BIOMECHANICS AND MOVEMENT ANALYSIS
YEAR TWO

6 JANUARY 1993

Welcome back to College! This morning I want to raise two issues that link our course to your soon to be presented draft for your Sports Technology/Pedagogy project.

I have provided very little opportunity on the course for you to talk together and to engage in discussion. I hope therefore that we can use your project proposals for the first part of the session.

I hope that we can engage in what is termed a SWOT analysis. Such analysis is a vehicle for assessing the:

Strengths)	
Weaknesses)	
Opportunities)	of an idea/proposal
Threats)	

Depending on how much time this takes, I would like to use the latter part of the session to discuss some issues related to SYSTEMATIC OBSERVATION. I have appended some notes and an article from a recent edition of the Quest journal.

In the next couple of weeks I want to look carefully at the processes and products of observation. For next week please could you have a look at the article by Welch (1992) and if possible at Paul Croll's (1986) book.

OBSERVATION

Paul Croll, Systematic Classroom Observation, (1986)

Discuss systematic observation in educational research. A research method:

> which uses a system of highly structured observation procedures applied by trained observers in order to gather data on patterns of behaviour and interaction (ix).

Its features include:

1. observation procedures are carefully defined and highly explicit

2. results are expressed in quantitative terms

In Britain, work on systematic observation in schools was first undertaken by Brian Simon. He worked with Deanne Boydell to develop systems.

> Systematic classroom observation attempts to arrive at a description of classrooms which are absolutely explicit in their purposes and which remove part of the subjectivity which occurs when individuals describe events (4).

As a research procedure:

1. it is explicit in its purpose(s) and these are worked out prior to data collection

2. explicit and rigorous in its definition of categories and in criteria for classifying phenomena in these categories

3. produces data which can be presented in quantitative form and which can be summarised and related to other data using statistical techniques

4. role of observer is essentially one of following instructions and any observer should record a particular event in an identical fashion to any other

It claims uniformity (6). Need not reject systematic observation because of difficulties:

1. Complexity may require different kind of conceptualisation and operational definition

2. Qualitative and quantitative methods not mutually exclusive

3. Reporting on an event and coming to an understanding of the meaning of events for participants

Systematic observation to provide accurate description of selected features (9). For example:

1. A descriptive overview of certain features.

2. Measuring effectiveness of different approaches.

3. Measuring impact.

4. Monitoring individual behaviour.

> A crucial step in any programme of research is the process of turning research ideas into a set of procedures for generating empirical data. (49)

Operationalisation: a complete research design. Empirical data gathering procedures have their validity only with reference to a specific investigatory purpose.

Most common procedure: paper and pencil with simple time-keeping device. 'Live' observation (51). Record and observation simultaneous. This is advantage but disadvantage is the limit placed on what can be observed.

> The problem of the complexity with which observers can cope is the major limitation on live observation (52)

Videotape is an alternative to live observation. In addition to possibly dealing with complexity, videotapes can be watched by a number of observers.

Limitations of video as a 'complete', 'flexible' record for observation.(53)

Process of designing programme of systematic observation and analysis of results: definition and analysis of variables. (55)

> A variable represents the process by which a concept which is of interest to the researcher but which exists at a theoretical level is turned into a set of working definitions whereby the results of observation or some data collecting process can be categorised and measured. (55)
>
> any observation which is to be made as part of the observational system should be capable of being classified according to the categories of the variable or variables in accordance with a pre-determined set of rules.(55)

Also an attempt to describe and categorise a process which is on-going in time. Observations are located at particular points in time and this may be a crucial factor in understanding them. (62)

Need to consider: frequency/duration location/sequence

Events can be recorded: continuously; by event; time sampling

Contextual information (78).

Cinematographical Studies, 1930-1939: An Overlooked Decade

John H. Welch

Biomechanical researchers who analyze data collected cinematographically usually acknowledge the work of late 19th-century cinematographers Eadweard Muybridge (United States and England), Etienne J. Marey (France), Christian W. Braune, and Otto Fisher (Germany). The acknowledgement is then typically followed by a review of the current literature. But most of these studies delete the significant "middle generation" of cinematographers—1930-1939—a particularly fruitful decade during which motion pictures were used to help identify biomechanical principles. This discussion will focus on the cinematographical studies of W.O. Fenn, H. Elftman, R.B. Glassow, E. Jokl, and T.K. Cureton, who have given biomechanics a rich legacy and helped define the discipline as it exists today.

Current biomechanical researchers who analyze data collected cinematographically often acknowledge the work of the early cinematographers. Eadweard Muybridge (USA and England), Etienne Jules Marey (France), Christian W. Braune (Germany), and Otto Fischer (Germany) are often cited for their ingenious work in the late 19th century. This rightful acknowledgement is typically followed by a review of the recent (post 1960) literature.

The scope of most current studies as well as space limitations have caused the significant "middle generation" of cinematographers to be deleted from recent literature. Yet investigators on both sides of the Atlantic in the first half of the 20th century demonstrated both the ability to identify those biomechanical principles which govern successful performance and a high level of sophistication in developing methods to measure and thereby analyze human motion. The period 1930-1939 was a particularly fruitful decade. A discussion of these investigators and their influence on current practices in biomechanics, along with other cogent career accomplishments, is the subject of this article.

Wallace O. Fenn

During the 1930-1939 era Wallace O. Fenn, who was then head of the Department of Physiology at the University of Rochester School of Medicine, studied running. He used cameras and film to analyze human motion and muscular mechanics. Fenn wanted to determine the limiting factors in running, why there seemed to be individual limits on sprinting speed. In 1930 he filmed a group of runners, students enrolled in a physical education class at his university. The runners were filmed behind a wooden lattice of one-meter squares, which formed a grid of horizontal and vertical lines from which measurements were made when the film was projected. The camera was equipped with a telephoto lens and the film was advanced manually with a hand crank. As the speed of the film through the camera was not known, wooden croquet balls 4 inches in diameter were dropped along a vertical scale located in the field of view in order to calculate the speed of the film, which was about 120 frames per second. The main source of error in the analysis was believed to be the buckling of the film during projection. This problem was solved by passing the film between two glass plates clamped together. Fenn believed the perspective error created by having the subjects run about one-half meter behind the lattice was a maximum of 1.7 %. The change in joint angles of the subjects from frame to frame was measured with protractor and plumb line (Fenn, 1930a).

