HOW BIOMECHANICAL RESEARCH CAN HELP THE COACH

Pekka H. Luhtanen
Research Institute for Olympic Sports, Jyvaskyla, Finland

INTRODUCTION

This presentation intends to provide a perspective on different sports that are based upon scientific studies and attempts to apply scientific information to practical considerations important to success in sports. The couch and scientist often have the same general objectives of improving sports performance, but their approach can be different. The sport scientists are concerned with the validity of the experimental design used, methodology employed and statistical analysis. The coaches are less concerned how or why certain types of information are obtained as long they are convinced that the results are valid and meaningful. When the scientists are arguing the smallest details of the results the coaches are looking more for a yes or no answer concerning questions of training consequences. The questions in the discussions between athlete, coach and scientist are often of the form: What is done? How is it done? Why does it work? The answers to What? How? and Why? are important to the athlete, coach and scientist, respectively.

FUNDAMENTAL RESEARCH - APPLIED RESEARCH

Fundamental research in biomechanics includes methods of data collection and data processing as well as basic research for human movement. Fundamental areas such as the tracking of human movement or the mechanics of skeletal muscle can enable specific applied research to be undertaken in particular sports. Applied research provides the basis for interpreting the results and thereby makes possible support services to sports. The understanding gained from applied research is a prime resource for coach education. In order to identify key areas for applied research in sports biomechanics, those sports primarily depend upon technique have been categorized as well suited to biomechanical analysis. However the role of interdisciplinary research is often important. These research approaches have been identified to enable applied studies to be carried out which would lead to technique modifications for improved performance.

EXPERIMENTAL- THEORETICAL APPROACH

One method of seeking answers to such questions is to use an experimental approach. Often the experiment is invisible to the athlete. By obtaining movement data on an individual athlete it may be possible to identify those elements of technique which are associated with the better performances. This may indicate how the individual can improve personal performance. By obtaining data on a number of athletes and identifying the characteristics of better athletes, it may be possible to gaininsight into how training should be structured.

Another method of investigation is the theoretical approach. This takes the form of idealization of the activity using a theoretical model. Hypothetical data are generated by using the model in specified situations. A theoretical model may also be able to provide a general description of movement which can lead to a more complete understanding than that provided by a number of particular examples.

EXPERIMENTAL- THEORETICAL MODELLING

Although the experimental and theoretical approaches appear to be quite different in nature they are both an integral part of scientific method. Initially a scientific investigation will probably take the form of a descriptive study which merely records what happens. The data may suggest a possible theory. Such a theory may be used to predict the outcome in a given situation. An experiment can then be conducted to determine the actual outcome. A comparison of theoretical with experimental outcomes can establish the accuracy with which the theory models the activity. This will indicate the level of confidence that can be given to theoretical predictions and may suggest how the theory can be modified. Sports biomechanics should be a balanced mix of experimental and theoretical modelling if a realistic understanding has been achieved. Both experiment and theory pose their own problems in sports biomechanics research.

PRACTICAL IMPLICATIONS

Practical, biomechanical and multidisciplinary implications will be presented using the methods and results of various research projects conducted in the Research Institute for Olympic Sports (RIOS) in cooperation with the top level coaches since 1991.

The overall goals of RIOS include interdisciplinary research into top performance in sports and applied services promoting successful performance of top athletes, coaches teams and sport federations. The

Interdisciplinary research is aimed at

- examining biomechanical, physiological, medical, psychological and sociological aspects of training, competition and coaching in individual and team sports,
- development of testing and coaching methods, educational material, training aids and equipment.

The applied services to offer are

- consulting and practical assistance to sport organizations, educational and training centres in charge of coaching education, as well as to the sporting goods industry
- information search, up-to-date and state-of-the-art reviews of problem areas
- special courses and intensive training seminars for coaches, athletes, sport scientist and administrators.

Coaching is teamwork where athlete and coach play a major role, The supporting roles from point of view of biomechanics will be played by researchers with their assistants for various phases of research concerning athletes in technical, tactical and mental aspects, environment, sport equipment and clothing. The problems What? How? and Why? have to be solved in a simple way so that the feedback for the coach and athlete is clear and easy to understand. For this purpose modem video and multimedia equipment offer useful procedures.

CHANGES IN RULES AND NEW PERFORMANCE TECHNIQUES

Changes in rules and new performance techniques facilitate cooperation with coaches and researchers and also research in sports biomechanics. Technical skills and biomechanics of a performance are highly combined with each other.

The regulatory skills required in any performance situation can be identified by asking three basic questions:

- What I am looking at?
- What am I thinking?
- What am I feeling?

