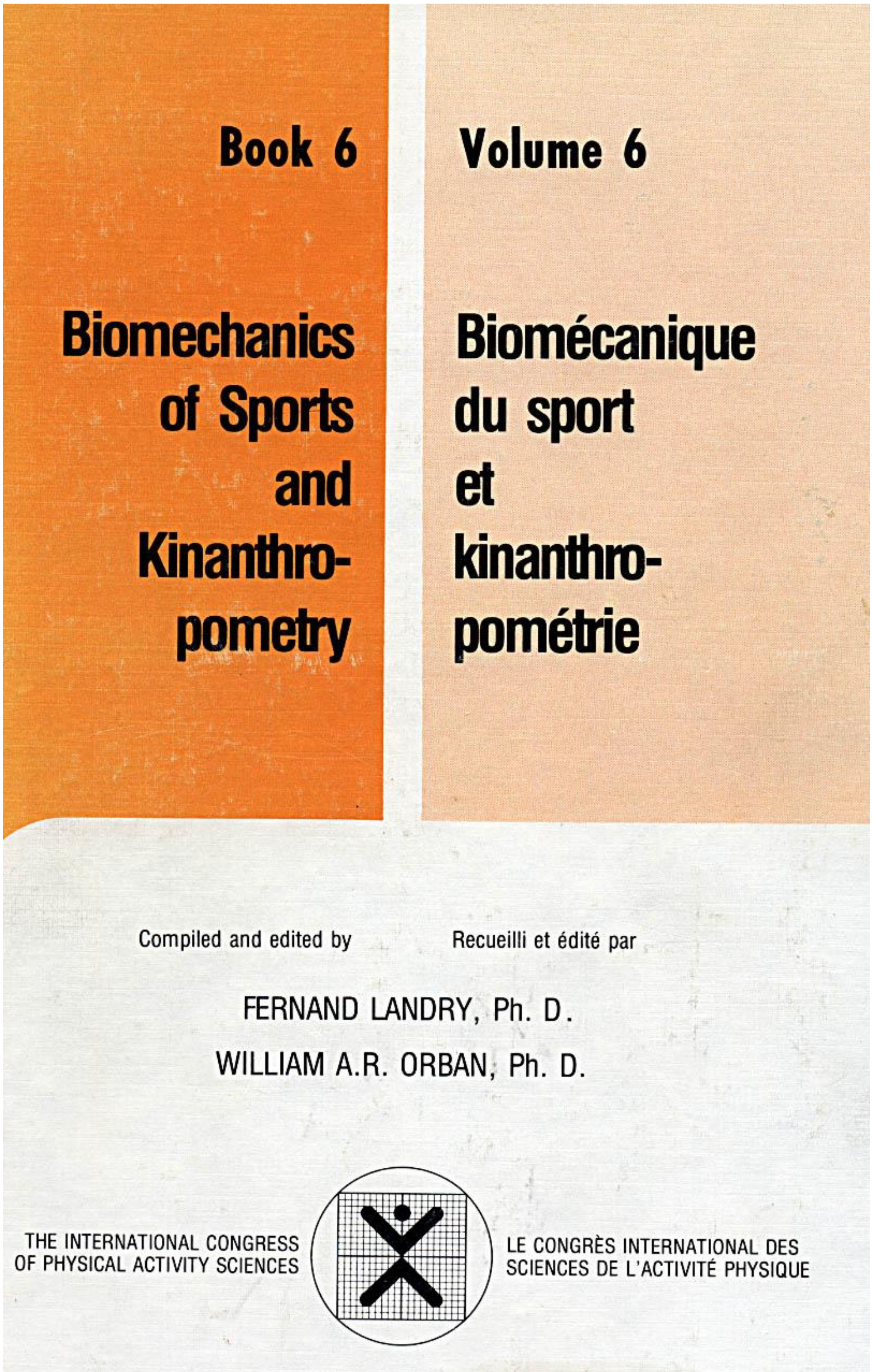
Appendix 2 to Chapter 16:

The Computerized Exercise Machine Concept Presentation



Computerized Dynamic Resistive Exercise

Gideon Ariel

Introduction

The relationship between resistance exercises and muscle strength has been known for a long time. Muscular strength may be defined as the force a muscle group can exert against a resistance in a maximal effort, and any motion by the human requires muscular involvement. Forty to sixty percent of the human body is composed of contractile tissue forming 437 different voluntary muscles, and the most fundamental function of these muscles is the ability to produce motion by their own contraction. The action of these muscles on the bones, which provides the leverage system, permits man to stand erect, carry out activities of daily living and participate in athletic performances requiring optimal efficiency in muscular contraction and coordination. This motion of the musculoskeletal system is governed by the strength of the muscles and skeletal structure.

