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## VIEWPOINT

# FORCE – THE ONLY CONDITIONAL QUALITY? POINTS OF VIEW ON CERTAIN ASPECTS OF THEORY OF SPORTS TRAINING

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Motto: *“The past shapes the present,  
but there will be a time when this present,  
will become past”*

### ABSTRACT

The current article is an innovative approach which promotes the hypothesis that there is only one conditional motric ability, and that is force. Even though the specialized literature is concordant with respect to the three conditional motric attributes, speed, force and resistance, we try to demonstrate that the force is the single conditional motric attribute manifested by man, as it represents the direct byproduct of the muscle contraction, as a result of the energy resulted from the metabolic reactions. From our point of view, speed and resistance are consequences of the manifestation of force, or different forms of force manifestation, corresponding to various requirements of the activities that the human individual performs or to the adaptation level manifested by him.

**Keywords:** *sports, muscle contraction, force, speed, resistance*

Far from us the thought of contradicting the specialists, nonetheless we will put in a new light arguments of theory and practice of physical training in order to bring clarification to a science in which some of the concepts are sometimes mistaken or approximately valued. These clarifications refer to human conditional motric attributes: speed, force, resistance.

The history of physical training reveals that the first specialists who studied the human movement observed the movement attributes empirically and it was thus that they defined the motric attributes. Ever since, all those who studied the practical and theoretical aspects of physical training and competition were circumscribed within the framework of this idea.

To the best of our knowledge, all the specialists of the sports science differentiate the motric attributes as follows: speed, force, resistance and skill.

R. MANNO<sup>1</sup> (and not only) is the first specialist to differentiate motric abilities as conditional and coordinative.

We shall not attempt to review all the definitions of the motric abilities enunciated over time by different authors. We intend to emphasize some aspects that seemed relevant in order to support the theory that *there is only one conditional motric ability (capacity) - force, which represents the frame of action of the human movement according to the adaptation needs to different demand types*. The analysis of force ability and combined force action is very complex and any attempt at making a schematization would only be an imperfect didactic emphasis of certain biomechanical, biochemical, physiological mechanisms involved that produce synergies, correlations and interdependencies. These are potentiated by the factor that has a preponderant psychological adaptive role through the functions of orientation, regulation and support and may only be approximated.

In relation to this fact, it is stated that *“Force, as a physical concept, usually represents the physical cause of movement”*<sup>2</sup>. Relative to force, *“it is notable that no physicist or other scientist has yet measured the force, but only its effects (especially deformation and movement).”*<sup>3</sup> Moreover, Oxford Dictionary (quoted by GAGEA, A., 2005)<sup>4</sup>

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<sup>1</sup> MANNO, R., *Les bases de l'entraînement sportif*, Ed Revue EPS, 1989

<sup>2</sup> WITTEKOPF, G., MARHOLD, G., PIEPER K., S., *Biologische und Biomechanische Grundlagen der trainingsmethodischen Kategorie »Kraftfähigkeiten« und Methoden ihrer Objektivierung*, Med. u. Sport 21 (1981), 225–231, In: Sportul de Performanță, Nr.281, CCEFS, București, 1988, p.5

<sup>3</sup> GAGEA, A., *Biomecanica analitică*, București, 2006, pag. 33

<sup>4</sup> Ibidem, pag. 33

states that: *“Force is the cause of effects”*. From this perspective, *“force - as expression of movement cause”* is one of the irreducible basic quantities of the biomechanics, alongside *distance* and *time*<sup>5</sup>.

In our opinion, force is the factor that generates movement. Movement per se has some characteristics: trajectory, acceleration, speed, time etc.

The concepts used in the specialized literature with reference to the force are as follows: *“the active force is the force that is generated by the muscle contraction in order to perform a movement; the resistive force is represented by the weight that antagonizes movement; and... movement is produced by the net force, i.e. the vectorial difference between active and resistive forces.”*<sup>6</sup>

The muscle force can be defined as the tension in a muscle or group of muscles which antagonizes a resistance. *“One of the most important functions of the muscles is to generate force on bone extremities in order to produce movement or to maintain positions”*.<sup>7</sup>

According to the definition of force from Oxford Dictionary quoted by GAGEA, *“muscle contraction produces muscle force”*<sup>8</sup>, and from our point of view, speed and resistance represent either an attribute of the movement, like speed, or a particularity of force manifestation, like resistance. Muscles don't produce speed, nor resistance, nor grace... Muscles produce contractions, and contractions produce muscle force.

