent change-of-direction performance (Koropanovski et al., 2022), while high-intensity interval training protocols do not always

Correspondence:

M. Milošević
Singidunum University, Danijelova 32, Belgrade 11000, Serbia.
E-mail: milosmilosevic80@yahoo.com

yield substantial increases in Wingate-derived anaerobic power. In tactical populations such as law enforcement, field tests, including the 2.4 km Cooper test, Wingate test, or the 300-yard shuttle run test (SR300y), are widely utilized to obtain reliable physical performance data (Koropanovski et al., 2022). These running tests are commonly paired with key physiological markers, such as capillary blood lactate concentration (indexing metabolic acidosis) and heart rate dynamics (reflecting cardiovascular exertion and cardiorespiratory fitness), both of which demonstrate well-established sex-specific differences (Dubuc et al., 2020). However, physiological conditioning alone does not fully explain performance preservation; for example, tactical training interventions in elite candidates have shown marked drops in lactate threshold and physical performance under sustained high-stress environments (Winters et al., 2019).

Although physiological metrics provide crucial diagnostic insight, reported heritability estimates for muscle anaerobic power range from 46% to 84% (Tucker & Collins, 2012), leaving a substantial proportion of performance variance unexplained by biological factors alone. Because empirical evidence demonstrates that peripheral anaerobic energy provision does not strictly limit peak power output, the Central Governor Model (CGM) offers a robust theoretical framework (Noakes, Clair Gibson, et al., 2005). CGM postulates that the subconscious brain regulates motor unit recruitment to prevent catastrophic homeostatic failure, rendering fatigue a conscious sensation or emotion that influences the decision to terminate exertion. Parallelly, trait theories of personality argue that enduring tendencies in human behavior reflect the individual peculiarities of physiological and neurobiological functioning, a premise supported by both classic and contemporary empirical literature. Indeed, empirical proof-of-concept evidence demonstrates that isometric neuromuscular characteristics, particularly explosive rate of force development, are significantly associated with and predictive of comprehensive psychological profiles across the Big Five, Dark Triad, and Mental Toughness dimensions (M. M. Milošević, Kitanović, et al., 2025). However, recent evidence in police students indicates that single psychological constructs, such as mental toughness, do not buffer the rate of physical performance decline during acute neuromuscular fatigue (Rajović et al., 2026). This highlights that isolated psychological traits are insufficient to override metabolic strain, reinforcing the necessity of exploring a broader, multi-trait psychophysiological architecture. Integrating CGM and trait theories suggests that central pacing mechanisms modulating AP may share underlying neural substrates with broad personality traits (Big Five), malevolent dark traits (Dark Triad), mental toughness, and empathetic disposition (interpersonal reactivity) (M. M. Milošević, Koropanovski, et al., 2025; Rajović et al., 2026). Although preliminary studies have highlighted psychophysiological interplay in athletic contexts (Broodryk et al., 2017), the complex relationship between personality traits, physiological stress response, and AP within law enforcement personnel remains under-researched.

Therefore, this proof-of-concept study aimed to explore the relationship between physical performance (AP), physiological recovery markers (blood lactate and heart rate), and psychological characteristics (broad personality traits, mental toughness, dark triad, and empathy) among Police Academy Cadets. It was hypothesized that psychological traits significantly contribute to the explanation of AP variance beyond traditional physiological indicators, thereby justifying their inclusion in psychophysiological performance models. Beyond establishing proof-of-concept for integrative selection and training frameworks in physically demanding occupations, these findings aim to provide theoretical insights into the neurobiological and psychological foundations of individual differences in maximal physical performance.

Materials and Methods

Study Design and Procedures

In order to determine the degree and direction of the relationship between variables, correlation design and procedures were performed. Data collection was performed in three sessions in total. In the first session, participants had to fill in the questionnaire related to the socio-demographic status, sports experience, and psychological inventories. On the second session, anthropometric data were collected, where participants were familiarized with the testing protocol. On the last session participants performed a physical test, consisting of a 10-minute warm-up, running variations and different calisthenics exercises, SR300y, after which their Blood lactate level and heart rate were measured.