With this film study, Fenn made an original contribution toward the understanding of human muscular action. Prior to this, what was ascertained about the mechanics of muscular action had been obtained from the study of isolated frog or cat muscles in the laboratory. Fenn's method was to begin with the observation of overt performance, apply physical laws, and then deduce facts about the actions of smaller anatomical entities such as individual joints and muscles.

Accurate measurements of human performance resulted from this application of physics to film data. Similarly, researchers today routinely project filmed images of athletes onto a surface for frame-by-frame analysis. During the 1984 Olympic Games, for example, the track events were filmed for later biomechanical study. The analysis will show such things as limb velocities and periods of acceleration, stride length and frequency, or a determination of joint torques of the hip, knee, and ankle. These parameters and others are used to establish a data base which will be used to describe optimum technique or style for the various events. Modern electronic equipment enables today's investigators to handle more data and treat more subjects in less time, but the basic procedures are essentially those used by Fenn.

For convenience of analysis, Fenn divided the study of running into two parts. First, limb movements were studied (1930a). Second, the movement of the center of gravity was studied as it changed its location within the runner's body during the stride and its horizontal path over the ground (Fenn, 1930b).

In addition to collecting data derived cinematographically, Fenn built a crude spring registered force platform and constructed a goniometric device. The former measured and recorded forward and backward forces of the feet during contact with the ground. The latter recorded motion at the shoulder. From this Fenn was able to relate arm motion to the mechanics of running. He concluded that internal muscle friction or viscosity was not as much a limiting factor to the speed of contraction as had been earlier postulated by A.V. Hill.

Fenn not only identified, but he also quantified with a high degree of accuracy the various mechanical forces involved in running. These were the kinetic energy generated by the limbs, ground frictional forces, the retardation force encountered by the foot at contact, wind resistance, and the work of moving the center of gravity. Fenn expressed these parameters in terms of horsepower and felt that they accounted for practically all the mechanical energy expended while running (Fenn, 1931).

About the Author: John H. Welch is with the Department of Physical Education and Recreation at New Mexico State University, Las Cruces, NM 88003.

Such factors are precisely what today's runners attempt to control in their efforts to improve. Whether reading *The Runner* magazine or a technical journal such as *Medicine and Science in Sports and Exercise*, most articles on running still discuss Fenn's points which were made more than 50 years ago.

In studying the path of the center of gravity as the runners progressed, Fenn found that the center first moved slightly upward and backward, then downward and forward during the running cycle. The apparatus used to measure horizontal ground reaction forces showed a forward (retardation), then backward (propulsive) pressure pattern with each foot contact. In 1931, with the collaboration of H. Brody and A. Petrilli, Fenn published an article that integrated the findings of the previous studies of sprinters with additional experimentation of the actions of individual muscles as they attempted to produce rapid movements.

The actions of the rectus femoris and biceps femoris in particular were studied during the running cycle, and the rectus femoris was found to exert a weak contractile force during the final phase of the forward or recovery movement of the leg. Another part of the study compared isometric force exerted by the knee extensors with that exerted during rapid motion. Fenn found a decrease in the ability of a muscle to exert tension as the limb approached maximum speed. These findings were of particular interest, as he believed they revealed one of the limiting factors in sprint running.

A modern principle of athletic training involves the isolation of specific muscle groups and exercising those muscle groups at speeds similar to those required in a particular sport—a form of specificity training. The use of weight training equipment with mechanical devices enables the athlete to do this. Runners, for example, exercise their legs by moving weighted equipment at high speeds, thereby attempting to improve upon one of the limiting factors identified by Fenn—the ability of the leg musculature to forcefully contract at increasingly higher velocities.

In 1931 the study of muscle tension during running was carried a step further when B.S. Marsh joined Fenn. Together they defined and described the presently well known force-velocity curve. Their article was titled "Muscular Forces at Different Speeds of Shortening." This classical study appeared in the British periodical, *Journal of Physiology*, in 1935. It was a direct result of Fenn's effort to identify the factors limiting running speed.

Fenn's studies of runners culminated in a paper, "The Mechanics of Muscular Contraction in Man," presented at the 1937 Symposium on Biophysics in Philadelphia. Fenn did not pursue the study of the nervous system in muscular movement, though he did point out the importance of this phenomenon and the need for greater understanding of its role.

The modern biomechanist can benefit from reviewing the life and work of this individual, since his studies were both innovative and meticulous. Fenn's abilities to define human motion research problems and to apply ingenious means to solve the problems aptly demonstrate what is required to do creative research today.

As impressive as Fenn's investigations of running were, they were but a footnote in a distinguished career of diverse interests and prodigious accomplishments. His first scientific article was published at the age of 23. Some 55 years later, in 1971, his last paper was submitted just before he died. During the intervening period he authored or coauthored 266 papers and held offices in numerous national and international scientific organizations. Of particular interest to physical educators, his papers included original work on electrolyte chemistry, muscle physiology, and respiratory function.

Wallace O. Fenn came to Rochester from Harvard in 1924 to chair the Department of Physiology in the new School of Medicine and Dentistry and was a revered member of the school for 47 years, serving as teacher, scientist, and administrator.

