PERFORMANCE ANALYSIS: IS IT THE BRINGING TOGETHER OF BIOMECHANICS AND NOTATIONAL ANALYSIS OR AN ILLUSION?

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In this paper, I consider what performance analysis is, what biomechanical and notational analysis have in common and how they differ. I review how performance analysis can help coaches and athletes and how it can help to analyse and improve sports performance. Some important current issues that affect the future of performance analysis are considered before I conclude with some signposts on how performance analysis needs to develop in the future if it to be a real fusion of the two 'disciplines' rather than an illusion.

KEY WORDS: biomechanics, notational analysis, performance analysis, sport performance

INTRODUCTION: The term performance analysis is used here to describe the combination of biomechanical and notational analysis techniques to study how movements relate to sport performance. Biomechanics is a respected sport science discipline and notational analysis is now well established. There are regular international congresses of notational analysts and sports biomechanists, although they are often separate congresses or parallel strands of the same congress.

The two 'disciplines' are drawing together; e.g. the British Olympic Association (BOA) set up its Performance Analysis Steering Group in 1998, bringing together biomechanical and notational analysts to advise the BOA on all issues of delivering performance analysis services to Olympic athletes.

Sports biomechanics and notational analysis share some commonalties:

- They are concerned with the analysis and improvement of sport performance.
- They involve the measurement of the movement of performers, making extensive use of video analysis and technology.
- They both emphasise feedback to coaches and performers, which requires careful information management.
- They use systematic techniques of observation and share a concern for data validity and reliability.
- They are based on theoretical models (sceptics might disagree) based on 'performance indicators' – that are amenable to the methods used in artificial intelligence (AI).
- They share strong theoretical links with other sports sciences (particularly the dynamical systems approach of ecological motor control).

Clearly, there are also differences. Biomechanics:

- Studies of the fine details of movement of, mainly, performers in individual sports.
- Involves technique analysis.
- Uses performance indicators (PIs) that are usually kinematic variables or parameters.
- Has its history in mechanics and anatomy.

Notational analysis, on the other hand:

- Focuses on gross movements or movement patterns in team sports.
- Is concerned mainly with strategy and tactics.
- Uses match, tactical and technical performance indicators.
- Has its history in dance and music notation.

THE USEFULLNESS OF PERFORMANCE ANALYSIS

To highlight whether sport views performance analysis as useful, I have selected some recent and current projects in the UK that make use of performance analysis of elite athletes.

Biomechanics is used by:

- World Class Performance Plans (WCPPs), eg for athletics, gymnastics, swimming, speed skating.
- WCPPs for disability athletics.
- England and Wales Cricket Board (ECB).
- Various other sports, e.g. golf, tennis, through consultancies.

Notational Analysis is used by:

- WCPPs, for example, netball, badminton, hockey, squash.
- WCPP for disability basketball.
- ECB and other Governing Bodies.
- Various other sports, e.g. rugby, soccer, through consultancies.

As to its value for the coach,

Biomechanics:

- Identifies the performance indicators that relate to good and bad techniques.
- Helps to identify how techniques can be improved.
- Facilitates comparative analysis of (groups of) individuals.
- Helps to identify injurious techniques.

Notational Analysis:

- Identifies the performance indicators that relate to good and bad team performance.
- Identifies good and bad performances of team member.
- Facilitates comparative analysis of teams and players.
- Helps to assess physiological and psychological demands.

As examples of the information that can be provided for the coach and performer, I choose cricket and soccer.

Biomechanics of cricket:

Bowler

- Ball release speed.
- Run-up speed.
- Technique classification; shoulder counter-rotation.
- Segment movement sequence.

Batter

- Bat and ball speeds.
- Foot movements.
- Segment movement sequence.

Notational analysis of soccer:

- *Match indicators*: shots on target, shots off target, corners, crosses.
- *Technical indicators*: passes, dribbles, lost control, tackles won and lost.
- *Tactical indicators*: Possession, passing distribution, dribbles, pace of attack.

It is interesting to look at what would happen if we swapped the analysts working with these two sports.

Biomechanics of soccer:

Kick

- Kinematics and kinetics of kicking leg; sequence of kicking leg joint actions.

