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PSYCHOPHYSIOLOGICAL MARKERS OF ATTENTION CONCENTRATION AS PREDICTORS OF PERFORMANCE IN STUDENT HOCKEY FORWARDS: ROC ANALYSIS

Evgeniy V. Bykov[✉], Elena G. Sidorkina, Vadim V. Sverchkov, Irina F. Kharina

Urals State University of Physical Culture, Chelyabinsk, Russia

Introduction. Attention is a key cognitive process in team sports. In hockey, competitive performance is critically dependent on rapid decision-making and efficient information processing under time pressure. However, the current literature lacks established threshold values for attention metrics that could be used to differentiate players according to their performance level.

Objective. To evaluate the prognostic value of attention concentration and sustained attention metrics as predictors of athletic performance among student hockey forwards.

Materials and methods. The cross-sectional study enrolled 50 forwards from the student hockey team of the Urals State University of Physical Culture, with a mean age of 21.9 ± 1.9 years. Sustained attention and concentration were assessed using psychophysiological testing with the NS-PsychoTest hardware-software complex; the results were expressed as quantitative and scoring metrics. Performance was evaluated based on an integral index of technical and tactical actions (TTA), calculated by the coaching staff from the data of official matches. Based on the TTA distribution, players were stratified into three groups: Group 1 (below the 25th percentile; low performance; $n = 16$), Group 2 (between the 25th and 75th percentiles; moderate performance; $n = 18$), and Group 3 (above the 75th percentile; high performance; $n = 16$). Group comparisons were performed using nonparametric Kruskal–Wallis and Mann–Whitney U tests. The effect size was estimated using Cohen's d . The predictive ability of attention concentration metrics was assessed via Receiver Operating Characteristic (ROC) analysis, including calculation of the area under the curve (AUC), sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).

Results. Statistically significant differences in attention concentration metrics were found between the low- and high-performance groups. For the quantitative attention concentration measure, $p = 0.003$ and Cohen's $d = 0.65$ (medium effect); for the scoring measure, $p < 0.001$ and Cohen's $d = 0.82$ (large effect). ROC analysis confirmed the high predictive potential of both metrics. For the quantitative measure, AUC was 0.805 (95% CI: 0.627–0.946), with an optimal threshold of ≤ 0.950 , sensitivity of 62.5%, specificity of 93.8%, PPV of 90.9%, and NPV of 71.4%. For the scoring metric, AUC was 0.812 (95% CI: 0.674–0.938), with an optimal threshold of ≥ 2 points, sensitivity of 87.5%, specificity of 75.0%, PPV of 77.8%, and NPV of 85.7%. The scoring assessment of attention concentration (on a 3-point scale) demonstrated diagnostic accuracy comparable to that of the quantitative metric (AUC: 0.812 vs. 0.805, respectively). Age-related effects were controlled using rank-based ANCOVA, which confirmed the independence of the observed differences ($p = 0.007$, $\eta^2 = 0.26$).

Conclusions. Attention concentration metrics demonstrated high predictive value and may serve as psychophysiological markers for differentiating forwards by performance level. Given its comparable diagnostic accuracy and ease of interpretation, the scoring-based assessment of attention concentration is recommended for practical application in the system of sports talent selection. The established diagnostic thresholds require validation in larger samples; however, they may already be applied in sports selection practice as additional objective criteria.

Keywords: attention; attention concentration; sustained attention; psychophysiological markers; forwards; university team; ice hockey; performance; competitive activity

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Compliance with the ethical principles. All procedures were conducted in accordance with the principles of biomedical ethics as outlined in the Declaration of Helsinki (1964) and its subsequent amendments. The study was approved by the Local Ethics Committee of the Urals State University of Physical Culture (Minutes No. 1 dated 17 Sep. 2024). Written informed consent was obtained from all participants after they had been fully informed about the nature of the study, as well as the potential risks and benefits.