Herbert O. Elftman

Herbert O. Elftman, a professor in the Department of Zoology at Columbia University, used the cinematographic technique during the 1930s to study walking. The human motion data collected with multiple cameras he combined with data derived from other instruments. He invented an apparatus to measure the points of application and magnitude of forces, as well as the pressure distribution of the foot during walking (Elftman, 1934, 1938). Elftman ascertained the film speed by including a vibrating reed of known period in the photographic field.

He analyzed the kinetics of the leg by applying d'Alembert's free-body diagram method, which shows body segments isolated with arrows (vectors) representing various forces acting on the segments. Having studied mining engineering at Berkeley before moving to Columbia, Elftman was uniquely qualified to apply engineering principles to the analysis of human motion—in this case the legs during walking (Elftman, 1939a). He also recognized the important role of the arms and published a discourse on this topic based on a three-dimensional analysis of arm actions. He discovered that the arms do not act as passive pendulums, but that they are under muscular control and that arm movement is an integral part of the dynamics of walking (Elftman, 1939b). This fact is well understood today by physical therapists rehabilitating infirm patients, backpackers climbing a mountain trail, racewalkers in competition, and divers approaching the end of a springboard. Today both walking and running are considered quadriped activities, but this was not the case before Elftman's cinematographical research.

In order to further his in-depth comprehension of the biomechanics of walking, Elftman analyzed body rotation. He calculated the angular momentum of the body at successive points during a walking step and showed that the trunk rotates about the foot as the foot is preparing to leave the ground. He quantified the rate of change of angular momentum and, from displacement curves of the body's center of gravity, Elftman computed instantaneous velocity and acceleration curves in three dimensions—quite an achievement in the precomputer era.

Elftman and John T. Manter (1934, 1935), one of his graduate students, compared the structure and function of the human foot with that of lower primates. Using a force platform developed by Elftman which recorded pressure distribution on the plantar surface of the foot, they noted differences between the human and chimpanzee foot. In humans, the heel touches the ground first, while chimpanzees make a simultaneous heel and forefoot contact, with more pronounced pressure exerted along the lateral border of the foot.

In describing the axis of weight distribution in the human foot, the investigators gave a detailed description of the path of body weight as it shifts forward from the heel during walking. Because of the motion permitted in the metatarso-phalangeal joints, the human foot can be flexed. Consequently, the foot's fulcrum is transferred from heel to ball and then to the toes before the foot is lifted from the ground.

Elftman's extensive work on walking influenced rehabilitative practices and prosthesis development for World War II amputees. Though crude in comparison to today's products, the prostheses were nonetheless designed to be as biomechanically compatible with the user as possible. Elftman's cinematographical work identified some of the func-

... determinants of walking and these factors were used as criteria in the design of the prosthesis. Much of the improvement in protheses in recent decades has been the result of the development of new materials which permit the artificial limbs to more closely resemble healthy limbs in appearance and function, rather than an improved knowledge of biomechanics.

In 1971 Herbert Elftman retired as professor of anatomy after completing 40 years of active teaching and research. Throughout a creative and productive career, his interests and inquiry progressed through mining engineering, geology, palentology, zoology, anatomy, and biomechanics of muscular action.

Ruth B. Glassow

Ruth B. Glassow taught kinesiology and measurement at the University of Wisconsin from 1930 until her retirement in 1962. In her early years at Wisconsin she was aware of the potential of photography, not only as a research instrument but also as a means for improving the instruction of physical education skills.

The 1930-1939 era was a productive time for Glassow; her efforts were directed toward course development, supervision of master's students, and professional service. However, there were few journal publications to chronicle this work. It is therefore necessary to cite former students who later recorded her contributions.

Widule (1980, p. 112) reported that Glassow experimented with slow-motion photography and integrated it into teaching methodology, demonstrating that students learning to high jump showed greater improvement when a film critique of their performance was included in the instruction. Miss Glassow was practicing "pedagogical kinesiology" long before the term came into vogue in the profession. Yet during the Kinesiology Academy's 1982 prenational convention conference, Kinesiology and the Teaching of Motor Skills, her name and work were not mentioned by any of the eight speakers.

Two master's theses written during the 1930s by University of Wisconsin students who used cinematography were described by Atwater (1963). These students were Harriette V. Peaseley in 1932 and Monica R. Wild in 1937. Peaseley studied the golf drive with motion pictures that were projected onto graph paper for the study of joint actions before and after a course of instruction in golf. Wild, using film analysis, studied the movement patterns of children throwing, including evaluations of ball velocity and the acceleration characteristics of the throwing hand. A third cinematographic study was completed in 1936 by Irene Clayton, who studied the standing long-jump of elementary school children to show skill changes with age (Glassow, personal communication, March 1983).

With the collaboration of her graduate student, Marion R. Broer, Glassow published an article in 1938 describing a device for the study of motion pictures. The two women improved upon an earlier model designed by H.M. Halverson, a psychologist. Halverson had designed a work table for the study of films which placed the operator in close proximity to both the projector and the tracing table. However, Halverson's setup produced a small image which made tracing difficult. Glassow and Broer's device retained the advantages of the Halverson arrangement but used a wooden frame with adjustable mirror and glass tracing surface, which made variation of the image size possible. Improvement was also made in the ease with which a person could do film tracing and this contributed to more accurate measurement.

In today's biomechanic laboratories there is great variation in the manner in which modern film data reduction instruments are arranged for operation. Most follow the example of Glassow and Broer and consider ease of operation important.

When AAHPER published the first ... was selected to write the chapter on photography and cinematographical research methods. She had, at that time, nearly two decades of experience in the development of techniques for filming human subjects and had devised methods of analyzing the filmed action. Glassow's influence in kinesiology extends beyond that of cinematographic techniques. She felt that kinesiology courses should be of practical use to teachers and coaches. Her method of teaching was to include the use of specific definable behavioral objectives. In the decades that followed, use of behavioral objectives in designing instructional programs became widespread.

