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Methods of Biomechanical Analyses in Sports

Joseph Rugai

Department of Teacher Education, Faculty of Education, Niger Delta University, Wilberforce Island Bayelsa State, Nigeria

Email address:
drjrugai@gmail.com

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Abstract: This paper discusses the concept of biomechanics and the different biomechanical analyses used in sports. Biomechanical analysis involves the evaluation of techniques, whether in sports, industry, or everyday life. Methods of analysis used in biornechanics vary, from those requiring expensive and complex equipment, to techniques utilizing little more than an acute eye and an understanding of the mechanics of movement. Qualitative or subjective method of analysis describes quality without the use of number, and this is the most frequently used during direct observation of movement. Quantitative analytical method entails the collection, measurement and evaluation of data from the activities of interest and it involves the use of number. Visual observation is inadequate to solve the performer's problem, unless qualitative and quantitative analyses are combined. However, the general aim of work in predictive analysis is to use a computer model of a person or piece of equipment to predict changes which would occur in a movement as a result of alterations to the input parameters. This paper therefore recommends that tools and materials needed for biomechanical analyses should be made available to sport and exercise scientists to enable more quantitative research, for optimal performance.

Keywords: Biomechanical Analysis, Sports, Qualitative Analysis, Quantitative Analysis

1. Introduction

Biomechanics is the physics of human motion. Biomechanics is the branch of science concerned with understanding the interrelationship of structures and functions of living beings, with respect to the kinematics and kinetics of motion (Adrian and Cooper, 2005).

Kinematics describes motion, including the pattern and speed of movement sequencing by the body segment, which often translates to the degree of coordination an individual displays, while kinetics studies the actions of forces associated with motion (Hall, 2009).

Sport kinematics analysis studies the positions, angles, velocities and accelerations of body segments and joints during motion, while kinetic analysis studies forces that produce the movement. When people or athletes learn a new motor skill or sport skill, a progressive modification of movement kinematics reflects the learning process. Is the skill correctly reproduced at the appropriate speed or velocity, or is the form or pattern well sequentially coordinated? Are the forces applied harmonized with the movement? Answers found will determine whether the techniques were correct or not or can be improved (Hay, 2003; Hall, 2009).

Athletes and coaches are always striving to reach peak performance. The current available evidence suggests that the use of technology makes it possible for coaches to provide their athletes with the best possible opportunities to achieve maximal performance (Adegbesan and Ekpo, 2004). Therefore, sports biomechanists need to adopt the correct methods of analysis to improve skills and optimize the performance of athletes and coaches.

2. The Concept of Biomechanical Analysis

Biomechanical analysis is the evaluation of a technique, whether in sports, an industry, or in everyday life. Methods of analysis used in biomechanics vary, from those requiring expensive and complex equipment, to techniques utilizing little more than an acute eye and the understanding of the mechanics of movement (Adrian and Cooper, 2005; Marshall and Elliot, 2005). The goal of sport biomechanics is to provide information to coaches and athletes on sport skill techniques that will help them to obtain the highest level of athletic performance (Smith, 2003). However, according to Glazier et a1. (2003), the concern of many influential investigators, for quite sometime now, is that biomechanical research and, more notably, sports biomechanics research, needs to move from its descriptive phase to a more analytical level (Baumann, 2007; Norman, 2009; Nigg, 2003); hence, the need to employ every available means to use the methods and materials for better analysis of skill and movement to improve performance. At any level of movement analysis, there is a need for interaction between the coach and biomechanists, if maximum performance is to be achieved. Objective or quantitative evaluation of movement requires that a permanent record be collected for a number of trials, so that each can be viewed and analysed. The recording of permanent data on movements may take a number of forms; for example, cinematography, videography, electromyography (EMG), accelerometer, dynamometry, electrogoniometry — though some of these techniques may not be available for general use (Adrian, 2003; Marshall and Elliot, 2005).

3. Methods of Biomechanical Analysis in Sports

Analyses in biomechanics may be classified under three general areas: subjective, objective and predictive techniques. Most coaches and paramedics use varieties of subjective evaluation techniques during their normal interaction with athletes or patients. They watch a subject, for example, to determine whether there are any gross abnormalities in the range of movements at the joint during walking, lifting, takeoff or release of an implement, such as in a javelin throw or the ball in jump shot. Sometimes, a coach may measure the forces a high jumper exert on the ground during a takeoff, by using a force platform to determine a change in the approach velocity. Predictive techniques attempt to answer the 'what if...' questions. For example, what effect would reducing the angle of ball release of a basketball player who consistently misses free throws have?

3.1. Qualitative Methods of Analysis

Qualitative analysis methods are also referred to as subjective methods (Marshall and Elliot, 2005), involving a non-numerical evaluation of a skill and is most frequently performed during direct observation of movement. It is a seemingly natural characteristic of good coaches and clinicians. This is the description of quality without the use of number. This skill can be learned and improved through practice. However, Adrian and Cooper (2005) explained that, for one to be consistent and reliable both in observing a performer's learning motor skills and in evaluating movement for practical, diagnostic, clinical or research purposes (viewed either in life or film), a researcher must adopt a definite observational plan. The plan might include the following steps:

a. view multiple times
b. view from multiple perspectives (planes)
c. focus on parts, then whole, then parts
d. form a visual mental image of the performance
e. use a checklist: either construct your own or use available ones.

Therefore, qualitatively describing the kinematics of a movement will entail identifring the joint actions, including flexion. extension, adduction/abduction, rotation and so forth. A detailed qualitative analysis might describe the precise sequencing and timing of body segment movement. This translates to the degree of skill evident on the part of the performer.