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✉ Evgeniy V. Bykov bev58@yandex.ru

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ПСИХОФИЗИОЛОГИЧЕСКИЕ МАРКЕРЫ КОНЦЕНТРАЦИИ ВНИМАНИЯ КАК ПРЕДИКТОРЫ РЕЗУЛЬТАТИВНОСТИ НАПАДАЮЩИХ В СТУДЕНЧЕСКОМ ХОККЕЕ: РОС-АНАЛИЗ

Е.В. Быков[✉], Е.Г. Сидоркина, В.В. Сверчков, И.Ф. Харина

Уральский государственный университет физической культуры, Челябинск, Россия

Введение. В игровых видах спорта одним из ключевых когнитивных процессов является внимание. Соревновательная результативность в хоккее напрямую зависит от быстроты принятия решения и эффективности обработки информации в условиях дефицита времени. В публикационном поле отсутствуют пороговые значения показателей внимания, позволяющие дифференцировать игроков с разным уровнем результативности.

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Цель. Оценка прогностического потенциала показателей концентрации и устойчивости внимания в отношении спортивных результатов нападающих студенческой хоккейной команды.

Материалы и методы. В кросс-секционное исследование были включены 50 хоккеистов студенческой команды Уральского государственного университета физической культуры (игровое амплуа — нападающие) в возрасте $21,9 \pm 1,9$ года. Устойчивость и концентрацию внимания (числовой и балльный показатели) определяли путем психофизиологического тестирования на аппаратно-программном комплексе «НС-ПсихоТест». Результативность оценивали по интегральному показателю технико-тактических действий (ТТД), рассчитанному тренерским штабом по итогам официальных матчей. На основе распределения ТТД игроки разделены на три группы: группа 1 (ниже 25-го перцентиля, низкая результативность, $n = 16$), группа 2 (в диапазоне 25–75 перцентилей, средняя результативность, $n = 18$) и группа 3 (выше 75-го перцентиля, высокая результативность, $n = 16$). Сравнение групп выполнено с использованием непараметрических критериев (Краскела — Уоллиса, Манна — Уитни), размер эффекта оценен по d Коэна. Прогностическая способность показателей концентрации внимания определена с помощью ROC-анализа с расчетом площади под кривой (AUC), чувствительности, специфичности, положительной прогностической ценности (PPV) и отрицательной прогностической ценности (NPV).

Результаты. Выявлены статистически значимые различия показателей концентрации внимания между группами низкой и высокой результативности. Для числового показателя концентрации внимания: $p = 0,003$, d Коэна = 0,65 (средний эффект); для балльного показателя концентрации внимания: $p < 0,001$, d Коэна = 0,82 (большой эффект). Значимых различий в устойчивости показателей внимания не выявлено ($p > 0,05$). ROC-анализ подтвердил высокий прогностический потенциал обоих показателей. Для числового показателя: AUC = 0,805 (95% ДИ: 0,627–0,946), оптимальный порог $\leq 0,950$, чувствительность 62,5%, специфичность 93,8%, PPV = 90,9%, NPV = 71,4%. Для балльного показателя: AUC = 0,812 (95% ДИ: 0,674–0,938), оптимальный порог — 2 и более балла, чувствительность 87,5%, специфичность 75,0%, PPV = 77,8%, NPV = 85,7%. Балльная оценка концентрации внимания (по трехбалльной шкале) демонстрирует диагностическую точность, сопоставимую с числовым показателем (AUC 0,812 и 0,805 соответственно). Контроль влияния возраста (ранговый ANCOVA) подтвердил независимость выявленных различий ($p = 0,007$, $\eta^2 = 0,26$).

Выводы. Показатели концентрации внимания обладают высокой прогностической ценностью и могут рассматриваться как психофизиологические маркеры для дифференциации нападающих по уровню результативности. Балльная оценка концентрации внимания благодаря сопоставимой диагностической точности и простоте интерпретации может быть рекомендована для практического применения в системе спортивного отбора. Установленные диагностические пороги требуют валидации на расширенных выборках, но уже могут быть использованы в практике спортивного отбора как дополнительные объективные критерии.

Ключевые слова: внимание; концентрация; устойчивость; психофизиологические маркеры; нападающие; студенческая команда; хоккей; результативность; соревновательная деятельность

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Финансирование. Работа выполнена в рамках исполнения государственного задания НИР на тему «Повышение эффективности спортивной подготовки хоккеистов студенческой хоккейной лиги на основе учета их психофизиологических и технико-тактических характеристик» № 777-00014-25-00 (2025 г.) и № 777-00029-26-00 (2026 г.).