She and her graduate students studied the trajectory of projectiles in sports such as volleyball, tennis, softball, basketball, and bowling. In addition to recognizing the importance of mechanical principles, she emphasized the role of kinesthetic perception in performance as an important part of the learning process. Ruth B. Glassow has had a marked influence on the field of kinesiology from the 1930s to the present. Her textbook, now co-authored with John M. Cooper and Marlene J. Adrian, is in its fifth edition.

Ernst Jokl

Before immigrating to South Africa and then to the United States, Ernst Jokl conducted a series of cinematographical studies in his native Germany. In 1930 and 1931, Jokl published studies of running and long jumping (then called broad jumping). Slow-motion films of both skilled and unskilled athletes were taken for comparative analysis. The findings of these studies were reported by Steinhaus (1932). Jokl found that skilled runners have a longer stride, that their trunks have more forward lean, and that their centers of gravity follow a smooth undulating pattern with less up and down motion of the head and shoulders as compared to unskilled runners.

One of his subjects was Paavo Nurmi, the "Flying Finn" who, during the 1920s and early 1930s, won seven Olympic gold medals and established 16 world records. When Nurmi's technique was compared to those of unskilled subjects, the unskilled displayed greater velocity fluctuation within a single stride and their knees raised higher above the ground. Today, sport scientists such as Peter Cavanagh and runners such as Edwin Moses recognize that velocity changes are inefficient because they require increased muscular effort. There is no need to fight inertia.

In the long jump, two technique factors characterized the better athletes. At take-off their trunks showed a slight lean toward the take-off foot. This placed their centers of gravity over the propulsive foot. When Jokl suggested this technique change to jumpers who were not employing it, they showed immediate improvements. Current world and Olympic long-jump champion Carl Lewis's best jump of 28 ft 10.25 in. was made at the 1983 U.S. Championships in spite of a drift to the right—a deficiency which a study of Jokl's findings might have corrected, suggesting to Lewis that he keep his center of gravity over the take-off foot at the instant of take-off. Jokl also found that skilled performers were better able to bring both legs forward during the second half of the flight in order to land in a "jackknife" position with both heels together and forward.

Ernst Jokl, M.D., has been a leader in the field of sports medicine in the United States. In 1954, he helped found the American College of Sports Medicine. This organization is now the largest body of sports physicians and scientists in the world and has influence with 11,000 practicing physicians, educators, and research persons. Jokl wrote a definitive monograph in 1964 entitled *What Is Sportsmedicine?*—a valuable source for those interested in the antecedence of current practices in the United States and Europe.

Thomas K. Cureton, then a Springfield College professor, applied the cinematographic technique to athletics during the 1930s. His articles on the track start, running, shot put, high jump, and broad (long) jump were used by several generations of track coaches and were often cited in physical education and athletic texts. His series of articles, which appeared in *Scholastic Coach* magazine in 1935, showed how the coach could use motion picture photography to understand the mechanical principles that govern successful performance. For example, Cureton explained how and why the forearm and pushing foot should be kept in line prior to release of the shot (Cureton, 1935a). Another article described how to identify the path of the body's center of gravity during flight in high jumping and long jumping and how the center of gravity is affected by the take-off angle (Cureton, 1935b).

Using a Grantland Rice Sportlight Film in 1930, Cureton studied the flutter kick of Johnny Weismuller and Martha Norelius, as well as films of intercollegiate swimmers. Through vector analysis, he compared the relative value of force applied by the lower limb in the down-kick and up-kick phases. He concluded that during the up-kick, the sole of the foot was in a position to apply effective propulsive force. This finding was rather surprising, as some instructors had thought of the up-kick as a recovery movement only. The study appeared in the first issue of *Research Quarterly*.

Nine years later (1939), Cureton published "Elementary Principles and Techniques of Cinematographic Analysis as Aids in Athletic Research." This article was used as a guide for many U.S. and Canadian researchers for two decades. In this article Cureton listed three purposes of cinematographic research: to determine the factors governing successful performance, to derive an understanding of the mechanics of the skill, and to lay the philosophical interpretation of athletic performance.

Cureton is widely known in physical education circles for his research at the University of Illinois. During his 28 years there he directed more than 100 theses and dissertations. Most of his research dealt not with elite athletes but with fundamental questions regarding the values of exercise and how one could best achieve the desired level of fitness. Years before the aerobic movement he advocated continuous rhythmical exercise to improve heart-lung function. Convinced of the necessity of warm-up and cool-down, he included them in all fitness classes and believes this is one reason none of the thousands of participants of all ages ever experienced an exercise-related fatality.

Before retiring in 1969, Cureton published more than 400 articles and 50 books and monographs on topics that included physical fitness, measurement, body mechanics, posture, swimming, track and field, and gymnastics—a prodigious accomplishment.

Any scholar who wishes to read the original works of the individuals discussed in this article will find the experience to be both stimulating and enlightening. Their work gave direction to human motion studies and, to a large degree, defined the discipline as it exists today.

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BIOMECHANICS AND MOVEMENT ANALYSIS

YEAR TWO

3 March 1993

What is a State of the Art Review?

The photocopy in the library is a copy of a review of Match Analysis completed in 1990.

I would like to say something about it and want to encourage you to read it since it will inform your assignment.

The review is based upon the following sections:

Development of Analysis

Invasive Games

Racket Games

Computerised notation

Recommendations

You will find some helpful bibliographical references.

Perhaps this could form a basis for next week?

BIOMECHANICS AND MOVEMENT ANALYSIS 2

WEDNESDAY, 7 OCTOBER 1992

GOOD MORNING!

In today's talk I want to make some general points about notational analysis. I thought it might be helpful for you to share my notes via the computer.

If you want to you can keep a computer record of these notes as file notes. There will also be some handouts.

My idea is that we will build up a range of skills and knowledges.

This morning, I want to say something about:

1. The philosophical underpinnings of notation
2. The historical roots of notational analysis
3. A practical project for next week.

