

Methods of Biomechanical Performance Analyses in Sport: Systematic Review

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Abstract Biomechanical analysis involves the evaluation of techniques and tactics in sports. Qualitative method of analysis describes quality without the use of number. Quantitative analytical method entails the collection, measurement and evaluation of data involves the use of number. On average, athletes and coaches can only recall 30% of performance correctly. Performance analysis helps with the remaining 70% by providing accurate performance data. The main aim of this systematic review paper discusses the concept of biomechanics and the methods of biomechanical performance analyses used in sports. Sports Biomechanics professionals work with coaches and athletes to break down technique to help enhance performance and prevent injury. The objective 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. Therefore, sport clubs, institutions, academies, managers, athletes and other concerned bodies working on development of sport and improving athletic performance for their coaching staff.

Keywords: *biomechanical analysis, qualitative analysis, quantitative analysis, tactical and technical evaluation, performance*

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1. Introduction

Biomechanics is essentially the study of forces and their effects on living bodies. It is the physics of human motion. Biomechanics is the branch of science concerned with understanding the interrelationship of structures and functions of living things, with respect to the kinematics and kinetics of motion [1]. Biomechanics in sport incorporates a detailed analysis of sport movements in order to minimize the risk of injury and improve sports performance [2]. It also refers to the description, detailed analysis and assessment of human movement during sport activities [3]. 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 [4]. Sport kinematics analysis studies the positions, angles, velocities and accelerations of body segments and joints. 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 [5]. There are skeletal, muscular and neurological considerations we also need to consider when describing biomechanics.

The coaching process is about enhancing performance by providing feedback about the performance to the player or team. Researchers have shown that human observation and memory are not reliable enough to provide accurate and objective information on complex sports such as soccer. The term Performance Analysis is used to describe an approach that combines biomechanical analysis (e.g. analyses of technique, motor control, etc.) and notational analysis (e.g. match analysis) in order to provide coaches and athletes with an objective set of information on performance [6,7,8,9,10]. Usually, this approach focuses on numerical indicators. Therefore, sports biomechanists need to adopt the correct methods of analysis to improve skills and optimize the performance of athletes and coaches. 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 [11,12].

2. Materials and Methods

The related literature search was conducted in the period since 2001 until 2020. Articles corresponding to year of study [2001(one article), 2006 and 2009 (two article) and from 2014-2020(six articles)] Therefore, most of the literature /articles/ are recent times/updated. Only

publications issued by scientific organization /articles regarding Biomechanical performance analysis in sport (Qualitative and Quantitative sport analysis, Technical evaluation and Tactical evaluation) were selected.

2.1. Literature Search Strategy

the Literature Search Strategy were used the terms (key words) in relation with sport performance: “quantitative analysis “qualitative analysis” “technical performance evaluation/assessment “tactical evaluation /assessment”, “biomechanical analysis” and “biomechanics and sport” A search was conducted in the following bibliographic databases: Online Research Databases, Web of Knowledge, and Science Direct, Sport Discuss, Google scholar, The references of all saved articles and organizations were reviewed for relevant citations.

2.2. Inclusion Criteria

All publications or articles focused in which there was information such as biomechanical sport performance analysis (qualitative performance analysis, quantitative performance analysis, technical and tactical evaluation of movement/assessment) were included. Studies based on written in English, between the year 2001 and 2020 were also included. In the case of similar studies with more than one publication, only the latest publication was taken for the present systemic review. Publications issued by scientific organizations regarding with biomechanical performance analysis in sport were selected.

2.3. Exclusion Criteria

The criteria such as articles written in other languages rather than English, reports published in books, reports published in conference, case reports, case series, Moreover, the studies related to biomechanical performance analysis in sport and studies with negative findings were not selected, studies that are not associated with biomechanical performance analysis(qualitative performance analysis, quantitative performance analysis, technical and tactical evaluation of movement/assessment) and the articles which could not be retrieved in full text.

2.4. Screening of Articles for Eligibility

Based on titles and abstracts, reference the articles were screened for eligibility, i.e. included publications regarding the link between biomechanical performance. All included articles were read in detail and significant information was extracted.

2.5. Data Extraction

From the selected publications, organizations and articles the following data such as year of study, characteristic of analysis, evaluation and results/findings/conclusions were extracted.

The electronic databases and the manual search of reference lists identified 79 articles. On the basis of title and abstract, we excluded 14 studies that did not meet

inclusion criteria. All information was obtained directly from the articles.

