Proceeding

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Muscle strength and the complexity of human movement

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ABSTRACT

The mechanisms that influence the ability to produce muscle force are to be found not only in structural or biomechanical elements, but also in factors inherent to inter and intramuscular control and coordination. In the execution of the motor gesture, the body, functioning as a system, produces a quantity of force which, to be effective for the intended purposes, must be managed and integrated by the nervous system. The various expressions of force must be considered in relation to the function. Too often, motor and sports training specialists focus on the development of strength in a rigid and standardized way, following pre-established patterns for every need. The objective of the study is to increase the knowledge of the characteristics that distinguish the different types of force expression through an approach that emphasizes their functionality. Through the PRISMA method, search engines (PubMed, Google Scholar, Scopus, PMCfreearticle, CrossRef). In conclusion, the study provides an alternative interpretation of the force that is expressed in different ways in relation to the purpose, leaving out, for this reason, reductionist classifications, not very applicable to biological systems.

Keywords: Reductionist approach; Complex approach; Performance.

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INTRODUCTION

Strength represents the only ability present in every motor gesture which, based on regulation and control mechanisms, has a different mode of expression. Through the ways of developing and controlling muscle strength, the human body can maintain postures or perform gestures by interacting actively with the surrounding environment. The mechanisms that influence the ability to produce muscle force are many and depend on various factors, both structural or biomechanical, and coordinative. The neuromuscular system produces force through processes in which various integrated structures are activated with precise timing and sequences. Motor gestures and sporting performance are influenced by a series of factors which are variously linked to each other; these factors can be divided into quantitative, qualitative and temporal aspects (D'Isanto et al., 2019).

In the execution of the motor gesture, the body, working as a system, produces a quantity of force which, in order to be effective for the intended purposes, must be managed and integrated by the nervous system. We are therefore talking about extremely complex phenomena, whose treatment can no longer be limited to simplistic classifications adopted for years following reductionist approaches. Muscle strength can in turn be classified in various ways, depending on the time of application and intensity. We will therefore have high strength levels for short periods of time and moderate strength levels for longer periods. At a sporting level, this classification is important as it allows you to plan and program athletic sports training in an optimal manner. Each sport is characterized, among other things, by the way in which strength is expressed. There will therefore be endurance sports, power sports, mixed sports and educational sports such as in the school (Cataldi et al., 2021). In the case of team players such as basketball, football or volleyball, it is observed that they present multiple and different dynamics during the game due to the variability of offensive and defensive performances (Altavilla et Raiola, 2019; Bourbousson et al, 2010).

The various expressions of force must also be considered in relation to the purpose: e.g., walking or moving an object or a technical-sporting gesture. Too often, motor and sports training specialists focus on the development of strength in a rigid and standardized way, following pre-established schemes for every need and often finding it difficult to achieve goals in terms of improving the psycho-physical condition or achieving of the condition of performance. The different types of force expression take into account numerous variables that can be linked to the characteristics of the subject to be trained, to sport-specific characteristics and environmental characteristics.

Too often the concept of muscle strength is interpreted in a generic way and in the same way for all motor and sports activities, without a contextualization that is instead appropriate. Muscle strength, on the other hand, needs to be treated appropriately with respect to pre-established goals. Attention should be paid to the complete gesture, and not to a part of it. For example, if you want to improve the explosive strength of jumping in volleyball, it is not enough to limit yourself exclusively to explosive training of the legs, but you have to work on the entire kinetic chain.

The objective of the study is to increase knowledge about the characteristics that distinguish the different types of force expression through an approach that emphasizes functionality, i.e., the consideration of the entire motor gesture in view of a purpose that can be of various kinds. (athletic-sporty, everyday life). A functional gesture is not just a multi-joint motor task that develops on a kinetic chain, through the precise interconnection of all the parts that make it up, but it presupposes a purpose, namely the achievement of a goal of various kinds. The most recent scientific evidence is taken into consideration, in order to provide sports operators with an additional reference tool for application practice in the motor and sports context.

METHOD

The research was conducted through a careful consultation of the scientific literature: book chapters on sports performance and sports training methodology and scientific articles published between 1923 and 2021. The consultation of the scientific literature took place through the use of specialized web research on scientific literature: PubMed, Google Scholar, Scopus, PMCfreearticle, CrossRef. The most recent articles and the most influential authors were considered. The following terms have been entered into the search engines: Muscle Strength, Training, Motor Units, Power, Muscle Endurance. These terms have been combined with each other and with other terms, namely: Strength training, strength and motor units, power training, endurance training, neural factors and strength training.