HISTORICAL ROOTS OF NOTATIONAL ANALYSIS

IN BRITAIN, THE FIRST PROFESSORS OF MUSIC WERE APPOINTED IN THE SIXTEENTH CENTURY AT OXFORD AND CAMBRIDGE.

THESE APPOINTMENTS WERE SUPPORTED AND FINANCED BY THE CHURCH.

THE FIRST PROFESSOR OF DANCE IN A BRITISH UNIVERSITY WAS APPOINTED IN 1990 AT THE UNIVERSITY OF SURREY.

NOTATIONAL ANALYSIS OF SPORT HAS BEEN PROMPTED BY NOTATION OF DANCE. THE WORK OF RUDOLF LABAN IS PARTICULARLY IMPORTANT IN THIS CONTEXT.

SOME OF THE EARLIEST WORK IN SPORTS NOTATION APPEARED IN USA. SEE FOR EXAMPLE:

L L MESSERSMITH AND C BUTHCHER'S (1939) ARTICLE ON THE DISTANCE TRAVELLED BY BASKETBALL PLAYERS.

SOME NOTATIONAL ANALYSTS ARE NOT SPORTS SCIENTISTS FROM ACADEMIC LIFE! CHARLES REEP'S WORK IN SOCCER HAS HAD A SIGNIFICANT IMPACT (SEE PHOTOCOPY)

CENTRES FOR NOTATION HAVE GROWN UP IN: SHEFFIELD, LIVERPOOL AND CARDIFF.

NAMES ASSOCIATED WITH PUBLICATION IN UK ARE: REILLY, THOMAS, SANDERSON, HUGHES, ALDERSON, BRACKENRIDGE, TREADWELL.

FROM DESCRIPTION

to MODELLING

to PREDICTION.

what observational skills you require to do this?

what kind of evidence do you require?

PATTERNED REGULARITIES

IDENTIFIED

THROUGH

SYSTEMATIC ANALYSIS

VIEWING AS AN ACTIVE PROCESS

real time events

lapsed time events

OBJECTIVITY

PURE and APPLIED.

QUANTITATIVE and QUALITATIVE

BIOMECHANICS AND MOVEMENT ANALYSIS
YEAR TWO

OBSERVATION INTO DATA INTO PRESENTATION

Last week we spent some time looking at the analysis of performance in invasive games.

My intention was to engage in some activity in order to look at some of the issues involved in systematic observation protocols. We also mentioned briefly the importance attached to reliability of data.

Two journal articles might be useful in developing our discussions:

Reliability

Johnson, R B & Franks, I M	Measuring the Reliability of a Computer-Aided Systematic Observation Instrument, Canadian Journal of Sport Sciences, 16(1),45-57

Time-Motion Analysis

Wilkins, H A et al	Time-Motion Analysis of and Heart Rate Responses to Amateur Ice Hockey Officiating, Canadian Journal of Sport Sciences, 16(4), 302-307

This morning I want to use the computer facility to work on data presentation.

FOR NEXT WEEK, PLEASE HAVE A LOOK AT THE ABOVE ARTICLES.

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EVALUATION

I think I misunderstood task! I thought I had asked them to look at State of the Art review!

They looked very surprised.

I used volleyball tapes to look at net game issues.

Erasmus student present: Thomas Just.

Explained purpose of the course.

Next week look at state of art review.

EVALUATION

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BIOMECHANICS AND MOVEMENT ANALYSIS
YEAR TWO
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Deciphering Research Reports: Moving Towards a Critical Sense of the Literature available to Movement Analysts

Introduction

Last week we discussed (or rather I talked overlong about) philosophical issues linked to notational analysis. In today's session I want to encourage your active participation.

Appended to this sheet is a copy of an article reproduced from the Journal of Sports Medicine.

I would like today's session to have three components:

1. A personal, close reading of the article.

2. A discussion with a colleague about what you have read.

3. A plenary session in which we can comment on the article collectively.

Whilst you may want to use your own framework for deciphering the research, perhaps you could consider:

Topic chosen

Methods Used

Data Collected

Results

By the end of your reading and discussion, can you come to a conclusion/informed judgement about the article?

For a discussion/example of deciphering sociological research see Gerry Rose, Deciphering Sociological Research (London, Macmillan, 1982). He suggests that:

> the reader needs to have a basic grasp of what is normally termed **research methods** or **methodology**; a second, and less obvious, requirement is for an **analytic framework** which is designed specifically for the task of deciphering. (1982:4)(original emphasis)

A computer-video aided time motion analysis technique for match analysis

ARAZ ALI, *Ph.D.*, MARTIN FARRALLY, *Ph.D.*

From the Department of Physical Education, University of St. Andrews, Fife, Scotland

The purpose of this study was to find out suitable methods for obtaining objective data on the time spent by players of different positions during walking, jogging, cruising, sprinting and standing still during match play activities. Computer programs and filming analyses with a simple notation system based upon symbolic representations of movements have been devised for analysis of individual players' behaviour. A technique was devised and employed with a small group of university players, aged 19-21 years of age. The subjects were filmed in several matches, and the video recordings were analysed using a microcomputer. The ratio of the time spent for the players were 56% walking, 30% jogging, 4% cruising, 3% sprinting and 7% standing still. ANOVA revealed that there are significant differences among the players for different positions on the field, for example the time spent on walking, jogging and standing still differed ($P<0.05$) among attackers, defenders and midfielders. A new method has been developed to obtain reliable information about the players' movement and performance in the game. The Authors believe that there should be further studies carried out involving more teams at different levels of performance to substantiate these preliminary findings.

[J Sports Med Phys Fitness 1991; 31:82-8]

Key words: **Motion Analysis - Association Football.**

Little research has been focused on the movement analysis of soccer players. There are several references in coaching and conditioning books relating to the match distances covered by various types of locomotion, but literature contains few studies where the reliability and/or validity of the measuring instrument was established prior to data collection.

