SPORTS BIOMECHANICS IN THE YEAR 2000: SOME OBSERVATIONS ON TRAJECTORY

Jackie L. Hudson
California State University, Chico, California USA

The purpose of this article is to present a vantage point for examining the trajectory of sports biomechanics at the millennial cusp. The classic texts of Kuhn and Ravetz are used to develop multiple perspectives on the history and sociology of science. A sketch of sports biomechanics is drawn from participation at previous international symposia and compared to the historical and sociological perspectives. If history can be used as a guide, sports biomechanists may need to be more self-reflexive if we are to avoid many of the pitfalls of immature and applied sciences.

KEY WORDS: immature science, normal/mature science, folk science, applied science

INTRODUCTION: Sports biomechanics is a relatively new science. Although people have been interested in the mechanics of movement for thousands of years, and our foundation sciences date from the scientific revolution, research in sports biomechanics is a late twentieth-century phenomenon. Not until 1982 were there a sufficient number of researchers to establish an international society dedicated to bridging the gap between biomechanists and practitioners. Given the newness of our field, it has been natural to focus on our future instead of on our brief past. Now, however, might be a good time – as we are caught up in the spirit of millennial reflection – to examine the patterns of our past to ensure that we achieve the future that we envision.

Historians and sociologists of science (Cf. Kuhn, 1970 and Ravetz, 1971) have traced the evolution of various sciences from their immature beginnings to their more mature versions. From this broad view it is possible to identify patterns and pitfalls that are relatively predictable for most sciences. It appears that the wisdom of the particular scientific community can have a moderating effect on the severity and longevity of its predictable problems. Therefore, the purpose of this paper is to present a framework for evaluating and advancing an immature science and to apply this framework to sports biomechanics, especially as it is practiced in ISBS.

METHOD: The following descriptions of science are a composite from Kuhn (1970) and Ravetz (1971): In general when we think of science, we think of the products and researchers of normal or maturing science. That is, the researchers in a normal science form a community with several common bonds that allow them to produce an accumulation of scientific knowledge with an ever-expanding scope and precision. Most of this activity of a normal science is organized around a paradigm – an accepted model or pattern. At one level a paradigm is a theoretical map that specifies model problems such that the details can be elucidated by mature scientific research. The theoretical map needs to be sufficiently articulated that a community will be compelled to adopt it as their framework. Yet the map must be sufficiently open-ended to leave many problems for the researchers to resolve.

At the most metaphysical level, the paradigm specifies the community's worldview about nature – that is, what entities nature does and does not contain and the ways in which those entities behave. That worldview undergirds the community's determination of what questions may legitimately be asked, what techniques and instruments are used in seeking solutions, what counts as data, what is relevant to explanation and interpretation, what will be accepted as a solution, and even what analogies and metaphors are permissible. These determinations restrict a community's vision by forcing nature to fit into the conceptual boxes supplied by the paradigm, but they also permit the group to agree to a set of rules and standards for scientific practice. Once the worthy problems are defined by the paradigm, individual scientists can treat the problems like puzzles and can be relatively assured that there will be solutions as long as they stay within the paradigmatic rules. As the field matures facts and laws are established, theories are refined, and problems become more esoteric; the field appears to make progress in the accumulation of knowledge. Occasionally the scientific enterprise opens up new territory, displays order, or generates useful information. However, the individual scientist almost never does any one of these things – the individual is engaged in solving a puzzle that no one before has solved.

How does one acquire the explicit and implicit knowledge of a paradigm? How do members of a scientific community learn to see the same things when confronted with the same stimuli? At a basic level a community's paradigms can be found in its textbooks that present the body of accepted theory, illustrate successful applications, and provide exemplary observations and experiments. By combining lecture with problem solving via paper and pencil and lab instruments, the future scientist is able to acquire theory, methods, and standards in an inextricable mixture. This is extended through exposure to the technical literature, by modeling experiments on previous puzzle-solutions, and from comparisons of one's own perceptions with the groups' perceptions. Over time one absorbs the group-licensed way of seeing, and this exerts a deep, often unconscious, hold on the scientist's mind.