Throw-In

- Ball release velocity and arm kinematics in throw in.

Header

- Impact forces in heading.

Notational analysis of cricket.

- *Match*: How batsmen were out, shot patterns.
- *Technical*: Types of shot, types of ball, types of dismissal.
- *Tactical*: Types of shot for a given ball and vice versa, field placing.

We see, not surprisingly, that biomechanists and notational analysts stick to their comfort zone whatever sport they analyse. We can identify various issues or challenges to the two, formerly fairly disparate, groups as they seek to work more closely together.

SOME CURRENT ISSUES

Some of the important current issues that affect the future of performance analysis are considered here around six important themes, which I consider performance analysts need to address. Bullet point highlights on each of these issues are then provided to focus more clearly on some important observations.

- Why don't biomechanists analyse team sports more?
- Why do notational analysts use such gross performance indicators?
- Why do both types of performance analysis pay such little attention to normalising performance indicators?
- Why do both not spend more time researching how best to feedback information to coaches and performers and then make more practical use of AI-based tools?
- Why have both paid such little attention to the role of variability in sports skills: is it noise, opponents, compensatory or functional and what are the implications for coaching?

A Biomechanist's View of Team Sports?

- Technique deemed to be less important than fitness training, psychological preparation and tactics.
- YET - the most important requirement for success in team sports is SKILL (what biomechanists study!)
- Few biomechanists have paid any attention to the interaction of skill and successful play, which might need more qualitative approaches than usual.

Why are some Notational Measures so gross?

- Numbers of goals, shots on target, corners, crosses, tackles etc. do not tell us much unless related to other things - e.g. goals: shot attempts - including ratios that allow inter-team and inter-player comparisons.
- How do such measures relate to skill; e.g. what are skill elements in a successful shot on goal.

Why so Little Use of Normalisation?

- Normalisation common in electromyography (e.g. EMG as % of MVC signal) and engineering (e.g. Reynolds number) but not used enough in performance analysis.
- Ratios of shots on target: shot attempts; turnovers to possessions (in rugby); winner: error ratios add information to the simple numbers.
- Differences in peak segment speeds and their timing have been found between elite and young fast bowlers in cricket. However, when normalised to ball release speed and overall movement time, the only difference is ball speed NOT temporal co-ordination or proportionate speeds.

Best Feedback and Use of AI?

- Little research into how, when and in what form to provide feedback to coach and performer to improve sports performance.
- AI widely used in medicine, diagnostics and gait analysis. Still not commonplace in biomechanics, despite enormous potential for development.
- Although big advances have occurred in notational analysis packages, they are still far from exploiting the full potential of AI.
- This all means that feedback to coaches is not as structured or grounded in theory as it should be.

Variability?

- Variability is a characteristic of skilled sports movements, including:
  - EMG patterns in stereotyped activity.
  - Competition throwing.
  - Sub-optimal throwing.

Why this Variability?

- The cynical view is 'errors in measurement'.
- A neuro-anatomical view might be noise in the neuro-muscular system.
- The importance of variability has been recognised mostly by ecological motor control experts as functional and compensatory.
- Some biomechanists have proposed an injury prevention function.
- No serious study has been reported of how variability is moderated by opponents in team sports.

THE FUTURE FOR PERFORMANCE ANALYSIS

- Biomechanics and notational analysis of performance could continue separately, but this would miss opportunities.
- A more unified approach would be helpful, for example looking at interactions between the players, their movement skills and success; biomechanists may need a more qualitative approach if this is to happen (cf. gymnastics judging; technique analysis charts in track and field athletics).
- More attention is needed to the meaningful normalisation of performance indicators to aid analysis and coaching.
- More research should be carried out into how best to provide feedback to improve performance and to embrace in this development more use of AI-based analysis tools.
- Further real world study is needed of the role of variability in sports skills: noise, opponents, compensatory or injury-functional, and the implications for coaching.

These challenges must be met if performance analysis is to develop in the future into a real fusion of the two 'disciplines' - not just in the equipment we use but in our theoretical models and research themes - rather than an illusion.