BIOMECHANICS IN TEACHING AND COACHING - SYSTEMATIC API'ROACHES TO THE IDENTIFICATION OF MECHANISMS IN I'ERFORMANCE AND INJURY

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INTRODUCTION

As biomechanists we are concerned with generating, synthesising and organising biomechanical knowledge for the student and the coach. What may be organised knowledge from the point of view of the biomechanist, may appear as random information to the coach. To help in the generation and conveyance of effective knowledge a systematic approach is required. This systematic approach involves setting out a framework or model which provides direction in the collection of biomechanical data, and which leads naturally to a consideration of the underlying mechanisms governing performance. The purpose of this paper is to identify and illustrate several systematic approaches to achieve this goal.

THE NEED FOR A SYSTEMATIC APPROACH

The human body can be considered as a number of linked segments. Each segment has several degrees of freedom and each degree of freedom can be described by several kinematic descriptors. The number of descriptors of a sports skill can therefore exceed several thousand. In many biomechanical analyses attempts are made only to evaluate a selection of these descriptors. This tendency has been reinforced by the ability of biomechanical equipment to generate vast quantities of data and the enthusiasm of researchers and students to collect data perhaps in the belief that this represents scientific progress. It has also been reinforced by the increase in biomechanical profiling of elite sport, essentially the compilation of a descriptive data base, often from pretigious conipetitions such as Olympic and World championships, leading credibility to the approach.

The mechanical characteristics presented as key variables in any study may be selected for several reasons. Perhaps the biomechanist thinks they are iniportant (e.g. Elliott, et al. 1986); perhaps the coach has requested them (e.g. Rash et al., 1990); perhaps they are an expression of an underlying mechanisms (e.g. Takei,1989), or perhaps they are nieasured simply because they are there to be measured (e.g. Miller, et al., 1989). The fact that little information is given to explain why these variables are measured is an indication that there is little by way of a systematic approach to the analysis of a sports event or action. There is a gap in our biomechanics methodology if reference cannot be made to underlying guiding principles in the biomechanical analysis of a sports event or action.

This is not to say that systematic or model approaches are not available, but that they are rarely acknowledged and poorly used. I'here are several which can Be identified, classified and modified from the literature.

TECHNIQUE MODEL

The term 'technique' used with reference to sports skills is understood to refer to the 'way of doing' or 'way of performing' the skill. There are many published articles which deal with the technique of performance for different sports. These range from the sports specific to the more biomechanical. A good example of tlie sport specific is that given by Tidow (1990) referring to tlie model technique of the long jump event. He divides the event temporally into several phases and describes the positions and actions that are characteristic of good technique for each phase. The phases follow classical divisions of the event but are amplified with the addition of sections specifically on the preparation for take off (the last few strides), landing and alternatives for flight styles. Each of these phases is clearly described and easy to follow. A good example of a biomechanical technique analysis is the report eminating from the analysis of the same event in the Seoul Olympic games (Nixdorf and Bruggemann, 1990). They defined a model of the technique which consisted of the usual four phases of approach, take off, flight and landing. They conducted three dimensional filming of the long jump and from an analysis of this reported data on variables such as stride lengths and frequencies and velocities over tlie last four strides. In addition they reported data on velocity and angle of projection, and various otlier data on body lean and time of foot contact. They also correlate numerous variables and found relationships between velocity and distance variables. An inovation introtluced into their report was a section on interpretation by coaches. Generally coaches asked for even more data than was presented, an indication that they were stimulated but not satisfied by the quantitative data. They were however excited by the attempt to draw links between variables and felt tliis was tlie most important part of the report.

These articles are typical of those reported in many other sports events both within athletics and in other areas. They serve to highlight a traditional approach to the breakdown of a skill. An analysis has taken place in that it has been brokendown into constituent parts, but this breakdown tloes not necessarily lead to an understanding of why these actions described are actually used. The breakdown of an event into its phases arid a description of each phase in verbal or numerical terms is a classic approach to the analysis of technique. As a structured framework this constitutes a model which guides tlie analysis of technique. This approach is rarely acknowledged, or referred to explicitly in most technique analyses. It is curious that the systematic breakdown of an event is not acknowledged as a such. It makes the process of teaching and learning more difficult because there is no framework from which to build the general principles of analysis. Students and coaches must be exposed to many instances of technique analysis before they are able to abstract the framework which is implicitely used, Not only is tliis is a most inefficient way of teaching applied biomechanics but it also has a more serious limitation. The assumed model which is abstracted from common usage does not lead to a demand for a rationale, explanation or identification of underlying mechanisms of operation which in turn can lead to a fuller understanding of the skill. A model can be easily specified which tloes demand such an estension, and this is illustrated below.

