EVOLUTION OF EXERCISE MACHINES

A. I. Netreba, O. L. Vinogradova, O. I. Orlov
State Scientific Center of the Russian Federation - the Institute of Medical and Biological Problems of the Russian Academy of Sciences, Russia

Keywords: sport, exercise machines, design, history, training, biomechanics.

Contents

1. Introduction
2. Free weight
3. Modification of constructive solutions
4. Modification of loading methods
5. Adoption of controlled power drives
6. Appearance of measurement instrumentation
7. Appearance of displays of parameters
8. Training process automation
9. Conclusion
Glossary
Abbreviations
Bibliography
Biographical Sketches

Summary

The process of creation of new exercise machines and modification of existing devices requires presence of two initial components: scientific-and-technological advance, creating new engineering opportunities and directions and deepening of theoretical knowledge in the area of physiology of exercises. In this chapter the path of development and modification of devices, used by people for training of different motor qualities, is traced. Design features of different exercise machines and functional characteristics of different power drives, used for application of specific loads, are considered.

1. Introduction

Sometimes it is much easier to trace the evolutionary path of this or that phenomenon, than its history. In the case of training devices, this path allows us to see a particular trend of their development in the future. The study of the historical path for the given area of human activity is less interesting. Actually, dates of appearance of this or that exercise machine or details of foundation, merging and liquidation of companies, manufacturing training devices, are not important for the theory and practice of sport, for medicine and scientific researches. It is much more interesting to trace the evolution of inventive ideas, novelties of scientific-and-technological advance and also theoretical knowledge from sports physiology, sports or clinical practice, penetrating the area of development of exercise machines. So, for example, it is absolutely not important and principally impossible to determine the moment of appearance of the first exercise machine, intended for special training of a certain motor quality of a specific group of

muscles. At the same time, from the evolutionary point of view, it is evident, that common weights or dumbbells are the simplest training tools. Such start points lead to an assumption, that the use of a common cast dumbbell for some exercises, in particular, for one-articulate hand movements, is uncomfortable, since in this case rotation motion actually should be executed about an axis of a tool. Otherwise, holding of a dumbbell in such movement requires an additional compressive stress of the hand muscles for elimination of its rubbing in a hand, since such friction leads to appearance of cutaneus corns or even to traumas. Thus, an idea to supply a dumbbell with rotating handle comes to an inquiring mind. In this case a dumbbell does not rub the hand, but rotates relative to its handle (supported with bearings), held by the sportsman. Such "small invention" significantly improves the efficiency of the training process. First of all, load on supplementary muscles, which in many cases limit training with high weight, is decreased. Secondly, such construction allows performing exercises rapidly - time for stoppage and inverse rotation of dumbbell is not wasted. The following step - appearance of a dismountable dumbbell. It is obvious, that prompt load increase/decrease capability allows selection of training weight more precisely, optimizing, thus, the training process on the whole. Usage of a large set of cast dumbbells of different weights is not efficient both from economic and ergonomic point of view. The following step - elongation of the handle of the dumbbell to hold it by both hands. Thus, we come to a classical barbell. And a sports physiologist, a trainer or a doctor does not care when and why this modification of sports equipment has appeared.

2. Free Weight

So, the first evolutionary step of development of training devices is a free weight. Distinctive feature of a free weight is an opportunity to perform training exercises with all possible degrees of freedom, and a minus point is that a great number of additional muscles, executing the role of stabilizers, is activated. Meanwhile, for a long time it is evident for sportsmen and trainers, that selective training of separate groups of muscles, participating in the whole movement, is more important for increase of efficiency of a target/competitive movement. It is connected, first of all, with unavoidable presence of lagging groups of muscles. The physiological mechanisms, underlying management of muscles in the execution of a complex multiarticulate motion (intermuscular coordination), work according to the principle of compensation and minimization of power inputs. In other words, for provision of adequate motions stronger groups of muscles take upon themselves a lion's share of the total load, unloading, thus, lagging groups of muscles. Therefore, this circle closes up, and the only way out is purposeful training of muscles-outsiders. Such conclusion, apparently, leads to an idea of limiting the number of degrees of freedom.

3. Modification of Constructive Solutions

From a design point of view all types of exercise machines can be subdivided into three big groups: units with a linear movement; units with an angular movement; load-block units.

In exercise machines of the first type the free weight can move only lineally. For this purpose special rails or linear bearings are used. A classical example of an exercise

machine with a linear movement is a well-known Smith-machine, consisting of a frame with vertical guides for sliding of a barbell with discs. It gives great advantages in performing such exercises, as squatting and bench press (standing, sitting, lying and with different angles to a horizontal line). In the execution of these movements with a usual barbell additional groups of muscles (at squatting - muscles of back, for presses - deltoid or pectoral muscles), which do not allow one to perform exercises with full concentration on basic groups of muscles, are engaged.

Exercise machines with angular movement (lever exercise machines) - hammer-machines are intended for selective execution of one-articulate movements: bending-unbending in shoulder, elbow, hip, knee and ankle joints.

An intermediate position between free displacement of weight and strictly limited movement is occupied by load-block exercise machines. On the one hand, movement in these units is free enough due to flexibility of a used cable, on the other hand – it is restricted, since the contact of the cable and the block, sliding on it, is rigidly fixed at a certain point of space. Load-block exercise machines are used for improvement of tractive force (at upper and lower traction) of flexor muscles. The main advantage of these exercise machines is automatic (at a level of a motor command) selection of an optimum trajectory of movement at considerably reduced role of stabilization muscles.

