Epistēmēs Metron Logos Journal No 4 (2020)
DOI 10.12681/eml.24289 ISSN 2585-2973

# On Sports Biomechanics Methodology

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## Abstract

Sports biomechanics is one of the most fascinating and formalised disciplines in sports science. While it uses a host of methods, on closer look, it lacks a thorough epistemological / methodological foundation besides what it implicitly borrows from the sciences it uses, such as mathematics and physics. Here, I shall attempt to portray what such a basic epistemological understanding would include and also try to address issues directly related to such an approach. I shall start by describing the most general context in which sports biomechanics exist and then, I will attempt to provide a structural context to bridge the gap between sports biomechanics and practice. In the conclusion it is suggested a more holistic approach in biomechanics.

**Keywords**: Epistemology, models, theory, structure, technique

## Introduction

As Latour has pointed out in his classic work "Laboratory Life", even in the most famous, Nobel-Prize winning laboratories, too many hard scientific facts have been "constructed" (1). At one point they are just hypotheses, opinions or ideas, and at another point they have become "hard facts" without anybody knowing how it happened. They are simply repeated in internal discussions so often that they magically transform into facts.

Under this prism, we shall consider the methodology of biomechanical modelling for sports. That is, we shall attempt to fit biomechanics research in our general approach about theory (2,3). While phrases such as "biomechanics of tennis strokes" are

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trending, such models are nowhere to be found in tennis. I have made a first attempt to present such a model in 2016 (4). Here I shall expand on the methodology of such models by covering a serious void in sports science which has created the most profound confusion in both sports scientists and practitioners: *epistemology*. In particular, I shall attempt to clarify the following concepts: method & methodology, structure, axiom, theory, model, truth, reality, verification, logic, statistics. Then, I shall attempt to present the rationale that such models should follow in an extended context (a bird's eye view)

## Basic epistemological background for coaches and researchers

In previous articles, we have been trying to lay the foundations of theory and understand where science became confused and why; several papers have been produced in this direction and this brief discussion reflects those findings (3,5,6). My approach is not historiographical but theoretical, i.e., purely epistemological. Our team has the unique advantage that it has been built around the work of the great mathematician D.E. Lekkas, who has created a whole mathematical field (theory of music: 7).

"Theory" is of course a Greek loanword (*θεωρία*: *theōrēa*). It is an abstract interpretation of an axiom. Abstraction is the process of eliminating meaning (or content) and adding generality (for example, the word "mammal" is more abstract and general than the word "human"). Axioms are the first postulates in an axiomatical (theoretical) system. Axioms are always completely abstract (this is why e.g. Einstein's theory of relativity *cannot* have the speed of light as an axiom). Axioms (and all resulting products, such as theories and models) are evaluated based on their consistency, their theoretical productivity and their elegance. Theories always identify with the axioms.

Unfortunately, Latin Scholars did not produce any term for the symmetrical Greek term *theōrēsē* (*θεώρηση*, meaning perspective). Therefore, "theory" confusingly means both a universal abstract standard and a personal point of view. This is in line with another disappointing selection on behalf of the Latin Scholars, who, despite translating every Greek Grammar term word-by-word (*claque*), they chose to call the basic Latin grammatical mode "indicative mood" (*modus indicativus*), the exact opposite from the Greek term; indeed a setback, an anachronistic choice with political connotations. There is no term in English for the Greek grammatical mood but is it very easy to make one up: it would be very accurate to use *definitive mood* as the exact translation of the Greek term (*enclisis horistikē*). When Greek is used to speak about the world, the world is defined; *conceived*. When any language that has some type of indicative mood is used, the world is indicated; *perceived*, as if there is no *fraud of the senses* anymore. Do not forget that the only reason epistēmē, theory and mathematics were produced in the first place was to solve the problem of the fraud of the senses – which is not even a "problem" since it has no solution. It is just an obstacle.