The majority of exceptions have been concerned with the motion analysis of athletes with the aim of identifying the total distance spent jogging, walking and sprinting (i.e. Winterbottom, 1959; Wade, 1967; Zelenka *et al.*, 1967; Whitehead *et al.*, 1968; Agnevik, 1970; Brooke and Knowles, 1973; Saltin, 1973; Vinnai, 1973; Reilly and Thomas, 1976; Ohashi, 1979; Nettleton and Briggs, 1980; Thapar and Sharma, 1982; Withers *et al.*, 1982; Franks *et al.*, 1983).

It should be noted that most of these have done analysis of distance (Fig. 1). However, few of them have used an objective analysis technique, which could give accurate information. For these reasons it was believed that analysing the total time spent by soccer players in different positions by using video and computer, could be of much value to coaches and managers.

The present study is aimed at finding the most accurate and suitable methods for obtaining objective data on the time spent by each of the individual players for different positions on the field during walking, jogging, cruising, sprinting and

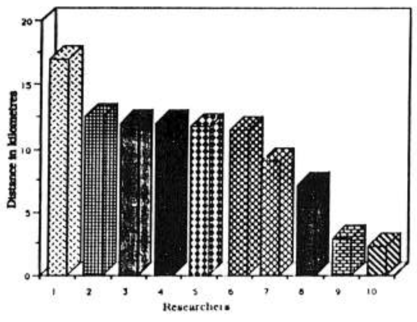

Fig. 1.—Summarises the mean total distance covered per game of soccer as recorded by several researchers: 1) Vinnai (1973); 2) Withers *et al.* (1982); 3) Agnevik (1970); 4) Saltin (1973); 5) Whitehead *et al.* (1968); 6) Zelenka *et al.* (1967); 7) Reilly and Thomas (1976); 8) Wade (1967); 9) Brooke and Knowles (1973); 10) Winterbottom (1959).

standing still. The main questions which the study raises, therefore are:

(i) Can filming of all the soccer players during a match be used for studying their movements?

Size of the pitch, location of cameras and player interactions all present problems in recording and reviewing individual player movements.

(ii) How successful is a filming analysis made of one soccer player at a time, for determining their behaviour in the game?

Following one player in close-up for the whole game may help to identify specific movement patterns but there may be problems of seating and interpretation of movements because the wider context of the game is not in camera.

(iii) Can a computer be used for analysis of the movement of soccer players in a live match?

Capacity and speed of data storage using microcomputers may be adequate but there may be problems in maintaining eye contact with the game during rapid periods of play.

(iv) How can a computer be used for analysing the game?

It is necessary to devise a computer coding system and data analysis programs.

Material and method

The filming apparatus

Consisted of a small fully self-contained, easy to carry Panasonic portable colour video camera (WVP-A2E). It features a high- band (3.9 MHZ/inch) integral strip filter (Newvicon TM) tube. It receives its power from a Panasonic portable video cassette recorder (NV-180 Series). The (WVP-A2E) is a high quality camera with an auto focus automatic light/iris control zoom lens that produces 280 lines horizontal resolution luminance with recommended illumination of 140 footcandles (1400 Lux) at F4.0. It has a graphics display through a micro-process which is able to select colour titles, data, time, stopwatch with lap time feature, record, fade and warning for battery.

Data apparatus

Consisted of an Epson HX-20 portable computer. The Epson HX-20 is able to fit into a briefcase and is powered by a long life battery. Its components are a microprinter, which has switch controls to the output of the built-in microcomputer. The Epson HX-20 is provided as standard equipment with an interface cable (cable set #702) for an audio cassette; it can write and read programmes and data, transferring it to and from the external audio cassette. The facility increases the memory stage capacity of the system sufficiently to read a whole match but some time is required to transfer data to the tape. All operations of the optional microcassette drive can be controlled under (Basic). The monitor display is liquid crystal which will show the menu displays as numbers and the function (programme names) which can be executed when the corresponding numeric keys are pressed. Memory space is divided into five programme areas, each capable of storing a separate basic programme which can be selected from the menu for immediate execution. In addition to the programme areas, the Epson HX-20 is provided with a RAM file area to facilitate data storage, as well as transfer between programmes.

Procedure

The videotape recorder, together with the camera mounted on a tripod, was positioned level with the middle of the pitch, 10 metres from the touch line. Twenty-one St. Andrews university football team players, aged between 19-21 years were filmed in several matches, and the video recordings were analysed using a microcomputer method.

Coding and data recording

The tape was replayed on a television monitor and coded for walking, jogging, cruising, sprinting and standing still. These categories are based upon the classification of movement used by Reilly and Thomas (1976), and describe the different movements in soccer very well. In the present study kicking, passing, heading, tackling, trapping, jumping and dribbling the ball have been counted as belonging to the previous movements described, for example, when a player dribbles the ball in a jogging situation the period of time spent in dribbling the ball was counted as jogging. It might be argued that movements when in possession of the ball should be analysed separately. However, it has been shown that, on average, a player is in contact with the ball for less than 3 minutes per game (Reilly and Thomas, 1976; Ohashi, 1979; Thapar and Sharma, 1982; Withers *et al.*, 1982; Van Gool *et al.*, 1988) and the movements with the ball are sufficiently similar to those without the ball to make the "ball effect" an insignificant part of all of the players' movements during the game.