Соответствие принципам этики. Все исследования проводились в соответствии с принципами биомедицинской этики, изложенными в Хельсинкской декларации (1964 г.) и последующих поправках к ней. Они также одобрены локальным этическим комитетом ФГБОУ ВО «УралГУФК» (протокол № 1 от 17.09.2024). Каждый участник дал добровольное письменное информированное согласие после получения разъяснений о характере предстоящего исследования, а также потенциальных рисках и преимуществах.

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✉ Быков Евгений Витальевич bev58@yandex.ru

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INTRODUCTION

High athletic performance in team sports requires efficient information processing and rapid decision-making under time pressure [1–4]. Attention, as a core cognitive process, underpins these capabilities. A meta-analysis by Ren et al. [5] provides quantitative support for enhanced cognitive control in athletes: compared with non-athletes, athletes demonstrated superior inhibitory control (standardized mean difference, SMD = -0.631) and working memory (SMD = -0.382). Notably, cognitive flexibility tends to increase with athletic skill level: athletes of higher proficiency demonstrate greater cognitive flexibility than those with lower expertise. Evidence from Liu et al. [6] further supports the link between expertise and visuospatial attentional capacity: athletes

outperformed non-athletes on multiple object tracking tasks (Hedges' $g = 0.56$), whereas skilled athletes showed a substantially larger advantage over novices ($g = 0.92$). Moreover, research indicates that the magnitude of cognitive differences is strongly influenced by the specific sport discipline [5].

Hockey is recognized as an open-skill sport, wherein the efficacy of perceptual-cognitive processes is a critical determinant of performance [7]. Neuroimaging evidence further demonstrates that elite hockey players exhibit greater neural efficiency than both novice players and non-athletes [8]. Evidence indicates that Junior-A forwards demonstrate a higher rate of sensory information processing than defensemen [1]. In contrast, findings from a separate study suggest the opposite trend among adolescent hockey players [9].

Despite the extensive body of research on attention in sport, no published studies were identified that report threshold values for attention metrics suitable for differentiating athletes by performance level. While existing literature commonly compares novice and experienced athletes, it generally lacks criteria applicable to individual-level screening. A systematic literature search was conducted in the following databases: PubMed, Scopus, Cochrane Library, Google Scholar, and eLibrary.ru. The search covered the period from 2010 to March 2026. The following keywords (in both Russian and English) were used: “внимание”/“attention”, “психофизиологические маркеры”/“psychophysiological markers”, “предикторы”/“predictors”, “хоккей”/“ice hockey”, “ROC-анализ”/“ROC analysis”, “диагностические пороги”/“diagnostic cut-offs”, “индивидуальный скрининг”/“individual screening”.

The primary objective of this study was to evaluate the predictive utility of attention concentration and sustained attention metrics as indicators of sports performance among forwards of a university hockey team.

MATERIALS AND METHODS

Study design and sample characteristics

Study design. The study employed a cross-sectional observational design. Data analysis was conducted retrospectively following the completion of data collection. The reporting of results conforms to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)¹ guidelines for cross-sectional studies, as well as to the core recommendations of the Standards for Reporting of Diagnostic Accuracy Studies (STARD)² statement for diagnostic accuracy research.

Psychophysiological testing and assessment of technical-tactical actions (TTA) were carried out during the pre-season preparation periods of the 2024/2025 and 2025/2026 seasons. The study cohort comprised 50 athletes.

Data were collected sequentially from all team forwards who fulfilled the predefined inclusion criteria. Attention metrics (serving as the index test) and TTA assessment (used as the reference standard) were evaluated independently to avoid cross-contamination. The coaching staff responsible for calculating the TTA had no access to the psychophysiological testing results. Conversely, the specialists who conducted the psychophysiological assessments were unaware of the players' current performance metrics. This double-blind arrangement minimized the risk of assessment bias.

Sample characteristics. Inclusion criteria:

- Member of the Urals State University of Physical Culture (UralSUPC) men's ice hockey team;
- Playing position: forward;

- No acute injuries at the time of assessment;
- Complete psychophysiological testing data and TTA records available.

Exclusion criteria:

- Playing position: defenseman or goalkeeper;
- Incomplete psychophysiological testing data and TTA records;
- Confirmed diagnosis of concussion within six months prior to the assessment.