Inevitably, this recidivism to past conceptualisations of the world, exemplified by the basic linguistic mode of indicative mood, rendered the foundational distinction between truth (*veritas*, *alētheia*) and reality (*pragmatikotēta*) non-applicable. In science it makes total sense to identify truth and reality. However, reality is about things themselves ("Dinge an sich" as Kant put it), to which we have no access, whereas truth is only about abstract theory. We cannot verify any theory in the real world because verification is about truth, not reality. What we can do is use the method of theory (analysis-synthesis & abstraction structure) and create theories in abstraction; only afterwards we may select theoretical systems that suit our needs. Both Latin and Greek have compatible terminologies for describing a truthful representation of reality: *verdict* (meaning: to speak truthfully, Gr. *etymegorēa*)

Models, on the other hand, are not perspectives; they are idealisations of the world, meaning we have eliminated content from the world (through abstraction). Models may be described mathematically, however this does not prove them right or wrong for a specific use when we apply them back to the world. Because models fall in between theory and *theorēsē*, there is a term used in music that may describe their mathematical side: *theorētika*, or, *theoretics*. Theoretics are applied theories.

In sports science there cannot be axioms because e.g. kinesiology is not an abstract field as mathematics is. Tennis cannot have theories either, only perspectives and models. Models in tennis cannot be verified with experiments, nor can they be produced experimentally in the sense that observations cannot translate directly to models. We make observations and we select aspects of our observations that we, for whatever personal reason or bias, wish to describe. We conduct experiments in order to select models according to our needs; however, experiments cannot verify or falsify anything that is theoretical. I do understand this sounds strange since scientists have been addicted to another *modus* of thinking for centuries. However, this is not how theory works because in logic we are only allowed to go from a cause to an effect, not the other way around (this is a common fallacy known as *begging the question*). Cause-effect relationships are always theoretical, i.e. set only by us, never by the phenomenon itself. Even "trivial" cause-effect relationships are set by us: why does the apple fall? Because of gravity? Because of gravitons? Because it is ripe? Because its stem is cut? Because of God's will? We must not confuse stimulus-stimulus, Humean types of addictions to event-sequences with cause-effect relationships! The biomechanical models of the Fosbury Flop, of a tennis serve, the Kinetic Chain, all are abstractions that any *one* application of them (or many, in order to produce "statistically significant results") can neither verify them nor disprove them; testing them with expensive lab equipment will only tell us which interpretation of the model works for us now, under the existing requirements, biases, needs and means. By the way, statistics is *not* a proving method; logic is – and logic never allows us to evaluate/infer the causes (models) from observations (measurements).

Let me conclude with causes. Philosophers, since Aristotle, discussed the ways to discover the causes of phenomena. Later scholars, even modern ones, missed that Aristotle discussed inferences using geometry (i.e. mathematics) as his reference point. In the Middle Ages thinkers such as Bacon, Scotus and Grosseteste made significant contributions in the systematisation of procedures to discover the cause of phenomena. However, even *they* missed that phenomena do not present themselves with their causes; how could they? The causes are always set by us and never dictated by the phenomenon. For example: an athlete sprains her ankle in a rally. What is the reason?

- Bad shoes
- Bad surface
- Lack of concentration
- The tension from the previous point that she disagreed with the umpire
- Bad footwork
- Physiological factors (dehydration / exhaustion, overtraining, hormones etc.)
- Bad mood because she had a fight with her girlfriend's second mom last night
- A ball boy that coughed
- Bad Karma
- Good Karma (something bad happens to avoid something even worse)

Not only are any of the previous reasons equally valid, but for different professionals, different reasons apply. For example: for her nutritionist, the relevant reason is the dehydration and the exhaustion; for her trainer it is her footwork; for herself it is the umpire (the most immediate source of frustration is usually to blame) and for her yoga teacher it is her karma.

My approach is neither subjective nor objective: it is theoretical. This last part is what science has lost: contrary to the classical dichotomy between subjective and objective, there is this third possibility: *theoretical*. Trying to fit science between the subjective-objective bipole is one of the greatest misunderstandings of the last many centuries.