3. What is the Biomechanical View of Performance Analysis?

Biomechanics in sport incorporates a detailed analysis of sport movements in order to minimize the risk of injury and improve sports performance. Sport and exercise biomechanics encompasses the area of science concerned with the analysis of the mechanics of human movement [12]. It is also refers to the description, detailed analysis and assessment of human movement during sport activities. Mechanics is a branch of physics that is concerned with the description of motion/movement and how forces create motion/movement. In other words, sport biomechanics is the science of explaining how and why the human body moves in the way that it does. In sport and exercise, that definition is often extended to also consider the interaction between the performer and their equipment and environment. Biomechanics is traditionally divided into the areas of kinematics which is a branch of mechanics that deals with the geometry of the motion of objects, including displacement, velocity, and acceleration, without taking into account the forces that produce the motion while kinetics is the study of the relationships between the force system acting on a body and the changes it produces in body motion [12,13]. In terms of this, there are skeletal, muscular and neurological considerations we also need to consider when describing biomechanics [14].

According to Knudson [15] human movement performance can be enhanced in many ways as effective movement encompasses anatomical factors, neuromuscular skills, physiological capacities and psychological/cognitive abilities. Biomechanics is essentially the science of movement technique and as such tends to be most utilized in sports where technique is a dominant factor rather than physical structure or physiological capacities [15], the following are some of the areas where biomechanics is applied, to either support the performance of athletes or solve issues in sport or exercise: Biomechanics is utilized to attempt to either enhance performance or reduce the injury risk in the sport and exercise tasks examined. It is also 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 [1,16].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 [17]. However, according to [18] Glazier et al. (2003), the concern of many influential investigators, for quite some time now, is that biomechanical research and, more notably, sports biomechanics research, needs to move from its descriptive phase to a more analytical level [20,21], 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 coaches and

bio-mechanists, 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 analyzed. 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 [16,22].

4. Methods of Movement Analysis

Methods of Biomechanical Analysis in Sports Analyses in biomechanics may be classified under two general areas: Qualitative/subjective and quantitative/objective. 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.

4.1. Qualitative Methods of Analysis

Qualitative analysis methods are also referred to as subjective methods [17,23] 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, [1] 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 identifying the joint actions, including flexion, extension, adduction or 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 [24], performance deficiencies may result from errors in technique, perception, or decision-making. [25], 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. [26,27] proposed the inclusion of a pre-observation phase, where a

model of the skill to be analyzed is developed and mechanical variables concerned and their relationships are described. It is sometimes difficult to distinguish qualitative studies from quantitative studies [28], this approach has contributed to a way of studying sports biomechanics based on the qualitative analysis of movement patterns [29,30].

Although sports bio-mechanists mainly use a quantitative approach to analyzing human movement patterns in sport, movement or performance analysts generally use qualitative or quasi-quantitative analysis [31]. The practical value of qualitative and quasi-quantitative movement analysis lies in its effectiveness in helping coaches to identify good and bad techniques, to compare athletes' performances, and/or to identify injurious techniques. It always comprises an important interpretable component that allows athletes to adapt to the changing characteristics of the competitive situation [32,33]. Qualitative Performance considers (i.e., interpretive, naturalistic, ethnographic, or phenomenological) tries to account for the athlete's subjective experience, thereby offering a detailed (or in-depth) description of how athletes make sense of their world. This type of study offers interesting opportunities for Performance Analysis, as it is widely acknowledged that qualitative research is especially suited to (a) understanding the meaning of events and actions, (b) understanding their context, (c) identifying unanticipated phenomena, and (d) understanding the processes by which the events and actions take place [34].

4.2. 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. Sports bio-mechanists often quantitatively study kinematics features that characterize elite performance of a particular athlete [4]. 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. According to [35] cited by [36] 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.

5. Technical Evaluation

Athletes' performance complexity can be reduced by using performance analysis techniques, presenting the results in systematic ways, and systematically integrating them into the coaching process [37,38]. This can be considered as valuable feedback for coaches, players, and sport researchers [39,40]. Whether performance analysis can be good feedback or an educational tool depends on the type and quality of the methods used [41]. An accurate

and reliable performance profile may improve the efficiency of the analysis procedure [42], and can provide useful feedback that can be easily understood by sports practitioners [43]. Performance profiling is a descriptive analysis that brings a collection of valid and reliable psychological, physical, and technical indicators together to characterize the overall performance of players and teams [44]. However, the properties of match/race performance indicators may vary along the matches played as situational variables have an influence on them [44,45]. Therefore, the data from a single match cannot represent a player's or a team's typical performance [46,49].