Participants

The sample for this research presented 32 students (Age =19.7±0.5 years, Body height (BH) =177.6±7.6 cm, Body weight (BW) =74.5±12.0 kg) of first and second year in Criminal Police University (CPU) among whom, 20 were male (Age =19.6±0.5 years, BH=181.7±4.7 cm, BW=80.9±10.1 kg) and 12 were female (Age =19.8±0.5 years, BH=170.9±6.5 cm, BW=63.8±5.3 kg). Additionally, students of CPU are a strictly selected population - extremely physically and mentally healthy and prepared individuals, being educated and trained for police work as future executives, commanders and officers.

All participants passed the physical fitness requirements for recruitment and attended specialized physical education classes (self-defense, use of force, and strength and conditioning) three times per week. They were informed about the aim of the study, the testing protocol, and potential risks. Including criterion was that the respondent was completely healthy at the moment. The exclusion criterion was the failure of the respondent to perform all tests. Only participants who signed informed consent were included in the study. The study was conducted in accordance with the European Commission's General Data Protection Regulation, the American Psychological Association-prescribed Ethical Principles and Code of Conduct and Helsinki Declaration. The study design was approved by the Ethical Board (number 484-2) of the Faculty of Sport and Physical Education, University of Belgrade.

Measurement settings

The study was conducted at the Criminal Police University (CPU). Control of PAC exercise activities and the rest periods between the testing sessions has been strictly controlled, since they were accommodated on the CPU campus. During the testing sessions, they did not have any other physical activities. Therefore, they were rested and had the same environmental conditions. The tests were conducted at the same time of each day, and under identical environmental circumstances (temperature 21 °C, relative humidity 58%, barometric pressure 1001 mb).

Measurement Procedures

Anaerobic Running

Anaerobic Running Performance was assessed using the 300-yard shuttle run test (SR300y) (Koropanovski et al., 2022; Rajović et al., 2026; White et al., 2015). The test includes 12 lengths of a 25-yard distance. It has been previously used with sports and tactical populations. The test–retest reliability of this test (ICC=0.83) has been reported (White et al., 2015).

The test was performed as an all-out maximal running effort, where participants were instructed to complete the 12 lengths of 25 yards in the shortest time possible.

Each participant's heart rate (HR) was monitored using a Polar (V800, Polar Electro, OY; Kempele, Finland) device secured with a chest strap. Maximal HR was recorded at the end of test

(HRend), as well as after 1, 2, and 3 minutes of rest (HRmin1, 2 and 3). Collection of Blood lactate level was performed 3 minutes (La3min) after the test when its accumulation has been reported to be at its highest (Goodwin et al., 2007).

Personality traits inventories

Short version of the Big Five Plus Two Questionnaire (BF+2; Čolović, et al. 2014), which consists of 70 items that are answered using five-point Likert-type assessment scales. The BF+2 assess five standard personality traits: Aggressiveness (Agg), Openness (Opn), Conscientiousness (Cns), Extraversion (Ext) and Neuroticism (Nrt) with the addition of positive and negative valence (PV and NV). PV refers to positive image of one self and narcissistic tendency, while NV refers to negative self-image and propensity for manipulative behavior. Scores vary from a minimum of 1 (poorly developed) to a maximum of 5 (extremely developed). The BF+2 has been widely used in scientific research and clinical practice, due to its positive psychometric characteristics (Čolović et al., 2014).

The Interpersonal Reactivity Index (IRI; Davis, 1983), which consists of 25 items that are answered using five-point Likert-type scales, assess an individual's empathy through four sub-dimensions: fantasy (Fnt), personal distress (PD), empathic concern (EC), and perspective-taking (PT). The score on the sub-scales varies from a minimum of 1 (poorly developed) to a maximum of 5 (extremely developed). The IRI has been widely used in scientific research and clinical practice, due to its good psychometric characteristics (Hawk et al., 2013).

The Mental Toughness Inventory (MTI; Gucciardi et al., 2015; Milošević et al., 2022), which provides a reliable one-dimensional assessment of the trait (MT). The instrument consists of 8 items, and the participants express the level of agreement with the statements by seven-point Likert-type assessment scales. The total score varies from a minimum of 1 (poorly developed) to a maximum of 7 (extremely developed). The MTI has good psychometric characteristics which are empirically confirmed and has been widely used in psychological testing (Gucciardi et al., 2015).

The Dark Triad Dirty Dozen test (DTDD; Dinić et al., 2018; Jonason & Webster, 2010), which consists of 12 items that are answered using seven-point Likert-type assessment scales. The DTDD assesses an individual's Dark Triad (DT) traits through three socially malevolent traits: Machiavellianism (Mch), Psychopathy (Psh), and Narcissism (Nrc). The scores vary from a minimum of 1 (poorly present) to a maximum of 7 (extremely present). The DTDD has been widely used in scientific research and clinical practice (Sabouri et al., 2016), due to its positive psychometric characteristics (Dinić et al., 2018).