How do mature sciences grow? Once a paradigm is accepted, it will be tested with the observations and experiments that are easily accessible to that science's researchers. Additional development may lead to a refinement of concepts that increasingly lessens their resemblance to their usual common-sense prototypes. Scholarship proceeds along three channels: 1) extending the knowledge of those facts that the paradigm displays as particularly revealing, 2) increasing the extent of the match between those facts and the paradigm's predictions, and 3) further articulating the paradigm itself. Eventually as a field grows in breadth, it may subdivide into sub-specialties. (And sometimes two sub-specialties from different root sciences will combine.) As the sub-specialties extend in their new directions, their researchers will acquire new paradigms even as they may retain vestiges of the paradigms of the root science. These vestigial paradigms are retained because they have utility, but they do not suffice for the guidance of research. A field that is reluctant to move beyond its vestigial paradigms may begin to devolve into confusion or chaos.

Fields which are advancing may also approach an unstable state. At any given time there will be pockets of disorder in a field. If these cannot be resolved by an adjustment in the paradigm, insecurity may ensue. When a field's complexity is increasing much faster than its accuracy, that is a warning that a change is needed. At this point there may still be a paradigm, but few researchers will agree what it is. Perhaps a reconstruction of the paradigm will quell the crisis, but, if not, there will likely be a scientific revolution that requires a new paradigm and a new set of commitments.

Just as traditional periods of science end with confusion or chaos, they typically begin in a similar state before a paradigm is accepted. The pre-paradigm period of a field is characterized by fact gathering that is seemingly random; moreover, without a paradigm, all these facts are likely to seem equally relevant. If a new technology has spurred the emergence of a field, there may be an excess of such facts. So even though individuals practice science, it does not add up to science as we know it. Without a common body of belief, each individual will need to build the field anew from its foundations including the choice of observations and methods. But nature is too complex and varied to explore at random; a map is just as essential as observations and experiments. Interpretation depends on at least some implicit body of intertwined theoretical and methodological belief that permits selection and evaluation of information. Instead, speculative and unarticulated theory is more common. Often the researchers will be divided into schools that have distinct views of nature and different opinions on what constitutes problems and solutions. In short, members of each school will see different things when they look from the same point in the same direction. When paradigms are insecure, the rules become important; thus there may be deep debates over methods and standards. Evidence of progress is hard to find except within a school, but even so, a school will not recognize work unless it is a bona fide addition to the collective achievement of the group. Researchers may start to wonder why their field does not seem to be moving ahead. The answer lies in acquiring a paradigm.

Some immature fields of science can be operating in parallel with a folk science. The characteristics of a folk science are: 1) there is a body of accepted knowledge, but it is not advancing, 2) the body of knowledge offers comfort to a group of believers, and 3) the depth of belief is greater than and independent of the achievements of the field. Even if an immature field can avoid becoming a folk science, there are other obstacles if the field is a human science or an applied science. Historically the human sciences have had difficulties in acquiring paradigms, and that has led to overt disagreements about the nature of legitimate science problems. That in turn has led to the need to divert energy to defending one's choice of problems in terms of their social significance. In addition, practical problems are made difficult by the fact that there may not be a solution. This means that the puzzle-solution model of normal science will not work. Evidently it takes a different approach to answer questions where the criterion is "meaningful" instead of "measurable." Finally, whenever practical answers are supplied by research, they are slow to reach the public given that many research reports are needed to establish a fact, textbooks are slow to acknowledge the fact, and the popularized version of the fact is usually based on the textbook version.

There are numerous perils and pitfalls awaiting any science that can be described as immature, folk, human, or applied. For instance, there are likely to be many conditions outside the science itself that influence the range of available alternatives. One such condition is the pressure to imitate mature sciences. To that end the scientists in a field may make heroic attempts to amass data and develop methods, especially quantitative, reductionistic ones. Rather than admit to any deficiencies, there may be a tendency to ignore or deny the inevitable pitfalls of the field. And paradoxically when a field tries too hard to look good, it may look bad. In particular quality control and integrity may suffer. One sign of this is that the rewards for writing papers are greater than those for reading them. The prescription for recovery is to start with common sense instead of esoterica, to strive for balance among philosophy (i.e., theory), history (i.e., descriptions), and art (i.e., methods), and to seek out qualitative relationships and aphorisms before quantitative models and laws.

