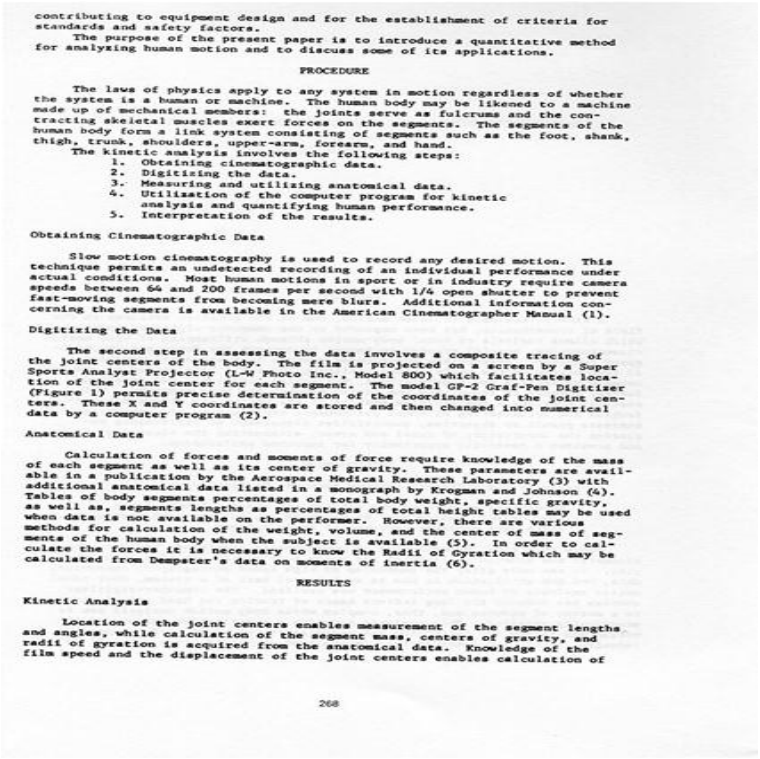
Patterns Of Human Motion: A Cinematographic Analysis



contributing to equipment design and for the establishment of criteria for standards and safety factors.

The purpose of the present paper is to introduce a quantitative method for analyzing human motion and to discuss some of its applications.

PROCEDURE

The laws of physics apply to any system in motion regardless of whether the system is a human or machine. The human body may be likened to a machine made up of mechanical members: the joints serve as fulcrums and the contracting skeletal muscles exert forces on the segments. The segments of the human body form a link system consisting of segments such as the foot, shank, thigh, trunk, shoulders, upper-arm, forearm, and hand.

The kinetic analysis involves the following steps:

1. Obtaining cinematographic data.
2. Digitising the data.
3. Measuring and utilizing anatomical data.
4. Utilization of the computer program for kinetic analysis and quantifying human performance.
5. Interpretation of the results.

Obtaining Cinematographic Data

Slow motion cinematography is used to record any desired motion. This technique permits an undetected recording of an individual performance under actual conditions. Most human motions in sport or in industry require camera speeds between 64 and 200 frames per second with 1/6 open shutter to prevent fast-moving segments from becoming mere blurs. Additional information concerning the camera is available in the American Cinematographer Manual (1).

Digitizing the Data

The second step in assessing the data involves a composite tracing of the joint centers of the body. The film is projected on a screen by a Super Sports Analyst Projector (L-W Photo Inc., Model 800) which facilitates location of the joint center for each segment. The model GP-2 Graf-Pen Digitizer (Figure 1) permits precise determination of the coordinates of the joint centers. These X and Y coordinates are stored and then changed into numerical data by a computer program (2).

Anatomical Data

Calculation of forces and moments of force require knowledge of the mass of each segment as well as its center of gravity. These parameters are available in a publication by the Aerospace Medical Research Laboratory (3) with additional anatomical data listed in a monograph by Krogman and Johnson (4). Tables of body segments percentages of total body weight, specific gravity, as well as, segments lengths as percentages of total height tables may be used when data is not available on the performer. However, there are various methods for calculation of the weight, volume, and the center of mass of segments of the human body when the subject is available (5). In order to calculate the forces it is necessary to know the Radii of Gyration which may be calculated from Dempster's data on moments of inertia (6).

RESULTS

Kinetic Analysis

Location of the joint centers enables measurement of the segment lengths and angles, while calculation of the segment mass, centers of gravity, and radii of gyration is acquired from the anatomical data. Knowledge of the film speed and the displacement of the joint centers enables calculation of

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