Statistics

The analyses were performed using SPSS (Version 23.0., Armonk, NY: IBM Corp) statistical software. Descriptive statistics for both sexes were calculated for the mean, standard deviation (SD), minimum (Min), and maximum (Max) values. The Kolmogorov-Smirnov test was used to assess the normality of the distribution. Standardization of AP scores was carried out by transferring raw scores to T scores according to gender. Pearson's correlation and multiple linear regression analyses backwards methods were applied to determine the degree and direction of the relationship between variables. The criterion for selecting the multiple linear regression model had been defined based on the selection of the simplest isolated system of predictor variables in regard to the shared variance and standard error. Significance was set at $p<0.05$, $p<0.01$ and $p<0.001$. The effect size of correlation coefficients was defined as weak =0.20–0.49, moderate =0.50–0.80, or strong ≥0.80 (Sullivan & Feinn, 2012).

Results

Descriptive statistical analysis (Table 1) performed at the level of the male and female subsample for all the variables, shows that for SR300y distributions of scores are quite separated with overlaps of male maximal and female minimal scores, which is not the case for the other variables. Non- parametric Kolmogorov-Smirnov test showed that there were significant ($p<0.01$) deviations from the normal distribution on NV and Mch for both subsamples, which is why they were excluded from further analyses.

Descriptive statistical analysis results indicate the necessity of standardization of SR300y results according to gender in order to be able to perform further analyses at the level of the entire sample.

Table 1. Descriptive characteristics of the study participants and differences between sexes

	Female (n=12)				Male (n=20)			
	Min	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
SR300y (s)	65.92	81.73	73.21	3.95	57.22	70.51	62.13	3.68
La3min	10.20	15.70	12.88	1.63	9.60	16.50	14.15	1.77
HRend	170.00	199.00	186.50	9.77	176.00	204.00	192.00	8.53
HRmin1	142.00	171.00	154.17	9.32	140.00	182.00	162.10	13.73
HRmin2	114.00	151.00	131.75	11.55	109.00	165.00	139.40	14.88
HRmin3	108.00	150.00	124.75	12.38	103.00	152.00	131.20	13.11
Agg	1.30	3.80	2.31	0.72	1.00	4.30	2.10	0.85
Ext	2.50	4.90	3.80	0.63	2.90	5.00	4.22	0.60
Nrt	1.00	2.70	1.44	0.53	1.00	3.20	1.52	0.71
NV	1.00	1.90	1.23	0.26	1.00	3.00	1.34	0.58
Opn	3.00	4.90	4.06	0.66	3.00	5.00	4.20	0.63
PV	1.80	4.70	3.38	0.98	2.60	5.00	3.67	0.74
Cns	3.40	5.00	4.49	0.56	3.70	5.00	4.63	0.45
Fnt	1.29	3.71	2.81	0.68	1.57	3.86	2.82	0.59
PT	3.29	4.43	3.74	0.37	2.57	4.57	3.69	0.54
EC	2.14	3.86	3.06	0.53	2.14	3.86	2.97	0.49
PD	1.86	2.57	2.23	0.22	1.57	3.00	2.20	0.33

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Table 1. Descriptive characteristics of the study participants and differences between sexes

	Female (n=12)				Male (n=20)			
	Min	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
MT	5.63	6.88	6.29	0.42	5.38	7.00	6.38	0.54
Mch	1.00	2.25	1.27	0.46	1.00	4.25	1.46	0.91
Psp	1.00	4.00	2.06	1.05	1.00	4.75	2.10	1.07
Nrc	1.00	3.75	2.40	1.05	1.00	6.25	2.73	1.71

Note. SR300y: Shuttle run 300 yards, HRend: maximal heart rate the end of test, HRmin1, 2 and 3: heart rate after 1, 2, and 3 minutes of rest, La3min: blood lactate level, Agg: aggression, Ext: extraversion, Nrt: neuroticism, NV: negative valence, Opn: openness, PV: positive valence, Cns: conscientiousness, Fnt: fantasy, PD: personal distress, EC: empathic concern , PT: perspective-taking, MT: Mental Toughness, Mch: Machiavellianism, Psp: psychopathy, Nrc: narcissism, DT: Dark Triad, Min: minimum, Max: maximum, M: mean, SD: standard deviation.