Rigging of a load-block exercise machine with a rigid element of a lever exercise machine with varying shoulder of force application (“Nautilus”-type machines) has revolutionized the training world. It has happened due to the use of a special rotating eccentric with a special profile and a rigidly attached working lever. Efficiency of training with the use of such exercise machines is explained by the following physiological basis. In connection with change of a number of simultaneously closed actomyosin bridges at change of length of a muscle, the force, demonstrated by the muscle, varies bewteen significant limits, depending on the angle in a joint. The free weight, as we know, is capable to provide only fixed loading. Therefore, in different amplitude phases muscles are underloaded or overloaded. Usage of a special profile of load change, corresponding to special features of a particular group of muscles, due to change of an arm of an applied force, sharply raises efficiency of training, allowing one to execute a motion with the maximum force during the whole amplitude. In due time usage of machines of "Nautilus" type was so eager, that special eccentrics were made for each fan of this exercise machine, since each person preferred his own individual profile of force distribution.

-

-

-

TO ACCESS ALL THE **11 PAGES** OF THIS CHAPTER,
Visit: http://www.eolss.net/Eolss-sampleAllChapter.aspx

Bibliography

Bekus R.D. (1998). *Physiological testing of a high-class athlete*. Kiev: Olimpiyskaya literatura. (In Russian). [The methodology of testing of parameters of functioning of a motor system of a human being is represented].

Cherkesov Yu.T. (1993). *Adjusting machines*. Maikop: Adygei State University Publishing. (In Russian). [A principally new class of exercise machines is considered].

Donskoy D.D. (1979). *Biomechanics*. Moscow: Fizkultura i sport. (In Russian). [Biomechanical laws of competitive and training movements are represented].

Fleck S.J. (2004). *Designing resistance training programs*. Human Kinetics. [Practical recommendations on development of programs of power training are given in this book].

Khutiev T.V. (1991). *Control of body physical state: training therapy*. Moscow: Meditsina. (In Russian). [Biological control systems and principles of their work, as well mathematical models used at medical treatment of cardiologic patients are considered].

Kots Ya.M. (1984). *Sport physiology*. Moscow: Fizkultura i sport. (In Russian). [Special features of different modes of muscle contraction are represented in details].

MacIntosh Brian, Gardiner Phillip, McComas Alan (2005). *Skeletal Muscle: Form and Function*. 2nd edition. Champaign: Human Kinetics, 423 p. [Molecular mechanisms of muscular contraction, a structure and functions of skeletal muscles are described in details].

Yushkevich T.P. (1989). *Training machines in sport*. Moscow: Fizkultura i sport. (In Russian). [Information about application of engineering devices in training of sportsmen is systematized].

Zatsiorsky V.M. (1995). *Science and Practice of Strength Training*. Human Kinetics. [Theoretical fundamentals of power training are represented].

Biographical Sketches

Alexey Ivanovich Netreba, Ph.D., works at SSC RF – IMBP RAS (The State Scientific Center of the Russian Federation - Institute of Medicobiological Problems of the Russian Academy of Sciences); currently, he is a senior scientist at the Laboratory of Physiology of Muscular Activity. In 2007, he defended his Ph.D. thesis devoted to studying of different modes of a muscular contraction. The range of his scientific interests: speed-force potential of muscles and its change under the influence of different forces (power trainings, unloading); use in training special training devices, modeling different modes of a muscular contraction. He published more than 30 scientific papers and holds 6 patents for inventions and useful models.

Olga Leonidovna Vinogradova, Doctor of Biological Sciences, Professor, is head of the Laboratory of Physiology of Muscular Activity of the SSC RF – IMBP RAS; she is a professor of the Department of Ecological and Extreme Medicine of Faculty of Fundamental Medicine of the Moscow State University named after M. V. Lomonosov. During 2000-2002, she was Chairman of the Commission on Physiology of Muscular Activity and Sport of the Section “Organism and Environment” of the Russian Academy of Sciences; during 2003-2004, she was coordinator of the Program of the Ministry of Education and Science “Methods of increase of work capacity in extreme conditions”. Prof. Vinogradova is an Associate Editor of the journals "Human Physiology" and “Aerospace and ecological medicine”, an organizer of the All-Russia schools-conferences on physiology of muscles and muscular activity in 2000-2011. The range of her scientific interests: physiology of muscular activity and regulation of vegetative functions. She is an author of more than 120 scientific papers.

Oleg Igorevich Orlov, Doctor of Medical Sciences, is Corresponding Member of the Russian Academy of Sciences and the First Deputy Director of the IMBP RAS on scientific work. He coordinates innovation activity of the mentioned Institute including a program of creation of a network of centers of physical health.
He is a professor at the Department of Multiprofile Clinical Education of the Faculty of Fundamental Medicine of the Moscow State University named after M. V. Lomonosov and at the Department of

Medical Informatics of the Moscow Medical and Stomatological University. He is a member of some international, interdepartmental and academic councils, and a member of the Board of the International Society on Telemedicine and Electronic Public Health. Prof. Orlov is a full member of the International Academy of Astronautics, a member of editorial boards of journals "Clinical informatics and telemedicine", "Telemedicine and e-Health", an e-magazine "Physiology of muscular activity".

The range of his scientific interests: space physiology and gravitational biology, telemedicine. He is an author of more than 70 scientific works on analysis of physiological mechanisms of human adaptation to conditions of weightlessness and problems of its modeling, and also to extreme factors (hyperbaric loads, rotation, accelerative forces), on evaluation of efficiency of different preventive measures at different stages of a space flight.