RESULTS AND DISCUSSION

13 book chapters and 16 scientific articles out of a total of over 100 publications evaluated were considered. Publication selection criteria were used: the chapters were extracted from books on training methodology and training physiology of international interest; the articles are in English, published in scientific journals.

Table 1 lists all the sources included in the review, highlighting, for each author, the subject of the publication and the source.

Table 1. List of sources.

	Authors	Topics	Publication	Title	Source
1	Antonio et Gonyea	Muscle hyperplasia	1993	Skeletal muscle fibre hyperplasia. Med. Sci. Sports Exercise	Scientific article
2	Bizzi E, Cheung VC	Muscle synergies	2013	The neural origin of muscle synergies	Scientific article
3	Bompa et Buzzichelli	Sport training	2018	Periodization: Theory and Methodology of Training.	Book chapter
4	Bosch F.	Strength training	2015	Strength training and coordination: an integrative approach	Book chapter
5	Carroll et al.	Neural adaptation to strength training	2001	Neural adaptations to resistance training: implications for movement control	Scientific article
6	Caruana	Holistic approach	2000	Holism and the Understanding of Science	Book chapter
7	De Angelis	System Theory	1996	La logica della complessità: introduzione alla teoria dei sistemi	Book chapter
8	Du Côteau et Pefferkorn	Motor abilities	1924	L'entraînement sportif	Book chapter
9	Fleishman	Factorial Analysis	1956	Psychomotor selection tests: Research and application in the United States Air Force	Scientific article
10	Fleishman	Factorial Analysis	1957	A comparative study of aptitude patterns in unskilled and skilled psychomotor performances	Scientific article

11	Fleishman	Factorial Analysis	1975	Toward a taxonomy of Human performance	Scientific article
12	Folland et Williams	Characteristics of muscle strength	2007	The adaptations to strength training: morphological and neurological contributions to increased strength	Scientific article
13	Gundlach	Motor abilities classification	1968	Systembeziehungen körperlicher Fähigkeiten und Fertigkeiten	Scientific article
14	Henry	Motor abilities classification	1958	Specificity vs. generality in learning motor skill	Scientific article
15	Henry	Motor abilities	1959	Reliability, measurement error, and Intra-Individual Difference, Research Quarterly	Scientific article
16	Henry	Motor skills	1961	Reaction Time — Movement Time Correlations	Scientific article
17	Hebert	Motor abilities classification	1912	L'éducation physique ou l'entrainement complet par la méthode naturelle	Book chapter
18	Hebert	Motor abilities classification	1913	La Culture Virile et les Devoirs Physiques de L'Officier Combattant	Book chapter
19	Helbert	Motor abilities classification	1919	C'est la vie, un grand respect au Renzamen	Book chapter
20	Heylighen et al.	Complexity	2007	Complexity and philosophy. In Complexity, Science and Society	Book chapter
21	Kelso	Systems theory	1995	Dynamic patterns: The self-organization of brain and behavior	Book chapter
22	Mazzocchi	Reductionism and Holism	2008	Complexity in biology. Exceeding the limits of reductionism and determinism using complexity theory	Scientific article
23	Santos et al.	Intermuscular coordination	2021	Intermuscular Coordination in the Power Clean Exercise: Comparison between Olympic Weightlifters and Untrained Individuals-A Preliminary Study	Scientific article
24	Schmidt et Lee	Motor Learning	2019	Motor Learning and Performance: From Principles to Application	Book chapter
25	Suchomel et al.	Muscular strength training	2018	The Importance of Muscular Strength: Training Considerations	Scientific article
26	Taylor et Wilkinson	Muscle hyperplasia	1986	Exercise-induced skeletal muscle growth. Hypertrophy or hyperplasia?	Scientific article

27	Von Bertalannfy	System theory	1968	General System Theory – Foundations, Development, Applications	Book chapter
28	Wallace et al.	Muscular strength and Neural contribution	2019	Muscular and Neural Contributions to Post activation Potentiation	Scientific article
29	Weineck	Motor and sport training	2009	L'allenamento ottimale	Book chapter

Reductionism

The subject of muscular strength has been discussed a lot over the years according to different approaches and with sometimes conflicting definitions. In order to simplify what, in reality, turns out to be an extremely complex concept, we have tried to catalogue and break up phenomena related to biological systems into simpler parts. This approach, defined Reductionism, represents an epistemological conception that tends to explain complex phenomena by breaking them down into simpler parts (Mazzocchi, 2008). It is an extremely effective way to explain the behaviour of complex systems, which are often the subject of study in fields such as physics, chemistry and engineering, but which, as many scholars agree, is not applicable to the study of complex systems.