All forwards of the UralSUPC men's ice hockey team who met the predefined inclusion criteria were enrolled in the study during the 2024/2025 and 2025/2026 seasons. Of the 52 forwards who played for the team over this period, 50 were included, yielding a coverage rate of 96.2% of the target population. The study sample is considered representative of the target population, given the near-complete coverage of eligible forwards from the team roster. An a priori power analysis was conducted using G*Power ($\alpha = 0.05$, $1 - \beta = 0.80$) to determine the required sample size for detecting a large effect size (Cohen's $d = 0.82$). The analysis indicated that 52 participants were required to achieve adequate statistical power. The actual sample size ($n = 50$) closely aligns with the a priori calculated target ($n = 52$), providing sufficient statistical power to detect the anticipated effect size. The findings should therefore be interpreted as applicable to university-level hockey forwards and should not be extrapolated to other athletic populations.

Psychophysiological testing

Psychophysiological assessment was conducted in the first half of the day under standardized conditions (isolated room, comfortable temperature, absence of extraneous stimuli). Testing was performed using the NS-PsychoTest hardware-software complex (Neurosoft, Russia).

Assessment of attention metrics

1. The numerical indicator of sustained attention reflects the consistency of attention maintenance over time. The scale is inverse: a lower value corresponds to better sustained attention.

2. The numerical index of attention concentration is defined as the ratio of correct responses to the total number of stimuli. The scale is inverse: a lower value corresponds to better attention concentration.

3. The sustained attention score was derived by grading the numerical index according to the NS-PsychoTest reference norms: 1 — low level, 2 — moderate level, 3 — high level. The scale is direct: higher scores indicate better sustained attention.

4. The attention concentration score was assigned using the same grading scale: 1 — low level, 2 — moderate level, 3 — high level. The scale is direct: higher scores indicate better attention concentration.

¹ Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ*. 2007;335(7624):806–8. <https://doi.org/10.1136/bmj.39335.541782.AD>

² Bossuyt PM, Reitsma JB, Bruns DE, Gatsonis CA, Glasziou PP, Irwig L, et al. STARD 2015: An updated list of essential items for reporting diagnostic accuracy studies. *BMJ*. 2015;351:h5527. <https://doi.org/10.1136/bmj.h5527>

Performance assessment. The performance of forwards was assessed using an integral TTA score calculated by the coaching staff based on official matches. The TTA score comprised eight components of in-game activity: skating movement, shots, passes, puck recovery, game discipline, shot blocking, dribbling/stickhandling, and positioning. Each component was rated on a 1–10-point scale. The final TTA score was obtained as the sum of scores across all components.

Based on the distribution of final TTA scores, all players were divided into three groups:

- Group 1 (below the 25th percentile) — players with the lowest TTA scores (low performance);
- Group 2 (between the 25th and 75th percentiles) — players with moderate TTA scores;
- Group 3 (above the 75th percentile) — players with the highest TTA scores (high performance).

Statistical analysis. Statistical analysis was performed using Python (version 3.12). Given that most variables did not follow a normal distribution (Shapiro–Wilk test, $p < 0.05$), non-parametric methods were applied. Descriptive statistics are presented as median and interquartile range (M_e , $[Q_1; Q_3]$). For age, which showed a distribution consistent with normality, the mean and standard deviation were reported as $M \pm SD$ (where M is the arithmetic mean, SD is the standard deviation). The 95% confidence intervals (CIs) for medians were calculated using the bootstrap method (10,000 iterations).

Group comparisons across the three groups were performed using the Kruskal–Wallis test, followed by Dunn’s post-hoc pairwise comparisons with Bonferroni correction.

Groups 1 and 3 were compared using the Mann–Whitney U test. The effect size was estimated using two approaches:

- Correlation coefficient $r = |Z| / \sqrt{N}$, where Z is the standardized U -test statistic and N is the total sample size. The r values were interpreted as follows: 0.10 — small effect, 0.30 — medium effect, 0.50 — large effect³;
- Cohen’s d was calculated using the formula $d = Z \times \sqrt{(n_1 + n_2) / (n_1 \times n_2)}$. The d values were interpreted as follows: 0.20 — small effect, 0.50 — medium effect, 0.80 — large effect⁴.