### **Analysis and debate**

In biology systems, the physical occurrence of force is related to the muscle activity, specifically the properties of the muscle fiber: excitability, contractility, elasticity, and plasticity.

Muscle contractions can be fast or slow. They may involve a large number of fibers or a very small one. Muscle contractions produce a force of a certain magnitude under the action of efferent nerve impulses. Physical factors of orientation, regulation and support play a crucial role in the performance of movements, just as physiologic (hormonal) and biochemical factors are essential for initial and subsequent adaptation to the charge. Level, speed and performance (exercise) time of the human force in an activity are dependant on physical and hormonal regulations, which determine the intensity and depletion volume of ATP (adenosine triphosphate) molecules and also the resulted energy. Consequently, the magnitude of the force produced by muscle contraction is dependant on the decomposed ATP amount.

*“ATP represents the sole chemical energy source immediately movable for the muscle contraction, in accordance with the following hydrolysis reaction:*



*This reaction releases almost 50kJ/ ATP molecule and is catalysed by ATPases at the end of myosin filaments in the muscle cell”*<sup>9</sup>.

Biologically, force is a manifestation of effort capacity and is produced by neuropsychic and muscular effort.

Physiologically, force is a neuro-muscular manifestation because the morphofunctional support of the force is nervous and muscular. It is neither exclusively neuropsychic nor exclusively muscular. Or, better said, it is psychic by control and support attributes, nervous by impulse transmission and muscular by performance.

Morphofunctionally, there are three types of muscle fibers: slow twitch, fast twitch and intermediate twitch. Regardless of the enzymatic equipment, of the required “fuel” or the energy mechanism that produces the energy necessary for contraction, the attribute of all these fiber types is muscle force. Consequently we cannot imagine that the recovery of ATP molecules decomposed in ADP, AMP and the energy necessary for contraction, using one energy mechanism or the other, may develop preponderantly one motric quality or the other.

For the manifestation capacity of the muscle force, the level of intensity and the duration of the performed effort depend both on the ATP amount and on the balance between the disintegrated ATP amount and the recovered ATP amount. The moment when the recovered ATP does not satisfy the energetic needs of the organism at a certain level of duty, the body either glides reflexively to a lower demand level, or the respective activity ceases.

There is a quasi-unanimity of the specialists regarding the statements referring to the manifestation modality of the motric abilities, i.e. they manifest natively only in isolated cases. We believe that they cannot even manifest in a pure state, because this statement in fact refers to *movement per se, with all its characteristics, which uses muscle contraction as source*. This is about the manifestation of a single attribute - force in different shapes, according to adaptation needs to a submitted request.

When statements are made about the manifestation mode of the motric abilities, they often include: *force-speed, resistance to force, force-resistance* etc. Regarding these formulations, we wondered many times: how much

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<sup>5</sup> Ibidem, pag. 41

<sup>6</sup> GAGEA, A., *Biomecanica analitică*, București, 2006, p. 41

<sup>7</sup> DUPONT, G., BOSQUET, L., *Metodologie de l'entraînement*, Ellipses, 2007, p.17

<sup>8</sup> GAGEA, A., *Biomecanica analitică*, București, 2006

<sup>9</sup> KOOLMAN, J., RÖHM, K., H., *Atlas de poche de biochimie*, 2<sup>eme</sup> edition, Flammarion, 1999, 462 p.

does one attribute represent and how much does another one, in such enunciations. Let alone enunciations such as: *force-speed in resistance mode* or others alike.

Moreover, we believe that we can state that *force is the sole biometric attribute generated by muscle contraction, while the rest of the muscle manifestations may be related to the force itself which forms the time and space action frame.*

Speed is an attribute of movement and is reported to the muscle contraction speed, which may depend on the number of nervous impulses, the number of contracting muscle fibers, the ATP amount that breaks down in a time unit, resistive force, the internal and external environment temperature etc. To GAGEA (2006), "*force by its variation is the factor that generates speed and its variation*"<sup>10</sup>.