In Classic Antiquity, epistēmē was a way out of this bipole: being subjective is too personal and being objective is impossible due to *the fraud of the senses*. The latter is not a matter of using better measuring techniques since the cause is never part of the phenomenon, but it is set only by us in theory, thus it is neither subjective (based on my senses) nor objective.

## Biomechanics in contemporary research

Understandingly, contemporary research does not distinguish the aforementioned concepts. Even *methodology* is confused with *method* as one may understand from the titles of various articles (e.g. 8). Methodology addresses the ways in which methods are constructed. A new methodology may also be a Paradigm if it is incompatible with existing methodologies. New or different measuring techniques do not necessarily constitute a Paradigm.

A general idea one has about the trends in biomechanics research is that it is of two sorts: presenting simple and general principles as well as guidelines on one hand (9–11) and on the other hand providing a more elaborate mathematical analysis of movements (12,13). The principles and the guidelines presented are usually related to various themes in Physics, such as the Newton's Laws, Kinetic Energy, momentum – but they may also be related to e.g. physiology (Range of Motion, Electromyography etc.).

On the mathematical side, there is a pluralism of models used: analysis, geometry, trigonometry, calculus, and linear algebra, just to name a few (14,15). Dressing up or expressing a phenomenon with mathematics does not "prove it" (if that makes any sense to begin with) – let alone make a mathematically expressed observation "prescriptive" for future actions. So, on what grounds can anyone claim that while all models in biomechanics are descriptive, it is implied that they are "objective", prescriptive and one can freely (inductively) generalise? Statistics! However, statistics are not a proving method or logical, which is the only general proving method in mathematics, dictates to start from the abstract theory and then go to the world (16). Quasi-mathematicity is a generalised methodological disease in science often used in an attempt to present something as being important because it has been described with equations; as the Latin proverb goes, *quid quid latine dictum sit altum videtur*. In formal philosophical language this is also known as *bullshiting* (17,18).

In this respect, the use of deterministic models seems promising (19). In deterministic models a goal is broken down into its constituents and this analysis can extend to many levels. For example, *time* could be the goal in 100 m sprint analysis, which could be further broken down to *speed* and *distance* (on a first level), but also stride length, stride rate, stride time, velocity at take-off etc. (multi-level analysis). All levels should be mechanically interconnected. The problem with deterministic models (and the solution at the same time) is that if the analytic method is not used in the beginning, subjectivism could become a problem (20). Why? Because theory is neither subjective nor objective; it is *theoretical*, a third distinct case. Mathematics in general are universal, intersubjective and infinitely generalizable as much as they are infinitely precise. Thus, they cannot be a product of neither personal perspective, nor bound to the specifics of this world. They only exist on a third level, one that is unknown to science: the theoretical level.

Finally, there are various computer imaging models, either 2D or 3D that demonstrate movements. In the same way, there could also be artistic or graphically designed models. The means used for the creation of an imaging illustration is not important; what is important is the methodology: has it been created by copying players (via statistics)? Has it been created based on the experience of the designer? Has it been created as an artistic approach to the movement? All these models are methodologically similar even if the former (the mathematical ones) are quantitative and the latter (the imaging ones) are qualitative. The critical difference is made only if the model has been conceived in abstraction as the method of theory dictates. The method of theory consists of the two pairwise methods, analysis-synthesis and abstraction-structure (20). The former is all about breaking down an entity into segments (analysis) and also combining the segments to create the same (re-synthesis) or a different entity (synthesis), and the latter refers to the inclusion of the said entity, as a whole, to supersets (abstraction) and subsets (structure). An athlete in analysis is broken down into e.g. tissues (analysis) or may be included in the superset of performers (abstraction). A great methodological danger exists when confusing these methods, e.g. to reduce talent (an abstract-structural component) to analytical-synthetical components, such as the type of tissue an athlete may have.