Adjustment for age. To control for the potential confounding effect of age on differences between Groups 1 and 3, a rank-based analysis of covariance (ANCOVA) was conducted. In this approach, the dependent variable was first ranked, and age was then included in the model as a covariate. The effect size for the “Group” factor was quantified using partial η^2 ; following conventional benchmarks, values of 0.01, 0.06, and 0.14 were interpreted as small, medium, and large effects, respectively.

Selection of optimal cutoff. The optimal cutoff values for attention concentration metrics were determined empirically via the Youden index ($J = \text{sensitivity} + \text{specificity} - 1$) within the Receiver Operating Characteristic (ROC) analysis

framework. These cutoffs were not predetermined a priori, which is consistent with the exploratory design of the study. The resulting thresholds should be independently validated in external samples to confirm their generalizability.

ROC analysis and diagnostic value. To evaluate the predictive ability of attention concentration metrics for classifying athletes into high- versus low-performance groups, ROC analysis was conducted.

The following metrics were calculated:

- The area under the ROC curve (AUC) with a 95% confidence interval (CI), estimated via bootstrap with 10,000 iterations;
- The optimal cutoff threshold using the Youden index;
- Sensitivity and specificity;
- Positive predictive value (PPV) and negative predictive value (NPV).

Participant flow. Of the 50 forwards, 32 players were included in the ROC analysis: 16 athletes were assigned to the low-performance group (below the 25th percentile of the TTA score) and 16 to the high-performance group (above the 75th percentile). The 18 players in the intermediate performance range (25th–75th percentiles) were excluded from the diagnostic accuracy analysis, as ROC methodology requires a binary comparison between contrasting performance categories.

Handling of missing data. The analysis was performed using complete data only. The proportion of missing data did not exceed 5%, and multiple imputation was not applied.

Software. The calculations were performed using the Python programming language with the following libraries: pandas (2.0.3), numpy (1.25.2), scipy (1.11.4), statsmodels (0.14.0), scikit-learn (1.3.2), scikit-posthocs (0.7.0). Visualization was carried out using matplotlib (3.8.0) and seaborn (0.13.2).

RESULTS

Performance groups were established based on the distribution of the integral TTA indicator. Group 1 comprised players scoring below the 25th percentile (low performance, $n = 16$); Group 2 included those within the 25th–75th percentile range (moderate performance, $n = 18$); and Group 3 consisted of players scoring above the 75th percentile (high performance, $n = 16$). Descriptive characteristics of the sample are provided in Table 1.

The results of the analysis of attention metrics across the three performance groups are presented in Table 2. Post-hoc analysis revealed that the main differences were observed between Groups 1 and 3 ($p = 0.002$ for the numerical score; $p < 0.001$ for the point-based score). Group 2 occupied an intermediate position, showing no statistically significant differences from either Group 1 or Group 3 ($p > 0.05$). Sustained attention (both numerical and point-based scores) did not differ significantly between the groups ($p > 0.05$).

³ Cohen J. *Statistical power analysis for the behavioral sciences*. 2nd ed. New York: Lawrence Erlbaum; 1988. <https://doi.org/10.4324/9780203771587>

⁴ Ibid.

Table 1. Sample characteristics (hockey forwards)

Parameter	Value
Total number, <i>N</i>	50
Age, years (<i>M</i> ± <i>SD</i>)	21.9 ± 1.9
Group 1 (low performance), <i>n</i>	16
Group 2 (moderate performance), <i>n</i>	18
Group 3 (high performance), <i>n</i>	16
Integral indicator of TTA, <i>M_e</i> [<i>Q</i> ₁ ; <i>Q</i> ₃].	49.0 [47.5; 56.5]

Table prepared by the authors using their own data

Note. Age is presented as the mean (*M*) ± standard deviation (*SD*). Technical and tactical actions (TTA) values are presented as the median (*M_e*) and interquartile range [*Q*₁; *Q*₃].