RESULTS AND DISCUSSION: As a scientific community, ISBS is diverse on many dimensions. In terms of nationality, the original membership was skewed toward North Americas, but the current membership hails from dozens of countries from all over the world. As for athletic background, we have members interested in dozens of major and minor sports. Some members have been players or coaches; most are also spectators. We have academic backgrounds in physical education/kinesiology, engineering, computer science, physics, biology, mathematics, and other fields. The age range of our members is from approximately 20-80 years. Some members were active researchers in sports biomechanics well before ISBS was founded in 1982, and others are new to the field. Perhaps in part because of the geographic rotation pattern of our symposia, there has been a large turnover of the people who attend our symposia from year to year. In sum, there are many demographic effects that are working against our becoming a cohesive community.

The unifying theme in our community seems to be that we all have some interest in sports and some interest in biomechanics. But it might also be said that many of us are not particularly interested in all sports or all facets of biomechanics. As another point of intersection we presumably share the value of bridging the gap between the researcher and practitioner. But the ways in which we manifest this are sometimes difficult to discern. In fact, the early ambition of having practitioners attend and interact with us at our research presentations has largely been abandoned.

In the early years most of us were concentrated in the area of applied sports biomechanics, but we have broadened our scope considerably in recent years. Now we have many presentations where actual humans or sports are only tangentially involved, if at all. We are so diverse in our interests that it is unlikely that our various sub-specialties will all be able to use the same paradigms. So the people in each of our sub-areas may wish to consider their own particular paradigmatic issues. In the following paragraphs I will be primarily focusing on the sub-area of applied sports biomechanics.

Do the researchers in applied sports biomechanics have a paradigm? Do we share textbooks, illustrative applications, methods, or exemplars? In general, the applied group seems to exhibit many of the characteristics of a pre-paradigmatic period with different schools. We learned sports biomechanics from several different texts (if in fact we learned from texts at all). Many of our texts included sections on Newtonian mechanics and gross anatomy which, though useful, are essentially dormant areas of research now. The remaining content of our texts varies considerably from book to book; this lack of standardization is indicative of an absence of an accepted paradigm. In many cases we also learned other scientific paradigms. Our division into schools may be based in part on which other paradigms and applications we have learned. For example, some people may embrace the metaphor of "man as machine" while it causes other people to bristle. There is no question that our field has been aided by technology. Our methods of data collection range from electromyography, to videography, to force transduction. Our concept of space varies from the somatic level (e.g., the center of gravity) to the segmental or smaller level. Similarly our concept of time varies from intervals of one second to much smaller instants. What rules do we follow when we decide how to observe space and time? As for exemplars, do we as a community recognize any examples of well done studies? How do we organize our material – by sport, by methodology, by concept, by caliber of athlete? Could we use the practitioners' ideas and literature to direct our inquiries?

To what extent is applied sports biomechanics an immature or ineffective science? We seem to primarily use the fact production channel of research to generate ever more complex and quantitative data. When we do not specify our paradigms, our information appears to be randomly acquired and equally relevant or irrelevant. Similarly there is no means for us to accumulate and interpret our information in meaningful ways. In particular, it would be appealing to know how specific sport activities may be indicative of broader categories of movement. Have you ever wondered when our field will start to move forward?

To what extent is sports biomechanics akin to a folk science? There are people who believe that our primary paradigm is Newtonian mechanics even though that field is not advancing. And there are people who see our high technology and believe that we can produce magical scholarship. To what extent are we these people? On the one hand, we may benefit from having a cadre of believers. But on the other hand, we may be losing people who become disenchanted.

How do we handle our mission of bridging the gap with practitioners in view of the difficulties of doing applied research? We seem to be ambitious in the scope of our studies, but we may be undertaking more than we can accomplish in single studies. And we may be deluding ourselves if we think we can provide practical answers in a hurry. Meanwhile we are surrounded by colleagues from more mature disciplines, and that puts pressure on us to measure up. That often means doing data-based work when we would be better off developing theory. Or it may mean writing one more article with little benefit to the reader. Years ago it was common to acknowledge our pitfalls as we sought to minimize them; could we renew our commitment to this critical area? Could we return to a common-sensical approach and a reexamination of our fundamental questions of "how do humans move?" how do better humans move?" and "how do humans move better?"

CONCLUSIONS: As a new science, applied sports biomechanics has many issues to deal with before it can reach maturity and reliably provide the answers that our clientele seeks. The simplest solution – common sense and balance – may be best for our difficulties.

REFERENCES:

Kuhn, T.S. (1970). *The structure of scientific revolutions* (2nd edition, enlarged). Chicago: University of Chicago Press.

Ravetz, J. (1971). *Science and its social problems*. Oxford: Oxford University Press.