TECHNIQUE MODEL

LEVEL	DETAIL
1. event	
2. phase	
3. phase descriptions	
4. rationale/mechanisms	

As a model, it requires a breakdown of the event into its temporal phases, For example the approach, the takeoff, the flight and landing for the the long jump. Each phase then requires a description, as given by Tidow (1990) for example. However the model now demands that the actions described are also explained. For example, the lowering of the total body centre of gravity (CG) during the last few strides in the long jump is an observable feature of good performers, while this is frequently described it is rarely explained. As biomechanists dealing with students and coaches it is imperative that we are able to identify the reasons for the things we observe and measure if we are to foster an understanding of a sports skill. There are some important advantages and disadvantages of this technique model as a vehicle for understanding sports skills. The advantages are (1) it is spatial, temporal and rational, in that it is easy to see, it is sequential and it is logically based on what athletes are observed to do; (2) it is closely related to a coaches view of an event, understandably as it is used widely as a basis for coaching; and (3) with the addition of the fourth level, the model focuses attention on the explanation of the described actions. The disadvantages are (1) it fails to explain the outcome of performances in that even if all the described actions are correct it will not necessarily lead to a good outcome; (2) fails to give direction to speed of movements; and (3) fails to give direction to physical characteristics such as muscle strength and muscle power output.

OUTCOME MODEL

The failures of the technique model lead naturally to consider how they might be overcome. The outcome of the performance is a clear focus for attention from both biomechanicians and coaches. The factors which are related to successful performance can be identified. Initially these will be mechanical, but are likely to go further by considering the biomechanical and even physiological. Unlike the technique model, which has not had a formal structure, attempts have been made in the literature to explicitly identify the factors which affect performance outcome. This approach is largely due to the work of Hay (1975) who introduced and has widely used a 'deterministic model' to describe performance outcome. While in his many works over the last decade or- so the detail of the model has developed, it has not developed beyond a hierarchical structure of dependent factors. Despite the fact that this model focuses on an important characteristic of an event - the outconie, it has not been used widely outside of the work of Hay and his collaborators. It is difficult to identify- the reasons for this, but certainly one reason may be that the model starts off simply and clearly, but quickly fades into Factors which become too general. As a model it is valuable but needs to be focusecl if it is to be helpful.

One way of achieving this is to repackage the model such that various levels in the hierarchy are identified, and that the final level has a positive function. This is done in the figure below.

OUTCOME MODEL

LEVEL	DETAIL
1. event outcome	
primary outcome determinant	
secondary outcome determinant	
tertiary	
2. primary mechanical factors	
secondary mechanical factors	
tertiary	
3. primary biomechanical factors	
secondary biomechanical factors	
tertiary	
4. mechanisms/rationale	

It can be seen that each of the levels in Hay's deterministic model can be identified and if the level identifying the mechanisms is included, there is a clear purpose to the lower heirarchical levels of the model.

The advantages of this model overcome the disadvantages of the technique model. The advantages can be identified as (1) the model focuses on the outcome; (2) it highlights key performance variables; and (3) it can introduce other factors relevant to performance. The disadvantages are (1) the model requires a detailed knowledge of mechanics and biomechanics; (2) it is abstract and therefore difficult to use; (3) it omits details of preparatory movements; and (4) it omits details of technique or 'how to achieve the outcome'.

CAUSAL MODEL

The two previous models are complimentary and can be used to help identify the mechanisms underlying performance. If these mechanisms are influential then there should be evidence of cause and effect relationships. A simple example could be the long jump where relationships between the length of approach, velocity of touchdown and the distance juniped might be expected. These are all linked causally by accepted mechanisms. The greater the length of tlie approach tlie greater the velocity at touchdown (up to a maximum); the greater the velocity at takeoff the greater the distance jumped as the body is governed by the mechanics of projectiles. These causal relationships would suggest a positive relationship between approach distance and velocity of touchdown, and a positive relationship between takeoff velocity and distance jumped. If these relationships are found they in turn reinforce our understanding of the mechanisms operating, and allow a prediction of the outcome of further modification in these variables. If such relationships are not found then our understanding of the underlying mechanisms neetls to be thought through again. The search for causal links between performance variables is often by a multiple cross correlation between measured variables. This 'shotgun' approach is likely to throw up several casual relationships, but do not in themselves lead to an understantling of causal relationships. In our own work (Lees et al., 1992a) up to 56 perforniance variables are measured arid potentially 1540 correlation coefficients could be generated. Chance would lead over 77 of these to be significant at the 5% level, and so an inspection of significant correlations without the help of a model would riot be profitable.