Table 2. Comparison of attention metrics between performance groups

Indicator	Performance group	Indicator value, <i>M_e</i> [<i>Q</i> ₁ ; <i>Q</i> ₃]	<i>p</i> *	<i>p</i> (25th vs 50th percentile)#	<i>p</i> (25th vs 75th percentile)#	<i>p</i> (50th vs 75th percentile)#
Sustained attention (score)	1 (low)	2.50 [1.75; 3.00]	0.378	0.568	0.125	0.205
	2 (moderate)	3.00 [2.00; 3.00]				
	3 (high)	3.00 [2.00; 3.00]				
Sustained attention (numeric)	1 (low)	0.97 [0.94; 1.01]	0.821	0.650	0.780	0.820
	2 (moderate)	0.98 [0.96; 1.02]				
	3 (high)	0.96 [0.92; 1.00]				
Attention concentration (numeric)	1 (low)	1.01 [0.98; 1.05]	0.003	0.105	0.002	0.519
	2 (moderate)	0.98 [0.95; 1.00]				
	3 (high)	0.95 [0.91; 0.98]				
Attention concentration (score)	1 (low)	1.00 [1.00; 1.25]	0.001	0.089	0.001	0.098
	2 (moderate)	2.00 [1.00; 2.00]				
	3 (high)	2.00 [2.00; 2.00]				

Table prepared by the authors using their own data

Note. * Kruskal–Wallis test; # Dunn’s post-hoc test with Bonferroni correction.

Table 3. Comparison of attention concentration metrics between low- and high-performance groups

Indicator	Performance group	Indicator value, <i>M_e</i> [<i>Q</i> ₁ ; <i>Q</i> ₃]	<i>p</i> (<i>U</i>)*	Cohen’s <i>d</i>	<i>r</i>	<i>p</i> (ANCOVA)#	η ²
Attention concentration (numeric)	1 (low)	1.01 [0.97; 1.05]	0.003	0.65	0.152	0.007	0.26
	3 (high)	0.94 [0.91; 0.982]					
Attention concentration (score)	1 (low)	1.00 [1.00; 1.25]	< 0.001	0.82	0.380	–	–
	3 (high)	2.00 [2.00; 2.00]					

Table prepared by the authors using their own data

Note. * Mann–Whitney *U* test; # rank-based ANCOVA with age adjustment; Cohen’s *d* –standardized mean difference; *r* — correlation coefficient; η² — partial eta-squared; *p* (ANCOVA) — *p*-value from the rank-based ANCOVA. For the scoring measure of attention concentration, ANCOVA was not performed due to lack of variability in Group 3 (all values = 2). Groups 1 and 3 were compared using an a priori contrast; therefore, no correction for multiple comparisons was applied.

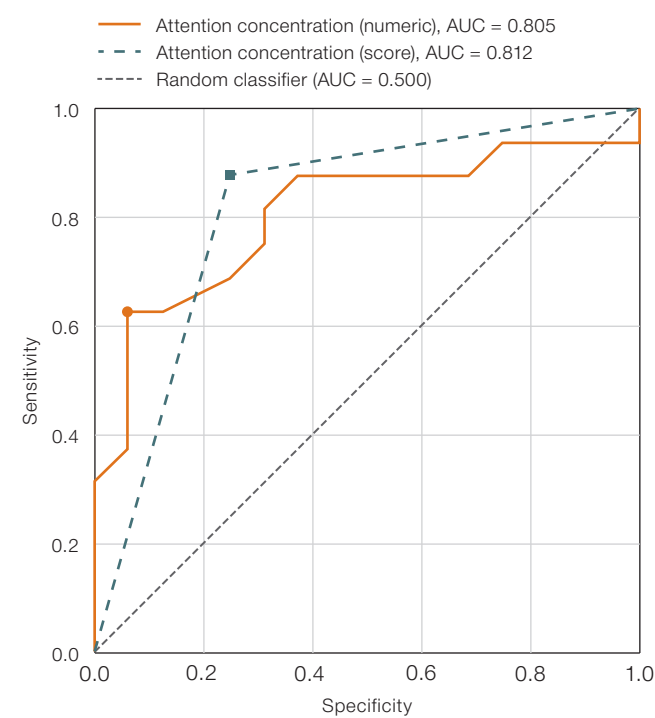


Figure prepared by the authors using their own data

Fig. ROC curves for numerical and scoring measures of attention concentration in hockey forwards

To further examine the differences between performance Groups 1 and 3, a Mann–Whitney *U* test was conducted (Table 3). The effect size was estimated using Cohen’s *d* and *r*. To control for the influence of age, a rank-based ANCOVA was performed.