What an athlete is looking at depends on their attentional focus, a number of different types can be identified (broad vs. narrow, internal vs. external). The demand of the activity will influence the attentional style an athlete should adopt.

What an athlete is thinking relates to the decision-making behavior. To be an effective decision-maker requires a tactical understanding of the options available to achieve the desired outcome.

What an athlete will be feeling is very much down to the individual's psychological character. A performer's emotional state will affect how they perceive a broad range of emotional states such as excitement, anger, anxiety, frustration, confusion, etc. Personalized interventions to help a performer to regulate these feelings will involve developing various mental skills and coping strategies. When athletes learn to listen and facilitate all proprioceptive senses also the use of imagery may help a performer to develop a certain aspect of their technique.

Ski jumping is an extraordinary example of a sport event where dramatic changes have taken place when the V-style after classic flying style was not anymore considered as a technical mistake in the ski jumping rules of FIS. In shot put, there are several athletes who have changed their shot put technique from the classic to the rotational technique.

BIOMECHANICAL SKI JUMPING RESEARCH AND COACHING

The head coach has been brought into the research group throughout the research project. Ski jumping performance can be divided into different phases as follows: gliding, takeoff, transient flight, actual flight, flare-out and landing. The purpose of the first study was to investigate ski jumpers in wind tunnel with simulated actual flight phase (Figure 1) in trying to reach the individual maximal lift to drag ratio and training of the optimal flying position with low pitching moment coefficient for the respective phase according to the feeling from their sensomotor feedback system.

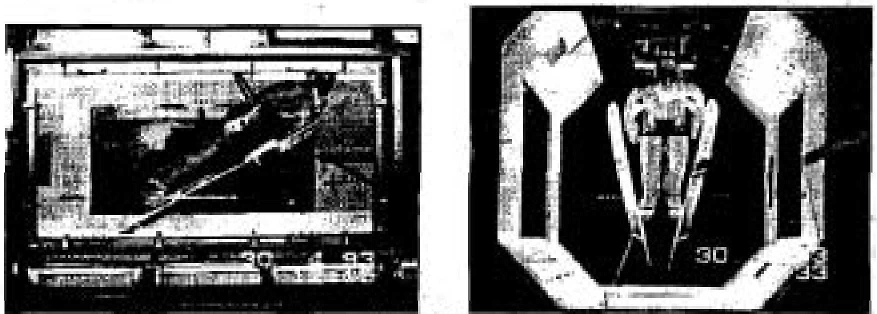

Figure 1. Side and front view of the jumper

The most practical biomechanical implication for coaching in this wind tunnel study was that the regulation of the bindings had to allow the necessary range of movement for the desired V-style position according to

the individual feeling.

A simulation program was created to calculate the length of jumps in different external conditions. The influence of the low jumper-equipment mass was found to play a positive role during the takeoff and flight phases but a negative role for the tangential release velocity. This observation was taken into account in the nutrition habits of thejumpers. For a more detailed flight phase analysis was constructed as a 2/3 scale model of a jumper which was attached to a sophisticated platform-balance. Using this model, different suits, bibs, skis and binding locations in the skis it has been possible to test the influence of all equipments for a maximum length of jump and safety. A human jumper has been used to analyze aerodynamical forces during takeoff phase. The simulation model has been adjusted along the research project. Avideo feedback with multimedia illustrations (lift, drag, lift-to-drag-ratid and speed) was given both to the coaches and ski jumpers.

ROTATIONAL TECHNIQUE IN SHOT PUT

The maximum range in shot put was approached using modelling and 3-D performance analysis. The 3-D analysis was concentrated on the acceleration of selected body segments, delivery phase, movement of the shoulder joint, extension of the upper armduring the last double foot contact phase and moment of the shot release. The most important factor was the shot velocity at the moment of release phase. In this phase the other parameters: release angle, release height and overreaching or incomplete reaching can influence positively or negatively for the range. The aerodynamical parameters were also taken into account. An idea of the motion of two mass points was chosen to apply in the technical training to increase rotational and thus linear velocity of the shot put in the release phase. A video feedback with multimedia illustrations (velocity of the shot as function of time and synchronized with the video frames) was given both to the coaches and athletes.