For the purpose of calculating the time spent for each discrete movement by the subject during a match situation, two systems were used. Firstly, a programme was designed for data collection using the Ep-

TABLE I.—*An example of data collection using the microcomputer method.*

Movement N.	Code N.	Activity	Time at end of movement
0	1	Jog	21:57:03
1	0	Walk	21:57:06
2	1	Jog	21:57:16
3	0	Walk	21:57:31
4	3	Sprint	21:57:36
5	0	Walk	21:57:39
6	1	Jog	21:57:42
7	2	Cruise	21:57:49
8	1	Jog	21:58:00
9	4	Stand-still	21:58:10
10	1	Jog	21:58:14
11	0	Walk	21:58:26
12	1	Jog	21:58:43
13	0	Walk	21:58:50
14	1	Jog	21:59:03
15	2	Cruise	21:59:13
16	1	Jog	21:59:36
17	3	Sprint	21:59:41
18	1	Jog	21:59:44
19	4	Stand-still	21:59:50
20	1	Jog	22:00:03

*The times spent in these activities were recorded in seconds

son HX-20 microcomputer. The main aim of the programme was to identify each movement and store the time spent by the subject in its memory as shown in Table I. A separate key on the microcomputer keyboard was allocated to each discrete movement category, with "Return" being used to indicate the end of the data storage.

It should be noted that the only problem with using the Epson HX-20 is that it has a small memory. This difficulty was overcome by stopping the video, and transferring the data from the machine memory onto microcassette tapes. This had to be done between 4 to 6 times per match, whenever the memory became full. However, the data collection programme was designed to send out a sound signal when the memory became full in order to avoid any error in recording the data.

Secondly the data can also be recorded by using a timer built into the VHS camera. The exact time spent in each particular movement can then be calculated from reading the clock displayed on the

TABLE II.—*An example of data collection from the timer which built into VHS tape.*

Walk	Jog	Cruise	Sprint	Stand-still
*3.56	21.06	2.64	4.12	6.8
11.44	2.0	11.4	8.60	1.56
16.84	6.0	2.64	7.88	5.76
3.52	2.6	13.48	4.12	8.0
14.96	4.40	3.52	1.8	2.42
2.40	10.28	2.12	4.30	3.04
13.28	3.76	3.92	3.04	4.0
2.72	3.8	3.20	3.36	3.04
4.8	6.08	5.48	2.92	9.24
4.94	4.96	4.48	4.18	3.76

*The times spent in these activities were recorded in seconds

screen, and noting down the time under, as shown in Table II. It should be noted that interpreting the data by hand or even using a calculator is time consuming and has a high risk of missing data. It is possible to lose between 2 to 6 minutes of data for each match. This was noticed when the total time spent on each movement was calculated and these totals were added together.

Results

For the purpose of analysis, two more programmes were designed. The first programme allowed the data to be transmitted from microcassette tapes to a mainframe computer. The second programme manipulated the data and analyses it:

(i) To count frequency of walking, jogging, cruising, sprinting and standing still for the whole match, and also for both halves of the match for every subject.

(ii) To determine mean and the standard deviation of the periods of walking, jogging, cruising, sprinting and standing still for a match and also for each half of the match for every subject.

(iii) To determine the total time spent and the standard deviation of walking, jogging, cruising, sprinting and standing still

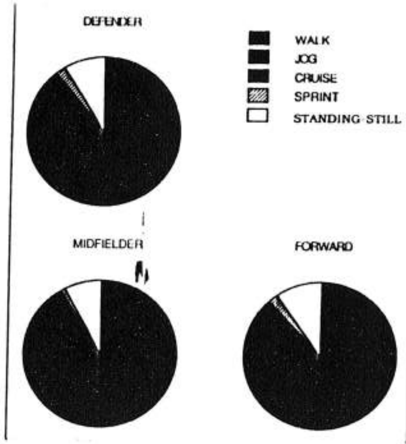

Fig. 2.—Time spent by soccer players in different positions on the field.

for a match and also for each half of the match for every subject.

For further analysis the subjects were divided into three positional roles, defence players, midfield players and attacking players, and the significance of the difference between positions was analysed using "ANOVA". ANOVA revealed that there are significant differences among the players for different positions on the field, for example the time spent on walking, jogging and standing still differed ($P<0.05$) among attackers, defenders and midfielders (Fig. 2).

Discussion

Results showed that the ratio of the time spent for the players were 56% walking, 30% jogging, 4% cruising, 3% sprinting and 7% standing still. Some examples of the implications of these findings are as follows:

(i) These percentages may suggest low physiological demand yet heart rate studies show high values (Van Gool *et al.*, 1983; Ali and Farrally, 1990). Perhaps it is the "mix" of the different activities, rather than their absolute values, which is important.

(ii) Sprinting for only 3% of the time, for example, may not seem very much but this is about 4 minutes and is equivalent to a distance of more than one mile (100 metres in 12 seconds, on average). Consequently sprint and cruise training is important.

It showed also that subjects spent less time in high intensity work "cruising and sprinting", in the second half. Saltin (1973) supported this finding. In evaluating the total distance covered per game of soccer, he reported that the total distance covered at maximum speed decreased significantly in the second half. There might be several reasons for this:

(i) Fatigue: soccer players may contribute much more effort to the game in the first half, and the longer the game goes on the more fatigued they become and the less contribution they make.

(ii) Results of the game: for example, on the one hand, when a team is winning by 3 or 4 goals, the players may be less enthusiastic about the match and contribute less to the game. On the other hand, when a team is losing by 3 or 4 goals the players may be less interested because they think that they can not win the match.

Several weak points can be pinpointed in the methods used by those researchers mentioned previously. Those techniques used by Reilly and Thomas (1976), and Withers *et al.* (1982) were found to be the most sensitive to the measurement of distance covered per game of soccer (Figs. 3 and 4).