Differences in the numerical attention concentration score were found between Groups 1 and 3 ($p = 0.003$). The effect size was $d = 0.65$ (medium effect) according to Cohen’s *d*, and $r = 0.152$ (small effect). After adjusting for age, the differences remained significant ($p = 0.007$), with an effect size of $\eta^2 = 0.26$ (large effect). Differences in the attention concentration score were also found between the groups ($p < 0.001$), with a large effect size (Cohen’s $d = 0.82$, $r = 0.38$). All players in Group 3 achieved the maximum score (2), indicating no variability within this group.

To assess the predictive ability of attention concentration measures for membership in the high-performance group, an ROC analysis was performed (Table 4, Figure). Preliminary data suggest the potential predictive value of both attention concentration measures ($AUC > 0.8$). For the numerical metric, the area under the ROC curve was 0.805 (95% CI: 0.669–0.974), with an optimal cut-off of ≤ 0.950 . The measure demonstrated high specificity (93.8%) and moderate sensitivity (62.5%). For the score-based measure, the AUC was 0.812 (95% CI: 0.781–0.987), with an optimal cut-off of ≥ 2 points. The metric demonstrated high sensitivity (87.5%) and moderate specificity (75.0%). PPV was 77.8%, and NPV was 85.7%.

For a clear illustration of the diagnostic accuracy of the score-based attention concentration measure at the threshold of ≥ 2 points, a 2×2 contingency table is provided (Table 5).

DISCUSSION

The present study revealed differences in attention concentration measures between forward hockey players with high and low performance levels. The effect size, estimated using Cohen’s *d* ($d = 0.65$), corresponds to a medium-to-large effect, indicating substantial practical significance of the differences. After adjusting for age using rank-based ANCOVA, the difference remained statistically significant, confirming that the effect is independent of age-related differences between the groups.

The present findings are consistent with the results of the meta-analysis by Ren et al. [5], which demonstrated that athletes outperform non-athletes in executive functions, particularly in inhibitory control and working memory. In our study, this effect is illustrated by within-group differences among players of a university hockey team. It was found that the attention concentration measure can differentiate hockey players with varying levels of competitive performance within the same playing position.

The neurophysiological interpretation of these findings is supported by the study of Yu et al. [8], who used functional near-infrared spectroscopy (fNIRS) to demonstrate that elite hockey players exhibit greater neural efficiency during attention-related tasks compared to

Table 4. ROC analysis of attention concentration metrics in hockey forwards

Indicator	Area under the ROC curve, AUC	95% CI*	Cut-off value#	Sensitivity, Se (%)	Specificity Sp (%)	Predictive value	
						positive, PPV (%)	negative, NPV (%)
Attention concentration (numeric)	0.805	0.627–0.946	≤ 0.950	62.5	93.8	90.9	71.4
Attention concentration (score)	0.812	0.674–0.938	≥ 2	87.5	75.0	77.8	85.7

Table prepared by the authors using their own data

Note. * confidence interval estimated using the bootstrap method (10 000 iterations); # threshold determined by Youden’s index.

Table 5. Association between attention concentration scoring (threshold ≥ 2 points) and membership in the high-performance group ($n = 32$)

Attention concentration (score)	Group 3 (high)	Group 1 (low)	Total
Positive test: score ≥ 2	14 (87.5%)	4 (25.0%)	18
Negative test: score < 2	2 (12.5%)	12 (75.0%)	14
Total	16	16	32

Table prepared by the authors using their own data

Note. Sensitivity = $14/16 = 87.5\%$; specificity = $12/16 = 75.0\%$; PPV = $14/18 = 77.8\%$; NPV = $12/14 = 85.7\%$.

less experienced athletes. In these players, activation of executive networks was lower, while task accuracy was higher than in novice athletes. Similar results were reported by Kirby et al. [1], who demonstrated that forwards exhibited faster sensory processing compared to defensemen, as indicated by a shorter N100 component latency ($p = 0.046$). This may reflect more efficient functioning of attention-related neuronal networks. Thus, the higher attention concentration observed in high-performance forwards may reflect both the neurophysiological “economy” of information processing and the accumulated perceptual-cognitive experience.

To evaluate the predictive ability of attention concentration, an ROC analysis was performed. Both the numerical and score-based attention concentration measures yielded AUC values greater than 0.8, which, according to the Hosmer–Lemeshow classification⁵, corresponds to “excellent” discriminative performance. The numerical measure is characterized by high specificity and moderate sensitivity, which makes it suitable for ruling out candidates with a low probability of success. In contrast, the score-based assessment demonstrates high sensitivity with moderate specificity, thereby minimizing the risk of overlooking promising athletes during the selection process.