In 1948 Delorme [3] adopted the name "progressive resistance exercise" for his method of developing muscular strength through the utilization of counterbalancing the weight of the extremity with a cable and pulley arrangement and, thus, gave load-assisting exercise to muscle groups which would not perform antigravity motions. McQueen [4] distinguished between exercise regimens for producing muscle hypertrophy and for producing muscle power. He concluded that the number of repetitions for each set of exercises determines the different characteristics of the exercise. Based on evidence presented in these early studies, hundreds of investigations have been published relative to muscular development through resistance exercise with various methods being introduced. Techniques for muscular development include isotonic, isometric, isokinetic, eccentric, concentric and many other exercise techniques. Each system has been supported and refuted by numerous investigations.

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In 1972, Ariel [2] introduced the Dynamic Variable Resistance exercise principles which resulted in the Universal Variable Resistance exercise equipment. For the first time biomechanical principles were employed in the design of exercise equipment. Rather than fit a man to a machine the machine was designed for the man.

Biomechanical Considerations

Biomechanics is the science which investigates the effects of internal and external forces upon living bodies. When a person uses any resistance device, whether it is a spring or a bar, there are two kinds of forces applied to this system. The internal forces are produced by the muscular system and the external forces are produced by the resistance device, in this case the spring or the bar. When considering any human force system, muscles, bones, and joints as well as externally applied resistance must be considered. Consideration of the magnitude of the externally applied resistance cannot be the only consideration in muscular training. Rather, the magnitude, action line, direction and point of application are all four characteristics which must be considered in developing maximal muscular training routine. Physical educators and athletes deal constantly with muscle forces, both normal and supernormal, but how much is actually known about the actual magnitudes of these forces? The actual forces produced by individual muscles cannot be predicted easily because of the indeterminate influence of a number of physiological and biomechanical factors. These include length-tension and force-velocity relationships as well as the location of the muscle attachments with respect to the joint. One way to determine the muscular involvement in the exercise is to refer to the moments of force produced by all the muscles at the particular joint. It is well known in resistance exercise that there exists a "sticking point" during which the apparent resistance is at its maximum. However, the absolute muscular force is relatively constant and varies slightly depending upon its force-length relationship. This variability of muscle length is of no significance when performing exercises with heavy loads. If this is the case, why is there a "sticking point" in the bench press, for example, above which the weight becomes "light"? This phenomenon is the reason for the programmable variable resistance exercise machine.

The Variable Resistance Concept

In conventional resistance exercise, loads are moved through a range of motion. The load remains constant throughout the motion but the muscular force is not constant because of the modifying effects of the lever system throughout the range of motion. For all practical purposes, the absolute muscular force is the same throughout the exercise, since the only difference is the force arm on which the muscle pulls. This explains why when performing an exercise such as the bench press, there is a point where the resistance is maximum and below or above this point the resistance is less. This fact illustrates the important phenomenon that throughout an exercise stroke, the muscle is working at its maximum potential during a very small range of motion. In order to resolve such a phenomenon, it is necessary to accommodate the biomechanical changes by varying the resistance. The programmable variable resistance exerciser varies the resistance under program control. This allows facilitation of maximum muscular involvement and optimized exercise productivity.

The Programmable Variable Resistance Exerciser

To design the proper layout of exercise machines with the appropriate resistance and the proper ballistic effect in accordance with the requirements of biomechanics and the anatomy of man, it is necessary to determine the moment of force in each particular exercise and simultaneously consider the muscular force and the dynamic forces due to the motion. This information allowed development of apparatus which assigns different resistances throughout the range of motion in order to accommodate the biomechanical changes occurring during the exercise and at the same time adjust for the ballistic characteristics of the movement.

The term "programmable variable resistance" refers to the principle embodied in a proposed series of exercise machines. These machines implement standard exercises, such as curl, leg extension, etc., in a way that provides greatly increased training efficiency. Training is automatically adjusted to match biomechanical parameters of the individual using the machine, and special exercise regimens can be easily implemented to meet the requirements of rehabilitation and of specific athletic activities. The programmable variable resistance machine adapts itself to the requirements of a scientifically prescribed training or rehabilitation program. Its fundamental, unique feature is that the muscular force curve can be changed at will, but this is only one aspect of a highly flexible structure. Other important properties include the following:

1. The machine is capable of determining the user's force curve and then adjusting its own curve to optimize resistance for him.

2. The overall force can be made to diminish in a prescribed way with successive repetitions during a session to allow for muscular fatigue.
3. Similarly, overall force can be made to increase from one session to the next, as the muscles develop; this takes place automatically on the basis of re-evaluation of user strength and of data stored during each session.
4. The stored data can be used to monitor progress, thus facilitating scientific control of long-term training programs as well as the acquisition of data for research.
5. Special training regimens can be implemented, involving not only specialized force curves, but also the possibility of training for specified velocity and range of travel.