Most qualitative analyses are carried out through visual observation and, as pointed out by Hoffman (2004), performance deficiencies may result from errors in technique, perception, or decision-making. Hail (2009), therefore, added that it will require more than visual observation to solve the performer's problem, making a combination of both qualitative and quantitative analyses imperative. However, McPherson (2008) and Hay and Reid (2008) proposed the inclusion of a pre-observation phase, where a model of the skill to be analysed is developed and mechanical variables concerned and their relationships are described.

3.2. Quantitative Methods of Analysis

This method is otherwise known as objective technique in biomechanical analysis. This is the collection, measurement, and evaluation of data from the activity of interest. Quantitative analysis implies that numbers are involved. According to Hall (2009), sports biomechariists often quantitatively study kinematics features that characterize elite performance of a particular athlete. Sometimes, this type of analysis results in constructing a model that details the kinematic characteristics of sound performance for practical use by coaches and athletes

Steps in quantitative analysis include the following:

1. Pre-observation stage; and this should include:
a. determination of performance goal and mechanical variables
b. identification and selection of critical variables
c. Determination of acceptable range for these variables
2. Development of an observation plan; to include:
a. observation desired
b. response observed
c. response diagnosis
d. discrepancy (allow for individual variation)
e. identify errors
f. rank errors
g. remediation
h. communicate error correction strategies.

3.3. Predictive Analysis Methods

Computer simulation and optimization techniques have been applied widely in studies of sports and human movement to predict sports movement. Adrian and Cooper (2005) explained that researchers have combined the mathematical modeling of the anatomical characteristics of a living body with simulation techniques for the purpose of predicting performance achievements and developing new performance techniques. The general aim of work in this area is that, by using a computer model of a person or piece of equipment (the 'system') to predict changes which would occur in a movement as a consequence of alterations to the input parameters, answers are provided to such question as: 'what would happen to the movement if this factor were changed to...?' (Marshall and Elliot, 2005).

4. Simulation Predictive Analysis Methods

Computer simulation is the use of a validated computer model (a set of mathematical equations describing the system of interest) to evaluate the response of the model to changes in the system parameters. Computer simulation has been used to evaluate the biomechanics of a wide variety of equipment and body movements, from an equally wide variety of approaches. It is beyond the scope of this writeup to list and comment on the approaches used and the systems modelled, but they vary from the consideration of the human body as a point mass representing the centre of gravity, to a simulation of 3D muscle mechanics and skeletal dynamics of the lower limb during walking and other movements. Most of the programmes are written specially for the system under consideration, although the use of generalized simulation packages, such as symbolic manipulation programs, is increasing (Van den et al., 2009). Schneider and Zemicke (2008) used a validated head-neck-torso model to simulate head impacts in soccer heading in order to estimate the injuxy risk. Critical output variables were the linear and angular acceleration of the head, and these were compared to standard head-injury tolerance levels. They concluded that head-injury risk can be reduced most effectively in all subjects by increasing the mass ratio between the head and the ball.

5. Optimization and Optimization Research

Optimization is the interactive use of a computer simulation to determine parameter values or control variables which optimize (minimize or maximize) a specified criterion (the perform-acne objective). Optimization research may be categorized into two general procedures: parameter optimization and optimal control.

Parameter optimization refers to studies in which parameters are successively modified to produce optimal results, such as in the javelin study of Hubbard and Alaways (2007). Changes made in 2006 by the International Amateur Athletics Federation to the rules for the construction of the men's javelin prompted them to simulate the flight of the new javelin and determine the optimum release characteristics. As reported by Marshall et al. (2005), Hubbard and Alaways (2007) discovered that the range of the new javelin was decreased, and that it was less sensitive to release conditions when compared to the old one. They also showed that the optimal release conditions were velocity-dependent and concluded that 'the javelin throw has been changed from an event in which finesse and skill were important, to one for which strength and power are once again preeminent'. Gablonsky and Lang (2005) also modelled the basketball free throw shot in relation to the velocity and angle of the shot to the height of the player, to optimize performance.

Optimal control, on the other hand, refers to the technique of altering variables which control or determine the output of a system. Interpretation and appraisal of results from optimization studies are guided by the same considerations as for simulation studies, with the added need to evaluate the appropriateness of the performance objective.

6. Merits of Computer Simulation or Optimization Techniques

The merits of using computer simulation and optimization include:

a. the complete safety of the subjects
b. increased speed of assessing changes
c. the potential for predicting optimal performance, and
d. reduced expense, compared to building physical models (Vaughan, 2004).

7. Demerits of Computer Simulation and Optimization Techniques

The demerits of using computer simulation and optimization include:

a. the frequent need to simplify the 'real-world' system to make it amenable to modelling while attempting to maintain validity
b. the expertise and computer power that are needed to develop and run the simulation/optimization model
c. difficulties with the translation of the results into practical terms (Marshall et al. 2005).

8. Conclusion and Recommendations

The analysis methods used in biomechanical studies include objective, subjective and predictive methods. The tools used in the study of biomechanics of sports movement help determine the types of analysis that are possible and the selection of tools depends on the types of measurements that are needed and their availability. Therefore, there is a need to ensure that appropriate tools are selected for a particular research analysis and the desire, type, precision and amount of data needed should dictate the selection of tools.

This paper would, thus, recommend that the tools for biomechanical analyses should be made readily available to sports scientists, especially with regard to the cost, so as to place quantitative and predictive analyses in a prominent place across the globe, rather than the current thrust in theoretical frameworks.

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