## Structural analysis of Technical Form

In a holistic approach (synthetically), such as the Distal Method, technique has its place in a broader, unifying picture; technique, in itself (analytically), should also be based on unifying principles when describing various shots. In the former case, a bird's eye view is needed if general expertise is also desired; in the latter case, it would be too complicated if each shot needed a totally different biomechanical approach.

Let us first see the greater picture which is comprised of the following components:[2]

1. Sense: information received from various receptors, such as proprioception. Two examples of sense are pushing and pulling sensations.
2. Feeling: the conscious experience of a sensible stimuli. We may take it for granted, but it requires some form of training to be able to interpret sensible stimuli into feelings (a tacit process, mainly taking place at the earliest stages of life).
3. Emotion: the psychological imprint of feelings. A hug produces sensible stimuli from many parts of our body and it may feel "soft". A soft hug from our friend could make us experience the emotion of happiness, whereas the same hug from a total stranger at night in a dark park would make us experience the most horrific fear.
4. Biomechanics: the abstract structure of body mechanics in theory (a combination of physics, geometry and physiology).
5. Technical form: the translation of abstract biomechanics to a concrete movement formation. Technical form refers to distinct movements, skills or shots. Technical form may also be described as applied biomechanics or *simplified synthesis* (or *simplified tactics* in a simpler model).
6. Technical style: after years of training the technical form becomes personalised, i.e. adapted to both our specific body kinesiological characteristics and to our preferences (even to our neurotic patterns, enters psychotherapy).
7. Movement synthesis/structure: both are movement sequences. Movement sequences that have no further aim are called syntheses (compositions). Movement patterns that have an aim related to a specific shot are called movement structures. Applied technical form is movement synthesis and simplified tactics is movement structure.
8. Tactical form: sequences of movements with an aim regarding the outcome of the whole rally (a point). May also be viewed as *applied structure* or *simplified strategy*.

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[2] Readers may also compare these ideas with: Hay, J. (1985). The biomechanics of sports techniques (3rd Edition). Eaglewood Cliffs, NJ: Prentice-Hall; Κόλλιας, H.A. (2003). Biochinetics of Sports Movement. [Βιοκινητική της Αθλητικής Κίνησης]. Thessaloniki: Christodoulides; Ae, M. (2020): The next steps for expanding and developing sport biomechanics, Sports Biomechanics

9. Tactical style: the personalised expression of technical forms after years of deliberate and well-structured practice.

Note: Forms are taught, styles are the long-term (*distal*) expressions of forms and occur spontaneously at some later stage of evolution (which may be defined as *maturation stage*).

10. Planning: the process of projecting to the future structured ideas that will be used as goals.
11. Strategy: set of sequences of movements with an aim regarding the outcome of the whole match. Strategy may also be viewed as applied planning.
12. Life purpose: sets of sequences of movements with an aim regarding the outcome of all matches.

Note: many different technical form combinations can express a specific tactical form and many different tactical form combinations may express a specific strategy (and many strategies may express a life purpose). Strategy is not obvious from a partial knowledge of tactics used and tactics is not obvious from a partial knowledge of technical forms used (also, life purpose is not obvious from a partial knowledge of strategies used).

| | *Level I* | *Level II* | *Level III* | *Level IV* |
|---|---|---|---|---|
| *Fundamentals* | Sense | **Biomechanics** | Synthesis/structure | Planning |
| *maturation stage* | Feeling | **Technical Form** | Tactical form | Strategy |
| *maturity stage* | Emotion | Technical Style | Tactical style | Life purpose |

Table 1. A proposed, multilevel structural analysis of Technical Form.

In Table 1 the different components are shown. The fundamentals are always necessary before we move on to the maturation stage. In the maturity stage the full potential of the individual has been expressed and if a proper training method has been used, world-class performance should be the outcome.