The obtained AUC values exceed those reported for many other assessment methods in sports psychophysiology. For example, in the study by Lemoyne et al. [10], discriminant analysis failed to identify significant selection predictors in a male sample of junior hockey players. The authors attributed this finding to the high homogeneity of the sample and the insufficient sensitivity of the tests used. In contrast to their approach, ROC analysis in this study enabled the detection of subtle differences within a homogeneous sample, highlighting the advantage of this method for talent identification. Tétreault et al. [11] demonstrated that scouts’ subjective assessments remain the best predictor of performance; however, incorporating objective psychological tests may improve the accuracy of performance forecasting. The present study offers a concrete and readily available tool to complement such assessments.

A comparison with the study by Zhang et al. [12], in which the individual alpha peak frequency (IAPF) parameter was correlated with the accuracy of a multiple object

tracking task in hockey players, indicates that the attention concentration measures demonstrate comparable predictive ability. Notably, our method does not require EEG confirmation and can be applied in field settings, which substantially broadens its practical utility.

In contrast to attention concentration, the measure of sustained attention showed no differences between the high- and low-performance groups, with a very small effect size (Cohen’s $d < 0.1$). This finding is consistent with the data reported by Heilmann et al. [13], who demonstrated that cognitive training incorporating virtual reality improves inhibitory control but does not exert a significant effect on sustained attention metrics in young hockey players. Sustained attention likely serves as an indicator of the central nervous system’s overall tone, while selective attention constitutes a trainable skill directly associated with on-ice performance. Consistent with this distinction, Yu et al. [8] found that neurophysiological disparities between elite and novice players manifest primarily as differential activation of the right dorsolateral prefrontal cortex during executive function tasks, with minimal divergence observed during sustained attention trials. This may explain why selective attention — being a more active and controllable process — shows a stronger association with skill level than sustained attention, which functions as a passive background mechanism.

We included only forwards in the analysis, which limits the generalizability of these findings to defensemen. This methodological constraint is particularly relevant given that Kirby et al. [1] have demonstrated significant differences in neurophysiological markers of cognitive processing between these two positions. Forwards exhibited significantly shorter N100 latencies than defensemen ($p = 0.046$), suggesting distinct position-specific patterns of cognitive load processing. Conversely, other traits — such as attentional switching speed and spatial analysis ability — may serve as more salient predictors for defensive players, warranting targeted investigation in dedicated samples.

CONCLUSIONS

Attention concentration is an informative psychophysiological marker for differentiating university hockey

⁵ Hosmer DW, Lemeshow S, Sturdivant RX. *Applied logistic regression*. 3rd ed. Hoboken: Wiley; 2013.

forwards based on performance levels. ROC analysis confirmed the high predictive capacity of these metrics, enabling effective discrimination between players with varying competitive efficiency despite sharing the same playing position. The superior attentional focus observed in high-performance forwards likely stems from a combination of enhanced neurophysiological efficiency — reflected in reduced cortical resource allocation during information processing — and accumulated perceptual-cognitive expertise, which facilitates rapid pattern recognition and optimal decision selection. The score-based assessment of attention concentration yields diagnostic

accuracy comparable to standard quantitative metrics, supporting its adoption in applied settings due to ease of interpretation.

However, several limitations warrant consideration: the cross-sectional design, lack of external validation, and reliance on a single university team sample. Consequently, future research should employ longitudinal designs and validate these metrics on independent cohorts to confirm the findings and refine diagnostic thresholds. A further promising avenue is the identification of key performance predictors in defensemen — such as attentional switching speed and spatial analysis ability.

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Authors:

Evgeniy V. Bykov, Dr. Sci. (Med.), Professor, ORCID: <https://orcid.org/0000-0002-7506-8793>

Elena G. Sidorkina, ORCID: <https://orcid.org/0000-0001-6854-7406>

Vadim V. Sverchkov, ORCID: <https://orcid.org/0000-0003-3650-0624>

Irina F. Kharina, Cand. Sci. (Ed.), Assoc. Prof., ORCID: <https://orcid.org/0000-0003-0354-1841>