It can be seen from these figures that there are observable relationships between these findings and our finding of the total time spent of each discrete movement. For example Reilly and Thomas reported that the defence and forward players covered more distance in walking

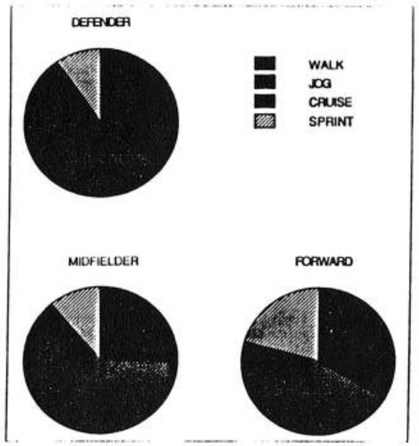

Fig. 3.—Total distance covered in different positional roles of English professional soccer players. Data from (Reilly and Thomas).

and sprinting and less in jogging and cruising but the midfield players covered more distance in jogging and cruising and less in walking and sprinting. In our study the defence and forward players spent more time in walking and sprinting and less in jogging and cruising but the midfield players spent more time in jogging and cruising and less in walking and sprinting (Figs. 2, 3 and 4).

Despite the subjects tested in each case being at different standards in the game, the technique devised produced data comparable to the distance studies. It appears, then, that different problems do make different physiological demands on players.

This should be reflected in training, resulting in a different emphasis for defenders, midfielders and attackers.

The computer which the researcher had access to, had a small memory, which means it was not possible to analyse the game live. This difficulty was overcome by filming the game first, then analysing the film in several stages. Using the computer was

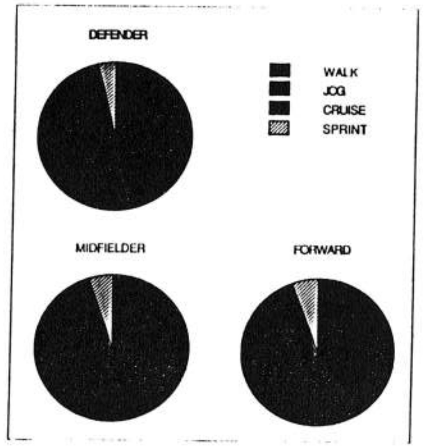

Fig. 4.—Total distance covered in different positional roles of Australian professional soccer players. Data from (Withers *et al.*).

shown to be a more accurate method of analysis than using the in-built timing mechanism of the video camera.

The time consumed was less when using the microcomputer because it was only necessary to stop the videotape a few times to transfer tha data from the memory onto microcassette, whereas with the video timer it was necessary to stop the videotape each time the subject changed his movement, in order to read and calculate the exact time spent in that particular movement and then note it down on the table.

A microcomputer with a bigger memory capacity could be used to analyse the player during live matches without requiring filming, provided it was portable and small enough to be used in a stand seat. This would remove the need for restoring the game and provide a more rapid analysis. The only drawback would be the inability to replay the game if an error in recording occurred. Experience has shown that a well-trained person provides negligible errors.

Conclusion

A new system has been established for the analysis of association football players' behaviour, by using computing and filming. This is more suitable and praticla for recording information about the players' movement and performance in the game.

Association football is an activity in which walking, jogging, cruising and sprinting are identified as the major contributory actions from which the total physical workload derives.

A computer program which can be used with or without video film analysis, with a simple notation system based upon symbolic representations of walking, jogging, cruising, sprinting and standing still has been devised to use in analysis of individual players' behaviour. This system is objective and reliable. Minute by minute analysis of behaviour can be obtained for each individual player in a match.

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Address reprint requests to: A. Ali - Department of Physical Education, University of St. Andrews, St. Leonard's Road - St. Andrews, Fife, KY16 9DY (Scotland).

Relationships among strength, endurance, weight and body fat during three phases of the menstrual cycle

RO DIBREZZO, *Ph.D.*, INZA L. FORT, *Ed.D.*, BARRY BROWN, *Ph.D.*
From the Human Performance Lab., University of Arkansas, Fayetteville, AK, U.S.A.

The purpose of this study was to investigate the relationships among body weight, body fat, and dynamic strength and muscular endurance during different phases of the menstrual cycle. Twenty-one female subjects, ages 18-36, with normal menstrual cycles and no dysfunction were tested for strength and endurance of the knee flexors and extensors on a Cybex II isokinetic dynamometer. Body weight and percent body fat were also assessed. Each subject was tested at three speeds (60°, 180°, and 240°/sec) during three phases of the menstrual cycle: mensus (within 24 hours of onset); ovulation (13-14 days from onset); and luteal (10 days from ovulation). The data were analyzed descriptively and by Pearson Product-Moment Correlations with each phase of the cycle and between cycle phases. Results indicated high correlations among most strength measures at the three test speeds for each phase during the cycle and between the cycle phases. Overall, the different phases of the menstrual cycle had little or no effect upon the relationships among body weight, percent body fat, knee extension and flexion strength or endurance.

[J Sports Med Phys Fitness 1991; 31:89-94].

Key words: **Menstrual cycle - Sport medicine.**

For decades there has been speculation as to the effect of the menstrual cycle on the athletic performance of women. It has only been since 1984 that women have been allowed to compete in running events longer than 1500 meters in the Olympics. Before that time, it was believed that women were not capable of such physical stress. Society has gradually changed its perceptions and attitudes about the influence of the cycle with regard to the abilities or limits of physical performance in women. Much remains to be explored about society's myths concerning the menstrual cycle in addition to the effects of the cycle and related dysfunction on the performance capabilities of individual women.

Review of literature

As women engage in more strenuous physical activities than ever before, additional research concerning women, exercise and the menstrual cycle has emerged. There is conflicting evidence in the literature of the effects of the menstrual cycle on exercise or physical work.

Menstruation begins with enlargement of follicles at the onset of mensus. One follicle gradually outgrows all the others and continues to grow for 14 to 15 days from the onset of menses. This growth ends with ovulation, defined as rupture of the follicular wall through which the ovum escapes. The empty follicle begins the luteal phase, which lasts for approximately 14 days or until the next mensus.

At the time of mensus, estrogen and progesterone are at their lowest levels. Estrogen levels slowly increase and then