Table 2. Pearson's correlation analysis for the whole sample

	SR300y	**La3min**	**HRend**	**HRmin1**	**HRmin2**	**HRmin3**
SR300y	/	-0.44*	-0.03	-0.41*	-0.43*	-0.28
Agg	-0.39*	0.05	0.2	0.50**	0.44*	0.42*
Ext	-0.13	0.07	-0.1	-0.14	-0.06	-0.01
Nrt	-0.16	0.03	-0.09	0.11	0.09	-0.01
NV	-0.11	-0.03	0.15	0.26	0.13	0.12
Opn	-0.06	-0.26	-0.11	-0.15	-0.07	-0.04
PV	0.02	-0.26	-0.02	-0.12	-0.07	0.01
Cns	-0.11	-0.06	-0.08	-0.11	-0.13	-0.08
Fnt	-0.12	-0.15	0.08	-0.12	0.06	0.1
PT	0.23	-0.18	-0.3	-0.40*	-0.29	-0.28
EC	0.02	-0.16	-0.13	-0.12	0.01	0.05
PD	-0.27	0.07	0	-0.16	-0.19	-0.21
MT	-0.04	-0.24	-0.15	-0.28	-0.12	-0.09
Mch	-0.17	-0.07	-0.03	0.18	0.06	0.07
Psp	-0.23	0.02	0.26	0.28	0.26	0.24
Nrc	-0.23	0.15	0.01	0.26	0.22	0.2

Note. *p<0.05, ** p<0.01, SR300y: Shuttle run 300 yards, HRend: maximal heart rate the end of test, HRmin1, 2 and 3: heart rate after 1, 2, and 3 minutes of rest, La3min: blood lactate level, Agg: aggression, Ext: extraversion, Nrt: neuroticism, NV: negative valence, Opn: openness, PV: positive valence, Cns: conscientiousness, Fnt: fantasy, PD: personal distress, EC: empathic concern , PT: perspective-taking, MT: Mental Toughness, Mch: Machiavellianism, Psp: psychopathy, Nrc: narcissism, DT: Dark Triad.

Correlation analyses revealed significant moderate positive correlation between Agg with HRmin1, Agg with HRmin2 and HRmin3, as well as a moderate negative correlation between PT and HRmin1. Weak negative correlation between Agg and SR300y was also significant. On the other hand, SR300y also significantly moderately negatively correlates with La3min, HRmin1, HRmin2.

The selected exploratory regression model (Table 3), explained 56.3% of SR300y variance (adj. R2=0.44, SEE=7.39, F=4.41, p<0.01). Due to multicollinearity, HRmin1, HRmin2 were not considered for regression analysis.

Table 3. Multiple regression analysis model of SR300yT for the whole sample

	Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**	**Collinearity Statistics**	
	B	**Std. Error**	**Beta**			**Tolerance**	**VIF**
Constant	126.63	25.90		4.89	0.01		
Agg	-8.58	2.73	-0.70	-3.14	0.00	0.37	2.70
Fnt	-5.21	2.62	-0.33	-1.99	0.06	0.68	1.48
PT	7.67	4.26	0.37	1.80	0.09	0.42	2.36
MT	-9.59	3.63	-0.48	-2.64	0.01	0.56	1.80
Nrc	1.94	1.34	0.29	1.45	0.16	0.45	2.23
La3min	-4.10	0.99	-0.75	-4.16	0.01	0.56	1.79
HRmin3	0.31	0.15	0.41	2.12	0.05	0.48	2.08

Model Summary: R=0.750, R^2=0.563, Adjusted R^2=0.440, SEE=7.39, F=4.41, p<0.01. Note. HRmin3: heart rate after 3 minutes of rest, La3min: blood lactate level, Agg: aggression, Fnt: fantasy, PT: perspective-taking, MT: Mental Toughness, Nrc: narcissism.

Discussion

This proof-of-concept study explored the complex interplay between Anaerobic Running Performance (AP), physiological stress and recovery indicators, and comprehensive psychological profiles in Police Academy Cadets. The primary finding demonstrated that a combined psychophysiological model accounted for 56.3% of the variance in AP (adjusted R^2=0.44), comprising two significant psychological traits alongside four physiological recovery markers (Table 3). These preliminary results indicate that anaerobic running performance in tactical populations may not be fully captured by metabolic and cardiovascular parameters alone, but could also be influenced by underlying personality traits and psychological dispositions. However, it should be remembered that the sample is small and the obtained model is exploratory.