Already in ancient times, the study of human movement has attracted scholars from all over the world and from every culture. The physician and philosopher Galen (Pergamum, 129 or 130 - Pergamum or Rome, 199 or 201), taking up and developing the research carried out in the third century. BC by the Alexandrians Erofilo (Chalcedon, 335 BC - Alexandria of Egypt, 280 BC) and Erasistratus (Ceo in Greece, 304 BC - Anatolia, 250 BC) had provided a good description of the anatomy of the nervous system and attributed to each anatomical structure a function, related to perception or movement.

At the beginning of the 1900s, the concept of measuring physical values was introduced with Georges Hebert (1912, 1913, 1919), a French teacher, who claimed the existence of the following physical qualities:

- Resistance and bottom;
- Speed;
- Dexterity;
- Knowledge of physical techniques;
- Virility.

In 1924, Bellin Du Cutteau, in his book L'entraînement sportif, introduced the acronym VARF, which summarized the concept of four capacities:

- Speed;
- Dexterity (defined Adresse);
- Resistance;
- Power

Between the end of the 1950s and the 1970s Henry (Henry, F., 1958; 1959; 1961) put forward the hypothesis of the existence of specific motor skills for each motor task, refuting the idea advanced for some decades, especially in the United States of the existence of a single general capacity. There are three aspects connected to this hypothesis: first, for Henry the number of motor skills was very high; second, he believed that these abilities were independent; third, every task or skill performed depended on a large number of these skills. For Henry, two tasks, although apparently similar, tend to have a very low correlation between them. The two tasks belong to a collection of distinct skills with little or no common element. Furthermore, according to this approach, the transfer between skills is very low.

Another important line of research uses the factor analysis method, so called for the statistical tool used. Various researchers have used this tool, but certainly the most active was Fleishman (1956; 1957; 1975). Factor analysis is a statistical method that subjects a large number of individuals to numerous tests. Tests are grouped into clusters or factors. Tests that make up a specific cluster or factor have relatively high correlations with each other, and therefore tend to represent a different group of capabilities, while tests that are members of different factors tend to show low correlations with each other. In this way, factor analysis groups a large group of tests into a smaller number of factors, each of which represents one or more different capabilities. Fleishman's work made it possible to list a list of capabilities (table 2) which indicate, in fact, the factors, or clusters, generated by the study according to the method of factor analysis.

Table 2. Motor abilities according to Fleishman.

Perceptual-Motor Abilities	Physical Proficiency Abilities
Control precision	Extend (or static) flexibility
Multi-limb coordination	Dynamic flexibility
Response orientation	Static strength
Reaction time	Dynamic strength
Speed of arm movement	Explosive strength
Rate control	Trunk strength
Manual dexterity	Gross body coordination
Arm-hand steadiness	Gross body equilibrium
Wrist-finger speed	Stamina (cardiovascular fitness)
Aiming	
Postural discrimination	
Response integration	

The meaning of Motor Skills of Gundlach, of 1968, still widely recognized by most scholars, introduced the division of the same into conditional skills and coordination skills and joint mobility.

Complex approach

The use of these classifications has helped to simplify the understanding of the characteristics of biological phenomena, but often omitting all those variables, subjective or environmental, which contribute to the realization of the phenomenon itself. This approach, defined as reductionist, has significant weaknesses when applied to complex systems. Perfect knowledge of the individual parts that make up the system does not guarantee understanding of the whole (Bosch, 2015). Complex systems have different levels of organization ranging from the subatomic realm to single organisms to entire populations and beyond. The characteristics of randomness and order are both relevant to the behaviour of the whole system. In fact, they are neither characterized by complete determinism nor by total randomness (Heylighen et al, 2007). Complex systems can sometimes exhibit regular and predictable behaviour but can undergo sudden changes in response to unpredictable environmental variables.

In the field of physical and sports sciences, the holistic approach, therefore, is more suitable for the study of the characteristic phenomena of this field of knowledge. Holism is the philosophical and methodological principle of some sciences, according to which complex systems are irreducible to the mere sum of their parts. Holism seeks to correct the mechanistic and reductionist drift of science and technology, and to consider physical, biological, psychic and social processes in their multiple interrelations (Caruana, 2000).