SOFTWARE DEVELOPMENT FOR COACHING PURPOSES

MATCH ANALYSIS IN SOCCER

Different team game analysis softwares (SAGE Game Manager) have been developed for soccer in order to analyze players and matches qualitatively (number of successful and failed executions) and quantitatively (time and distance characteristics) using video or live. The results have been applied to the Finnish youth and Olympic teams in cooperation with. the head coach. Many coaches record and analyze the performance of their own players or team and their opponents. By analyzing matches, the coaches try and find ways of increasing their effectiveness and detect weaknesses that can be exploited and strengths that require special attention. Analysis can be very valuable in team preparation. The Olympic team analysis was produced using the SAGE Game Manager which is a software package and useful tool for all aspects of game analysis using video recording.

For the analysis the coach must decide specifically what he wishes to analyze and why he is doing the analysis. Is it of an individual, a group, or the entire team in a match, tournament or during the whole season of his own team and/or opponents? The coach must be very clear at the outset about what he wishes to analyze and what benefits will accrue to the player(s) or team from the analysis.

The software package offers with numerical and graphical analysis on the aspects as follows:

Team characteristics:

- **ball in possession in time and distance**
- effectiveness of the attacking play
- team profiles to get to the attacking third, vital area and scoring trials
- goals
- set play
- fouls
- injuries etc.

Player characteristics (successful and failed in number and percentage)

- passes
- controls
- runs with ball
- shots
- interceptions
- duels etc.

When analyzing a game using video, the data entry included team and player identification and incidence identification as follows:

- Who?
- What?
- Where? and
- When?

All matches covering each player handling the ball has been detected for the analysis. Distance covered by the ball has been presented graphically and in meters covered by the ball in possession.

Average match statistics, average successful attacking statistics per team, individual player statistics per team as well as scoring analysis has been presented. The history of each goal has also been explained. A similar software has been developed also for match analysis and player profile analysis in badminton.

PHYSICAL LOADING IN SOCCER

A software has been developed to analyze physical loading in soccer matches or any kind of practical training with the ball in soccer. This kind of analysis has been necessary for coaches in order to evaluate and define the physical loading levels of the real soccer matches, mostly used drills und small-sided games. The software utilizes Polar Electro heart rate monitors.

TALENT SEARCHING IN DISTANCE RUNNING

Talent searching in long distance running is important both on the club, school, district, association and national team levels. The system will require educated coaches or observers for screening the runners. The described methodology will make it possible to screen and process large amounts of data on individual athletes in a relatively short time with a moderate high reliability. The longitudinal follow-up and documentation will improve validity of the expert system.

Talent searching software based on expert systems have been developed in cooperation with top coaches and researchers for distance running, soccer and cross country skiing. The purpose of this chapter is to introduce a prototype of an expert system with a complex knowledge base to predict talent for long-distance running in male athletes at age of 16 - 20 years. The prototype was developed with Xi Plus (Expertech Ltd.) rule based expert system shell and can be used in compatible PC - microcomputers.

The knowledge of the domain area was described using hierarchical tree structures, which were in connection to the anthropometrical, physiological (maximal aerobic capacity, submaximal endurance, anaerobic power), biomechanical (economy and efficiency in running) a psychological (mental aspects) research results in long-distance runni In this prototype the main level in the hierarchical structure was named t talent in long-distance running. The first sublevel included total results running, training and environmental factors. The second sublevel includ

1. Results: competitions, physical testing and psychological evaluatior
2. Training: quantity, quality and intensity and
3. Environmental factors: health, economical situation, family life etc.

All variables in all levels were evaluated on the average verbally numerically in five categories. The probability of the talent was evaluat and utilized in recruiting young talented distance runners.

TALENT SEARCHING IN SOCCER

The purpose of this chapter was to introduce a prototype version of a microcomputer based expert system to predict talent for success in junior soccer players at age 14 - 15 years. The tree structure of talent was planned by four experienced national youth team coaches and a soccer researcher. The expert coaches also evaluated the relative weight coefficients of different branches in the tree structure, rules and rule combinations for conclusions of the talent prognosis. The Finnish junior national team candidates served as subjects when evaluating the prognosis of talent of the goalkeepers, defenders, mid-field players and attackers for a junior national team. The content of talent was structured for each player position and was divided into sublevels which included the soccer performance as a whole; training and psycho-social factors. The total soccer performance of a player consisted of the individual skills, game understanding in attack and defensive play, and physical and psychological characteristics of the players. The training included volume and quality of training. Living habits, family life and health status were evaluated in six variables for psycho-social factors.

The PC microcomputer based prototype program was developed with Xi Plus 3.5 (Expertech Ltd.) rule based expert system shell. All variables in different levels were evaluated in numbers from 1 to 10. Evaluations were done in ten skill, nineteen game understanding, fourteen physical and thirteen psychological variables. The experienced coaches evaluated each player in each variable. According to the averaged numeric combinations the probability of the talent was evaluated by microcomputer. The described methodology made it possible to process a large amount of data on an individual player and screen a large number of players in a relatively short time.