A lot may be said about the interconnections of these 12 components; however, I shall focus on the biomechanics and technical form ("technique" from now on). The most important question for biomechanics and technique is how do we progress from the fundamentals to the maturation stage (which is an important question for all four levels). The answer is through sense and feeling (and through emotion we may progress from technical form to technical style). I have already argued, this connection is so crucial that it may be the only way to actually make distance learning possible (21); but it is quite true for any type of learning when it comes to teaching technique. Here we shall see in much greater detail how biomechanics are transformed to technique.

## From biomechanics to technique

The technical form is what we may observe and reach a conclusion such as "that performer belongs to that specific school", whereas the technical style is what makes us exclaim "I recognise from the movement alone that it is that specific performer!". There are many reasons technical forms develop; even quite odd ones, such as politics. Some reasons include:

- Disabilities or movement limitations, such as in the story of the overweight Kung Fu master who developed a Kung Fu style that worked for him and his students followed without necessarily being overweight.
- Imitation, such as the case in Eagle Claw or Mantis Kung Fu where insect movements are imitated. In tennis this is how people develop their technical form, imitating top players who supposedly have some kind of optimum technical form (this assumption has created a never-ending vicious cycle, besides being counter-theoretical).
- Deception, such as the drunken style boxing.
- Political and religious matters that pose limitations to how a movement may be performed.
- Biomechanics, taking into full consideration the optimum mechanics of a movement in order to produce a result in the most efficient way.

I will argue next that the best bridge from biomechanics to technique is *structure*. Structure is the word Latin Scholars selected to express the Greek term *domē* (δομή). Alas, they again chose to stop prematurely. Therefore, in e.g. English only two terms are available and consequently, only two ideas are conceivable: "structure" and "structuring". However, the inherent quadrupolar structure of the Greek language goes all the way. Four symmetric terms exist:

1. *Domē* (abstract archetype)
2. *Domēkē* (the methodology of creating / constructing)
3. *Domēsē* (the actual process of creating / constructing)
4. *Domēma* (the final tangible product after creating / constructing)

Let us attempt to correlate these four terms one by one with our concepts about biomechanics and technique:

1. Biomechanics: the abstract idea of a movement drawn on a piece of paper
2. Teaching methodology: practice programs, skill segmentation, practice distribution, pedagogical principles.
3. The actual training which takes place.
4. The technical form or the technical style.

There is the much sought-after bridge between theory and practice. It should also be mentioned that the Distal Method provides tools for all these four stages since it has been created based on these epistemological principles (22).
Going from *domē* to *domēkē* and then to *domēsē* and to *domēma*, all four and in this order, is not just a random idea but an Aristotelean theoretical necessity in Classical Epistemology[3]. Any deviation from this naturally ordered symmetry, results in a distorted view. As is customary in Classical Epistemology, one is free to choose any other way that one can demonstrate it to be:

1. Consistent
2. Theoretically productive
3. Elegant

Measuring methods are an important part of the sports biomechanics methodology but I will not go into that at all. Measurements cannot be prescriptive, even if they concern top players or successful trials. In Classical Epistemology, models are made first, and then measurements take place: for theory, world is not the start of our theoretical work but its end. If verification of theories in the world could happen, then of course observations could be used to improve theories – as is the case in the scientific method. However, no verification of theories via observations, at any level, is possible. If it was possible then all the achievements of Classical Epistemology would be in vain and epistēmē could never have emerged: witchcraft would be all there is (as is almost the case nowadays with the so-called experimental method).

## The future

A unified prescriptive biomechanics' methodology should emerge. At some point it should also become an interdisciplinary field accounting for all possible combinations presented in Table 1; for example:

[3] Classical Epistemology, as is described in the author's articles in Epistēmēs Metron Logos Journal

- Technical biomechanics
- Biomechanical technique
- sensory biomechanics
- biomechanical sense
- emotional biomechanics
- biomechanical emotions
- tactical biomechanics
- biomechanical tactics etc.

Bioinformatics will play an increasingly important role in the study of sports biomechanics. However, bioinformatics, expert systems, Artificial Intelligence and the like are not panacea. It is important to understand that the means are always of secondary importance in relation to the methodology.

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