The individual athlete's performance effects may generate additional variance in the data of a single match and fail to produce a significant difference in the comparison between groups [47]. Accordingly [47], stated that the nature of the data and the performers are the two main factors that should be taken into account when considering the number of matches or races required. Due to the availability of data, the profiling subject has developed over time from the analysis of single players or teams to more comprehensive analysis including a larger number of players or teams [48]. Previously, median and 95% confidence intervals [49,50] were used to present the typical performance of subjects and its spread of performance, while currently profiling techniques are commonly based on mean and 95% confidence intervals [51,52]. Due to the nature of complexity and highly dynamic behavior in different types sport matches [44,52,54]. Match location, team quality, individual quality, quality of opposition, and match outcome are examples of situational variables that have been investigated so far [52,53,54]. The quality of the opponent is considered the main factor for variation in match technical performance analysis.

According to [44] cited by [55]. The technical match data was analyzed under the following five situational variables: (1) competition stage: group stage; (2) match location: home and away; (3) quality of team: teams that qualified into the next stage and teams that didn't qualify into the next stage; (4) quality of opponent: opponents that qualified into the next computation stage and opponents that didn't qualify into the next computation stage; and (5) match/race outcome: win, draw and lose.

6. Technical Analysis

Sports performance assessment is the players' ongoing training; therefore, emphasis should be placed on developing intelligent and creative players [56,57]. An intelligent player is one who is capable of controlling the greatest possible number of technical-tactical variables in a short time and choosing the best possible option at all times during the game. While that, creativity entails varying, rare and flexible decision-making in complex game situations [58]. Some of the variables which must be controlled in order to be an intelligent and creative player are, among others, space time command, the different rhythms of the game, the scoreboard and timing of the match, the opponent's strengths and weaknesses, one's own limitations and the potential of the team during each

play. These features are part of the player's ability to adapt to the context of the game, known as tactical knowledge [59]. Tactical knowledge not inherent to players; it is developed and learned. Therefore, it must be assessed progressively throughout their training. Having excellent knowledge and specific experiences are the basis to making the right decisions quickly and being able to solve situations of different levels of uncertainty successfully. The evaluation of observable tactical behavior in athletes or players has been a study subject of great interest in recent years [60,62]. The analysis of decision making and the specific technical-tactical skills is essential to develop optimal and comprehensive training processes for athletes [60,62]. The inclusion of tactical skills as well as technical competencies in the team training at an early stage is becoming a key topic in scientific discussions [58,61,62,63]. The talent program of the German Soccer Foundation (DFB) assigns a significant role to tactical creativity (divergent tactical thinking) and tactical game intelligence (convergent tactical thinking) at an early stage in youth football training. Generally, we need to move away from the traditional teaching-evaluation approach in sports, focusing on sports tactic evaluation. Currently, technique and tactics are considered two inseparable representations of a player's actions [64]. That is because it is important to adopt a more ecological approach when it comes to training and evaluating athletes/performance analysis. Along this line, the use of observable assessment tools is common in sports research, since it allows us to analyze and describe the dynamics of the game [65].

7. Conclusion

In Biomechanics, movement patterns/skills are assessed based on knowledge of human anatomy and mechanics. Bio mechanists' work with coaches and athletes to break down technique to help enhance performance and prevent injury. Researchers have shown that on average, athletes and coaches can only recall 30% of performance correctly. Performance analysis helps with the remaining 70% by providing accurate performance data. In sports biomechanics analysts collect data through a variety of tools (i.e. video, GPS, photo etc.) and process the information using various statistical methods (CSI). 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. At any level of movement analysis, there is a need for interaction between the coach and bio mechanists, 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 analyzed. Hence the need to apply every available means to use the methods and materials for better analysis of skill and movement to improve performance. 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. Therefore sport clubs, institutions, academies, managers, athletes and others concerned bodies working on developing sport and

improving performance their coaching staff /offices there must be need bio mechanists.

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Sports biomechanics allows detailed analysis of sports movements. With these results the mechanics of movements can be improved to allow better sports performance and/or less injury risk. Sports biomechanics is often confronted with very special requirements. High performance athletes need to get analyzed in competition to get relevant information. Results have to be communicated and be understood by athletes and trainers to make use out of them in training. Methods used in sport biomechanics can differ and mostly include 2D or 3D kinematics, kinetics, EMG or pressure. A special requirement in high performance sports is the analysis in competition, where no markers or sensors can be used. 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 biomechanics 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. Sport performance analysis is the science of observing and recording events and actions during competition and training environments. The content in Sport Performance Analysis examines techniques used to assess and monitor sporting performance using real-time and lapsed-time coding systems. The 3 main notational coding methods (time-motion, tactical and technical) are considered with reference to analysis during match-play and training activities. Effective video capturing techniques across a range of sports and the appropriate use of video in the coaching process will be explored. The impleme