TECHNOLOGICAL APPLICATIONS

LASER RADAR

The newly developed laser diode system LAVEG Sport opens up new prospects of carrying out kinematic analysis of acceleration phases for training purposes in various kind of sports. The distance-time and velocity-time functions of interest as well as individual kinematic parameters of motion are recorded in on-line mode and thus they are immediately available to the trainer and athlete as instantaneous information (Viitasalo et al. 1995). Research Institute for Olympic Sports has used the radar system for measurements of instantaneous speed in cross-country skiing, kayaking,, javelin throwing and jumping events.

The measurement principle is based on travel-time measurements of laser pulses transmitted by a semiconductor laser diode. The laser beam is diffusely reflected at the athlete/device without using a reflector and then registered by a laser detecting diode inside the LAVEG-Sport. The kinematic functions are computed by means of a microcontroller on the basis of Individual distance measurements executed with quartz-tabilized counter timing. A sample rate of 50 Hz enables covering movement processes of 30 s duration up to a distance of 200 m in all velocity ranges occurring in sports.

THROWING GATE

Release velocity and angular parameters at release are important variables from the point of view of feedback for coaching throwing events. Truditionally, these have been determined using filming/videoshooting and motion analysis which is a rather slow feedback method for athletes. The first version of a throwing gate had been introduced 1987 (Viitasalo and Korjus, 1987). This was developed for indoor training and testing purposes. The new measurement system has a capability to measure all track and field throwing events on-line during competition (Viitasalo et a., 1995). The gate consisted of two infrared walls with the first one 2.0 m and the second 2.5 m high. In this version the photocells work with fan shape at a frequency of 50 kHz in the detection mode so that the resolution is 2-3 mm in the vertical direction. When the gate notices a triggering object (e.g. javelin tip) at the first infrared wall, the electronics turn to the location phase, in which the photocells work parallel at the a frequency of 1 kHz having vertical resolution of 15 mm. Thus both of the infrared walls are able to sample a 2.6 m long javelin 86 times while it is flying at 30 ms $^{-1}$. In addition to the release velocity and attitude angle values the equipment with its microcomputer software can calculate the angle of attack at both photocell gates. This throwing gate has been used also in several sports competitions in Finland.

PHOTOCELL CONTACT MAT

The photocell contact mat, has been developed to measure important parameters for coaching purposes in running and jumping: contact time, flight time, step and stride frequency as a function of running time or running distance (Viitasalo et al., 1995). The instrument consisted of two separate photocell bars and a microcomputer. The width of the current version was selected at 1.12 m based on the width of an athletic running lane. Both of the two photocell bars consisted of 19 receiving photocells and two transmitting units sending fan-shaped infrared light to the receiving photocells. The combined horizontal resolution of the two infrared fans perpendicular to the running direction was less then 50 mm. The distance that the current version could cover was up to 120 m. The receiving photocell electronics worked at a frequency of 3 kHz. For bipedal running (speed 3.6 - 9.3 m/s) the resolution of the photocell contact mat was less than 1 mm and 0.4 ms. The low coefficient of variation found between the photocell contact mat contact times and force platform contact times suggested that the photocell contact mat is an accurate and fast instrument to measure ground contact times in running and jumping events.

SUMMARY

Throughout this paper it has been a trial to develop by means of biomechanics an approach to analyzing performance, athletes, equipment, external conditions, team and measurement methods in sports in order to help a coach to find individual answers to the questions in the discussions between athlete, coach and scientist. What is done? How is it done? Why does it work? The answers to these questions are important to the athlete, coach and scientist but they are never easy.

However, the major goals of biomechanical applications in training, coaching and single performance are in a longer training process' performance optimization and load optimization. In the major fields of application of sport biomechanics in the area of performance optimization the scientists have to be able to answer the more complex questions: What are the limiting factors of the sport techniques of performance or performer? Which factors are still trainable and how much? What are the individual faults or deficits in a single movement or performance? How training can support a performance while optimizing the identified factors and deficits using biomechanical methods? The number of questions and different scientific levels of approach clearly illustrate that different working planes are involved. It has to be differentiated between questions and tasks concerning basic research, applied research and scientific services in elite sports. Training is a long-termed and well organized process in elite sports. During the process the athletes not only optimize their physical requirements but also their performance techniques. The role of the applied biomechanist in this process is to analyze the intended changes of different parameters and to allow a fast feedback of the amount and direction of possible changes and development.

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