

The Performance Attribution Index (PAI): A causal and interpretable readiness framework for integrating monitoring data in elite sport

Eytan Ellenberg¹

¹Founder, Fair Research Organization, Jerusalem, Israel

Athlete monitoring | Performance attribution | Readiness assessment | Workload management | Game theory | Team sports

Headline

Elite teams collect extensive monitoring data but struggle to transform these signals into competitive readiness. The Performance Attribution Index (PAI), based on cooperative game theory, decomposes win-probability drivers into contribution and limitation factors. Across 4,956 basketball games and 12,643 football matches, PAI showed improved calibration and earlier detection of readiness decline compared to standard metrics, offering clear, interpretable decision support for high-performance environments.

Aim of the paper

Modern elite sport generates large quantities of monitoring information. Clubs routinely track fatigue profiles, workload ratios, and neuromuscular load (e.g., GPS-derived metrics), all associated with performance variation and injury emergence in team sports[1,2]. Tactical context also shapes match demands[3]. Yet despite increasingly sophisticated systems, practitioners still lack a causal and interpretable link between internal signals and competitive impact.

In most environments, medical, conditioning, tactical, and analytics departments operate in parallel rather than within an integrated causal framework. Key decisions may therefore be made without a shared understanding of why the data support—or do not support—a given operational choice.

To address this gap, we developed the Performance Attribution Index (PAI), grounded in the FAIR (Factor Attribution for Impact & Risk) methodology. PAI provides a 0-100 readiness score reflecting the balance between contribution potential (efficiency, tactical alignment, stability of form) and limitation factors (fatigue, overload, psychological state, contextual disadvantage).

This report demonstrates PAI's practical application in basketball and football and evaluates whether it improves readiness assessment relative to standard performance indicators.

Design

Retrospective cohort analysis across two professional team sports.

Methods

Athletes and Data Sources

The basketball dataset included 4,956 NBA games from publicly available sources, involving professional male athletes competing at elite international level. The football dataset consisted of 12,643 matches from top-tier European professional leagues. All datasets were publicly available, fully anonymized, and consistent with the Declaration of Helsinki.

Statistical Analysis

PAI performance was assessed using calibration curves and temporal-lag analyses. Attribution stability was estimated using 1,000 bootstrap resamples. Effect magnitudes were interpreted using standardized mean differences: trivial (<0.2), small (0.2–0.6), moderate (0.6–1.2), large (>1.2). All analyses followed established magnitude-based inference frameworks[5,6].

Results

Basketball

PAI detected readiness decline 3.2 days earlier (95% CI: 2.8–3.6) than standard indicators. Athletes in the top readiness quintile achieved a 68% win rate (95% CI: 64–72%) versus 32% (95% CI: 28–36%) in the bottom quintile ($d = 1.15$, moderate-to-large effect).

Football

Top-quintile players exhibited a 61% win probability (95% CI: 58–64%), compared with 35% (95% CI: 32–38%) for the bottom quintile ($d = 0.89$, moderate effect). Attribution stability remained high ($CV < 12\%$) even during congested competition periods.

Discussion

Practical Applications

PAI enables:

- Unified decision-making across medical, performance, and tactical staff
- Early-warning detection of readiness decline (2–4 days lead time)
- Causal interpretability showing why a player is in a given readiness state
- Scenario simulation to support load and recovery strategies
- Improved communication across departments by providing a single readiness signal

Limitations

- Analyses relied on public data; inclusion of internal GPS and neuromuscular metrics would improve precision
- Validation is currently limited to elite male professional contexts
- Match-to-match granularity; daily in-house monitoring could improve sensitivity

Practitioners can implement PAI immediately by integrating it into weekly medical–performance meetings, using the attri-

bution breakdown to identify early limitation factors and plan individualized load adjustments.

References

1. Impellizzeri FM, Marcora SM, Coutts AJ. Internal and external training load: 15 years on. *Int J Sports Physiol Perform.* 2019;14(2):270-273.
2. Armitage M, McErlain-Naylor SA, Devereux G, Beato M, Gabbett TJ. The training-injury prevention paradox: should athletes be training smarter and harder? *Br J Sports Med.* 2016;50(5):273-280.
3. Rein R, Memmert D. Big data and tactical analysis in elite soccer. *SpringerPlus.* 2016;5:1410.
4. Shapley LS. A value for n-person games. In: Kuhn HW, Tucker AW, editors. *Contributions to the Theory of Games.* Princeton University Press; 1953. p. 307-317.
5. Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. *Int J Sports Physiol Perform.* 2006;1:50-57.
6. Buchheit M. The numbers will love you back in return. *Int J Sports Physiol Perform.* 2016;11:551-554.
7. Sampaio J, McGarry T, Calleja-González J, et al. Exploring game performance in the NBA using player tracking data. *PLoS One.* 2015;10(7):e0132894.

Conflicts of interest

The author declares no conflicts of interest.

Data availability

Data derived from publicly available NBA and European football statistics. Code available upon reasonable request.

Copyright: The article published on Science Performance and Science Reports are distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated.



THE TRAINING
SCIENCE
PODCAST

ATHLETICA



VALID

