

STRENGTH AND POWER IN SPORT

VOLUME III OF THE ENCYCLOPAEDIA OF SPORTS MEDICINE

AN IOC MEDICAL COMMISSION PUBLICATION



IN COLLABORATION WITH

THE INTERNATIONAL FEDERATION OF SPORTS MEDICINE



EDITED BY

PAAVO V. KOMI

SECOND EDITION

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Science

STRENGTH AND POWER IN SPORT

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Forewords

In 1991, the IOC Medical Commission published Vol. III of the Encyclopaedia of Sports Medicine series, on the topic *Strength and Power in Sport*. Professor Paavo V. Komi, as editor, recruited a team of 29 internationally renowned scientific colleagues to produce a reference volume that constituted an important contribution to scientific literature in an area which arrived relatively late in the study of exercise and sports science.

Since the publication of the first edition of *Strength and Power in Sport*, a large volume of research literature has appeared both to reinforce the information contained and to expand the body of literature relative to the training and performance of strength and highest power. The popularity of the first edition and the availability of such a large amount of new information led the IOC Medical Commission to decide that a second edition of this important volume was both justified and essential.

I would like to thank the IOC Medical Commission for yet another valuable contribution to literature in sports medicine and the sport sciences.

Dr Jacques Rogge
IOC President

Extensive research started appearing in the literature of the 1950s concerning aerobic metabolism and the importance of cardiopulmonary function to relative long periods of physical activity. Additional research subsequently appeared on the subject of sprint events and team sports. The physical expression of explosive movements and the training of strength relative to sport were, however, neglected. 'Strength training' in earlier times prompted unjustified fears of the athlete becoming 'muscle bound' with a resultant loss of flexibility. These mistaken beliefs discouraged athletes from training with free weights and high-resistance exercise machines now associated with the training of strength and highest power.

This second edition adds valuable information concerning the basic science and provides additional information that can result in better performance, the prevention of injuries, and greater enjoyment of sports participation by the elite athlete, the recreational athlete, the young athlete and the veteran athlete.

Strength and Power in Sport will certainly continue to be the most frequently cited source of information on this topic area and, in its new and expanded second edition, will make an even greater contribution to the health, well-being and success of athletes of all ages.

I would like to thank Professor Komi for having again gathered a team of authoritative scientists from around the world as co-authors to produce this all-new second edition.

Prince Alexandre de Merode
Chairman, IOC Medical Commission

Preface

It was a rewarding pleasure to follow the success of the first volume of *Strength and Power in Sport*. Since its publication in 1991, the volume has been reprinted several times. In addition, it has been translated into German (1994). Despite the continuous interest in this first volume, it became obvious that the material had to be updated before any additional printing or translating could be planned. During the last 10 years, a considerable amount of knowledge has become available through an increasing number of studies performed both on basic mechanisms and applied aspects of strength and power training. Thus, it was necessary to produce a new volume with the latest possible information.

The editorial work of the first volume was a challenge, but the second volume of *Strength and Power in Sport* was perhaps an even more motivating experience. We were fortunate to receive acceptance of most of the previous authors to revise their chapters, but new contributions from other authors were also included in this second volume. The recruited team now consists of 39 contributing authors representing the most prominent scientists and clinicians, all of whose interest have involved the various problems related to strength and power training. But more importantly, they have all established themselves as world leaders in their particular research or applied area.

Several books have been published related to strength and power which have advanced our understanding of the subject area. In the present volume, we have made an effort to take a slightly

different approach to the problem. While it is very easy to demonstrate improvement of muscle strength with almost any method (if sufficiently intensive), the present volume, *Strength and Power in Sport*, examines the basic mechanisms and reasons for beneficial strength exercises. In order to give state-of-the-art information – as is the purpose of the Encyclopaedia of Sports Medicine – a great portion of the book is devoted to the basics of strength and power and their adaptation. The material is divided into five sections.

- 1 Definition of fundamental terms and concepts.
- 2 A comprehensive coverage of the biological basis for strength and power including the structural, hormonal, neural and mechanical aspects. This material is presented in 10 different chapters.
- 3 A detailed examination of the reasons (mechanisms) leading to the adaptations of the organism when subjected to various strength and power exercises. This section covers nine different topics ranging from cellular and neural adaptation to endocrine and cardiovascular responses.
- 4 Special problems of strength and power training including age-related changes, the potential use of electrical stimulation, and clinical aspects.
- 5 The volume finishes with a more applied and solely sports-orientated section where three chapters cover the current knowledge of the practical strength and power training principles, as based on available scientific knowledge.

The way the material has been presented varies slightly among the chapters. In some cases, considerable depth and detail were necessary

while, on the other hand, a few chapters have been written in a more readable and overview-type format. Whatever the writing style has been, the material should be accessible to readers with a background in the biological aspects of sport sciences. Because of the wide coverage of the basic mechanistic features of strength and power training, it is expected that this volume will become required reading for many graduate programmes in the medicine and science of sport. The study of strength and power is one of the major components of sports science and an understanding of the relationships among neural, hormonal, muscular and mechanical factors

is central to athletic performance as well as to strength and power needs of other human populations. Thus, it is believed that this second volume of *Strength and Power in Sport* fulfills well the major objectives established by the IOC Medical Commission for this material: Importance of understanding the basic problems in various aspects of Strength and Power in order to analyze different sport events and to plan objectively training and conditioning not only of athletes but other groups as well.

Paavo V. Komi
Jyväskylä, Finland

Units of Measurement and Terminology*

Units for quantifying human exercise

Mass	kilogram (kg)
Distance	metre (m)
Time	second (s)
Force	newton (N)
Work	joule (J)
Power	watt (W)
Velocity	metres per second ($\text{m} \cdot \text{s}^{-1}$)
Torque	newton-metre (N·m)
Acceleration	metres per second ² ($\text{m} \cdot \text{s}^{-2}$)
Angle	radian (rad)
Angular velocity	radians per second ($\text{rad} \cdot \text{s}^{-1}$)
Amount of substance	mole (mol)
Volume	litre (l)

Terminology

Muscle action: The state of activity of muscle.

Concentric action: One in which the ends of the muscle are drawn closer together.

Isometric action: One in which the ends of the muscle are prevented from drawing closer together, with no change in length.

Eccentric action: One in which a force external to the muscle overcomes the muscle force and the ends of the muscle are drawn further apart.

* Compiled by the Sub-commission on Publications in the Sports Sciences, IOC Medical Commission.

Force: That which changes or tends to change the state of rest or motion in matter. A muscle generates force in a muscle action. (SI unit: newton.)

Work: Force expressed through a displacement but with no limitation on time. (SI unit: joule; note: 1 newton $\times$ 1 metre = 1 joule.)

Power: The rate of performing work; the product of force and velocity. The rate of transformation of metabolic potential energy to work or heat. (SI unit: watt.)

Energy: The capability of producing force, performing work, or generating heat. (SI unit: joule.)

Exercise: Any and all activity involving generation of force by the activated muscle(s). Exercise can be quantified mechanically as force, torque, work, power, or velocity of progression.

Exercise intensity: A specific level of muscular activity that can be quantified in terms of power (energy expenditure or work performed per unit of time), the opposing force (e.g. by free weight or weight stack) isometric force sustained, or velocity of progression.

Endurance: The time limit of a person's ability to maintain either an isometric force or a power level involving combinations of concentric and/or eccentric muscle actions. (SI unit: second.)

Mass: The quantity of matter of an object which is reflected in its inertia. (SI unit: kilogram.)

Weight: The force exerted by gravity on an object.