Descriptive analyses (Table 1) confirmed that the participant sample represents a highly conditioned and mentally robust cohort. The physical capability of these cadets mirrors that of specialized tactical populations, such as military special operations candidates. Furthermore, post-exercise maximal heart rate (HRend) values confirmed that the SR300y protocol successfully pushed participants past their lactate threshold, validating its use as an effective field test for AP (Matabuena et al., 2019). Peak blood lactate concentrations (La3min) were comparable to values recorded in elite athletes, while rapid post-test heart rate deceleration observed within two minutes of recovery highlights high cardiovascular fitness across both male and female cadets (Dubuc et al., 2020).

The psychological profile of the sample further reflects the efficacy of the institutional selection process. Cadets exhibited high scores in Extraversion, Openness, Conscientiousness, and Perspective Taking, alongside exceptionally high Mental Toughness, surpassing values typically reported in elite athletic populations (M. Milošević et al., 2024; Zarić et al., 2021). Conversely, Neuroticism, Negative Valence, Machiavellianism, and Psychopathy were markedly low compared to normative general population data (Čolović et al., 2014; Dinić et al., 2018). These psychological dispositions align with prior research demonstrating that engagement in high-intensity anaerobic training fosters emotional stability, stress tolerance, and anxiety reduction (Selmi et al., 2018). Effectively, the selection framework successfully filters for individuals possessing both high motor capacities and adaptive behavioral traits required for law enforcement duties.

Correlation analyses revealed a significant association between trait Aggression and motor performance, consistent with evolutionary and psychophysiological models linking aggressive disposition to physical force production (Gallup et al., 2007). Crucially, lower trait aggression was accompanied by a faster rate of cardiovascular recovery (Table 2). This suggests that the interplay between personality traits and physiological exertion extends beyond simple conditioning levels, pointing to distinct central autonomic regulation mechanisms.

The multiple regression model (Table 3) provides crucial theoretical insights into the psychophysiological determinant architecture of AP. Because the criterion variable (SR300y) is measured in seconds, negative regression coefficients signify shorter completion times and superior physical performance. The model demonstrated that higher trait Aggression, Mental Toughness, and Fantasy (an empathic sub-dimension), combined with lower Perspective Taking and Narcissism, significantly predicted higher AP alongside physiological markers (La3min and HRmin3). The contribution of Mental Toughness reinforces its established role in physical exertion and performance preservation (Rajović et al., 2026). Interestingly, higher Fantasy paired with lower Perspective Taking suggests that an internal, dissociative cognitive focus may assist in pushing through extreme physical discomfort during maximal anaerobic exertion, aligning with classic research on cognitive coping strategies during exhaustive exercise.

The substantial variance explained (R^2=56.3%) underscores the magnitude of central psychological influences on anaerobic output. From a theoretical standpoint, these findings provide robust empirical support for the Central Governor Model (CGM) (Noakes, St Clair Gibson, et al., 2005) and trait theories of personality (M. M. Milošević, Kitanović, et al., 2025). While metabolic strain (La3min) and autonomic recovery (HRmin3) represent peripheral limitations, central personality traits appear to modulate the subconscious pacing and motor unit recruitment mechanisms governed by the central nervous system. These results also extend recent personality research (Papageorgiou et al., 2019) by demonstrating that traditional models (e.g., Big Five) should be augmented with Dark Triad traits, Mental Toughness, and Empathy to fully capture human performance variance. At the end of the interpretation of these results, it should be kept in mind that this is only a pilot study, which the sample is small and the obtained model is exploratory.

Several limitations should be considered when interpreting these findings. First, a major limitation of this study is that it was conducted on a relatively small sample of participants (n=32), which may limit the generalizability of the findings to broader populations. This restriction of range may attenuate certain correlations; for instance, because Mental Toughness was uniformly high across the sample, its true explanatory power in broader populations might be underestimated. Second, the cross-sectional nature of the study precludes direct causal inferences regarding whether anaerobic training shapes these psychological profiles or whether specific personality traits inherently drive higher physical achievement. Future research employing larger, more diverse cohorts and longitudinal designs is warranted to confirm these common latent psychophysiological structures and to refine integrative selection algorithms for tactical professions.

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Conflicts of Interest
The authors declare no conflict of interest.

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