Figure 1 illustrates the flow chart for such a machine. This machine is also unique in that all resistance is program controlled. To control the machine's resistance, a sensor is attached at the pivot point of the handlebars. The sensor measures the net force being exerted on the bars and transmits this information through some intermediary computing device to a meter in front of the user. The computing device sets the force necessary to center the meter needle and, hence, the force demanded of the user. The user has continuous feedback as to whether he is exerting enough, too little or too much force.

Variable resistance is achieved by sensing the instantaneous position of the handlebars with an angle-measuring device at the pivot point. Knowing the angle, the computing device mentioned previously can consult a stored force curve and set the meter-center force accordingly.

The computing device referred to above is implemented as a general-purpose digital computer or microprocessor, and the sensors provide electrical outputs. With the addition of some means of storing data and some additional information-input and display devices, the hardware for programmable variable resistance is complete. All of the aforementioned features are now implemented by means of stored programs for the computer and possibly by external processing of stored user data. The operation of the full configuration can best be described by following a typical sequence of user sessions with the machine.

Before beginning his training program, the user supplies identification and other pertinent data for inscription by a central agency on the data-storage means, probably a magnetic-tape cassette. The user will retain this cassette in his possession, inserting it in a reader/

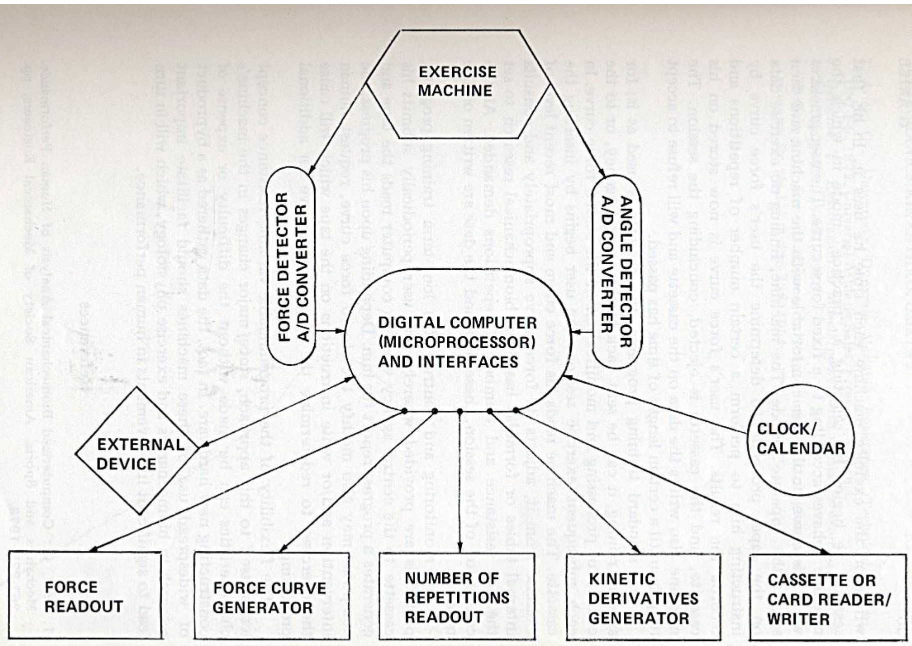

Fig. 1. The programmable variable resistance exerciser flow chart.

writer on the exercise machine each time he uses it. In his first session, he begins by selecting a "practice" mode in which the machine behaves according to a fixed force curve. The user practices with this curve until he is comfortable with the machine and then selects the "operate" mode. The machine, finding no exercise data on the tape, proceeds to determine the user's force curve by instructing him to perform a certain number of repetitions and records the results. The user's force curve is now stored on his cassette, and the cassette is ejected, concluding the session. The machine also writes the data on the cassette and will refuse to accept it again until a certain length of time has passed.

For standard training programs, the cassette is used as is; for special training, it can be sent back to the central agency, or to the coach, for processing and modification of the stored force curve. In each subsequent exercise session, the user begins by inserting the cassette. The machine reads his force curve and most recent level of exercise from it, adjusts its force curve appropriately and consults internal tables or formulas based on biomechanical research to set the net resistance and number of repetitions demanded. At the conclusion of the session, these data and the date are written on the tape.

For monitoring and control of a long-term training program, protocols are provided whereby the user periodically submits his cassette to the central agency where a computer reads the tape and generates a progress report for him. Depending upon his progress, the computer may also modify the stored force curve, request human intervention and/or write instructions on the tape which will cause the exerciser to redetermine the user's force curve for additional processing.

The flexibility of the programmable variable resistance concept lends itself to this approach, since major changes in the machine's characteristics can be made without the difficulty or expense of constructing new hardware. In fact, the data gathered as a byproduct of widespread use of these machines should facilitate important research in biomechanics and exercise physiology, which will in turn lead to significant improvements in human performance.

References

1. Ariel, G.: Computerized Biomechanical Analysis of Human Performance. Mechanics and Sports. American Society of Mechanical Engineers, pp. 267-275, 1973.