There has been one useful example in tlie literature which has attempted to draw links between performance variables which would be expected to be linked following a consideration of the mechanisms underlying performance of the event. This is by Hay and Nohara (1990) and relates again to long Jumping. In their summary of significant correlations they are able to link together variables such as touchdown distance, touchdown horizontal velocity, vertical velocity at takeoff, height of takeoff and distance jumped. This

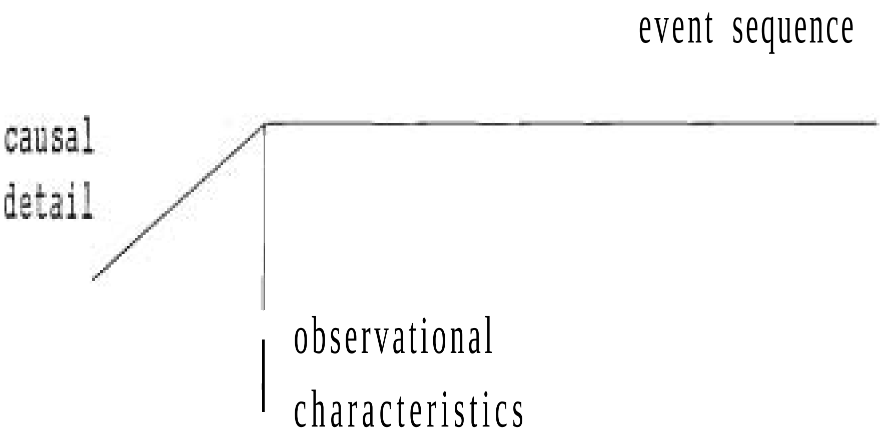

Figure 1 Causal Model.

approach is much more useful in establishing an understanding of the critical performance variable than any other systematic approach used in the literature. The approach of Hay and Nohara, as important as it might be, stems from the insight gained from a decade of concentratetl work in tlie event rather than by following systematic procedures. Their result is not a motlel as such, but a model can he proposed which allows these links to be made. A causal model can be proposed which is diagramatically represented in Figure 1.

The essential features of this motlel are that two or more observational characteristics (for example velocity of touchdown, velocity of takeoff, distance jumped) are linked causally in time as they appear as a part of the event sequence (i.e. velocity of touchdown, velocity of takeoff, and tlistance jumped woultl be linked in that order due to their temporal sequence). The thirtl dimension describes tlie greater levels of detail between observational characteristics. For example at a simple level in tlie long jump there has always been a concern for the relationship between approach velocity and tlistance jumped. Generally there is a significant positive relationship reported (eg Hay, 1986), as would be expected on the basis of a knowledge of tlie underlying mechanical factors. However, in attempts to explain the influence of other observational characteristics, a more detailed level can be chosen. Such an example would be the relationship already described by Hay and Nohara, (1990). Yet further causal detail can be proposed to help explain further more complex mechanisms thought to be operating, and these are discussed in Lees et al., (1992b).

As with the previous models there are advantages and disadvantages. The advantages are (1) the motlel is based on a theoretical underpinning of an event; (2) it attempts to draw links between critical variables and not just any variable; (3) provides a genuine basis for enhanced performance and training regimens; *(5)* can lead to improvements in technique; (6) can exist at a simple level but is capable of further refinement in detail; and (7) incorporates the best elements of tlie Technique model and the Outcome model. The disadvantage is that a detailed knowledge of biomechanics is required for satisfactory use.

CONCLUSIONS

The three models identified above are reflections of approaches that are used by sports biomechanists but they have been identified and formalised. In each case the models have been given some extra features which helps to focus their application. Without these extra additions the models lack the sense of purpose which is require to make them useful. It is not suggested that these models are definitive either in their number or scope, but are likely to cover many requirements in biomechanics.

The fact that systematic approaches to the understanding of events has not been a routine feature of biomechanics research is quite surprising. It failure to appear at research level has also meant that it not an accepted approach in tlie teaching of students or the collaboration with coaches. It is the contention of this paper that the use of systematic approaches to the would help all concerned to reach their goals sooner, and in so doing enhance the quality of our work and the value of' sports biomechanics to others.

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