General systems theory (De Angelis, 1996; Kelso, 1995; Bertalannfy, 1968) attempts to overcome the limitations of the reductionist model. The modern vision of motor skills is that of an integrated model that considers the gesture in its entirety and not as the sum of individual parts. The different expressions of muscle strength are possible thanks to the integration and coordination of several variables according to patterns learned through training (Schmidt & Lee, 2019). Strength is characterized by a combination of morphological and neural factors including muscle cross-sectional area and architecture, muscle-tendon stiffness, motor unit recruitment, rate coding, motor unit synchronization, and l 'neuromuscular inhibition (Suchomel et al., 2018).

Types of force

Strength, as the only ability always present in the motor gesture, can be expressed in different ways, depending on the intensity and duration of the effort. They are: maximum strength, power and resistant strength. Maximum force is the highest level of force that the neuromuscular system is able to express in a maximum voluntary contraction (Weineck, 2009). Speed represents the neuromuscular system's ability to produce force in the shortest time possible. It forms the basis for the development of potency. Lastly, endurance is the ability to be able to express a certain effort for as long as possible, be it alactacid, lactacid or aerobic, while maintaining the intensity required by the type of performance at an adequate level (Cazzetta, 2015).

The three expressions of force depend, in different ways, on the same factors. These factors are: morphological, neural, energetic. Morphological adaptations occur at various levels. They include an increase in the cross-sectional area of the muscle, with an increase in the size of myofibrils, a change in the type of muscle fibre, muscle architecture, myofilament density (Folland & Williams, 2007). There is controversy over whether muscle fibre hyperplasia also plays a role (Taylor & Wilkinson, 1986; Antonio et Gonyea, 1983). Although some animal models have provided evidence for a role of hyperplasia in muscle hypertrophy, support for this phenomenon in humans is limited. Neural factors (Wallace et al. 2019; Carrol et al., 2001) are represented by the intermuscular and intramuscular coordination mechanisms. Intermuscular coordination, i.e., the coordination between muscles working together in a given movement, corresponds to muscle synergies (Santos et al., 2021), i.e., coordinating neural structures that function to relieve the computational load associated with the control of movement and posture (Bizzi & Cheung, 2013).

Intramuscular coordination is the ability of the muscle fibres that make up a single muscle to contract efficiently. A good level of intramuscular coordination helps to improve strength without there being a noticeable increase in the cross section of the muscle and therefore in body weight, and this is a positive fact especially for those athletes who need to maintain body weight in the limits established by the requirements of the discipline.

Finally, the type of energy substrate used, and its availability play an important role in the type of muscle strength expressed. The faster energy systems, which use ATP and CP phosphates through anaerobic degradation, allow high intensity efforts but for short periods, while the slower ones, which use lipid carbohydrates as energy substrates, allow less intense efforts, but for longer periods. long. The efficiency of energy systems depends, among other things, on the ability of the neuromuscular system to withstand the development of tension and the accumulation of fatigue resulting from training or performance. This ability can be improved through the optimization of the recruitment of motor units, the correct use of energy reserves in an efficient manner and the improvement of the reuse of catabolites as energy substrates (Bompa et Buzzichelli, 2017).

CONCLUSIONS

The purpose of the revision was mainly to list the characteristics of the various expressions of muscle strength according to two different approaches: the reductionist and atomist approach which tends to explain complex phenomena by breaking them down into simpler parts, and the holistic approach which considers phenomena in their entirety. The review highlighted critical issues regarding the reductionist approach, useful for controllable phenomena characterized by little variable environments. The human being and all the phenomena related to it are characterized by complexity and, therefore, the approach that best explains these phenomena is the holistic one. Therefore, the most recent scientific evidence agrees in considering the mechanisms of development of muscle strength and its expressions, phenomena that occur in response to constantly evolving environmental stimuli. Training is the process by which objectives of improving physical fitness or performance are pursued. These objectives respond to the concept of functionality, that is, the ability to perform effective gestures to achieve a specific purpose within a given environment. Therefore, coaches who want to improve the quality of movements must consider the gestures in their entirety in response to various situations and limit analytical approaches only in cases of necessity. Strength in its expressions will raise its levels of manifestation only if there is an optimal transference: training must concern both organic-muscular and neural aspects as well as a technical-tactical context. The results of this study may have practical applications for strength and conditioning coaches and for physical activity operators in school and gym settings. Further research can further enhance knowledge about the methodologies to be used in strength training programs.

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