It is our opinion that *resistance as a motric quality is nothing else but individual action modes of muscle force.* It is the fact that resistance may be of short, medium or long duration, that determines us to make this statement. During movement performance the force magnitude is inversely proportional with its application time. The greater the applied muscle force, in comparison with the potential of the reference individual, the shorter the action time, in which case the specialists discuss about "*short time resistance or anaerobic resistance*". If we change the reference, the lower the applied muscle force, the greater it becomes the possibility of applying it during a longer period. In this case specialists discuss about "*long time resistance, endurance or anaerobic resistance*". Generally, the motric resistance is nothing else but the reliability of the human body to maintain/ apply a relatively constant force during a longer period.

These statements lead us to the elaboration of a principle according to which, regardless of the human activities, the magnitude of the applied force is proportional with the activity time length.

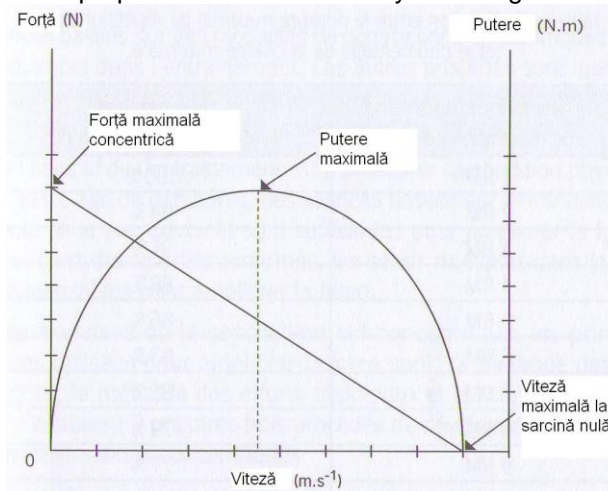


Figure 1: The relation between force and speed<sup>11</sup>

To this purpose we may affirm that both speed and resistance are proportional with force and depend on it. From this perspective, if we analyze the relation between force and speed, as mentioned in the theory of physical training, we may notice that there is an inversely proportional relationship in the manifestation of one or the other of the mentioned abilities.

We also notice that this relation may be correct in the left area of the chart: the greater the resistive force, the smaller the net force and as a consequence the speed of movement is also smaller. This claim seems erroneous to us, when we study the axis of speed. It seems that the smaller the resistive force, the greater the speed of movement.

There are two questions we may ask ourselves:

1. What happens to speed when the resistive force decreases continuously to zero? Does this speed increase progressively? To what extent?
2. And if the magnitude of the active force tends asymptotically to zero, what will the speed magnitude be?

In order to be more categorical, in this relation we could also input values. Specifically, if the force  $F$  is null ( $F = 0$ ), what magnitude would the speed and the resistance have? The question is rhetorical, and the answer is more than obvious.

<sup>10</sup> GAGEA, A., *Biomecanica analitică*, p. 57

<sup>11</sup> DUPONT, G., BOSQUET L., *Metodologie de l'entrainement*, Ellipses, 2007, p.19

A possible formula of the force developed by the individual should contain many more parameters that refer to the total quantity of energetic substances, to psychological factors with imponderable value, yet determinant, to the efficiency of metabolic processes etc., all being related to the time factor. However, this formula would contain even a larger number of variables which interact and whose significance is difficult to establish due to several reasons.

Regardless of the human activities, the force may manifest under the following aspects:

- “of maximum acceleration;
- of maximum speed;
- of maximum distance or duration.<sup>12</sup>”

Moreover, GAGEA details that the measure of force may refer to “speed variation in time, namely the second space derivative, which is acceleration”, to “space variation in time, namely the first derivative of space, which means speed” and in the third case “the measure of force may refer simply to space (distance)<sup>13</sup>”.

Concordantly with the modalities of force manifestation, according to the planned and scheduled activities and goals, the muscle exercise may have as purpose: “development of force increase phase, increase of force maximum, to increase the contraction tension sustentation time<sup>14</sup>” or to enable the highest number of consecutive contractions.

Moreover, regardless of the performance of the human individual or the “motric attributes” required during the performed actions, we can assert that the effect of all these qualities may be quantified as energy which is converted to heat and mechanical work.

“The energy is a physical quantity that characterizes the state of systems at a certain moment and the mechanical work is a form of energy exchange, which is a process or state transformation physical quantity<sup>15</sup>”.

The kinetic energy theorem (KE) refers to the mechanical work performed by the resultant force, applied against the material point. The mechanical work equals the variation of kinetic energy of the material point.

If  $Mw = F * d * \cos \alpha$ ; whereas  $Mw$  = the mechanical work,  $F$  = force,  $d$  = displacement,  $\cos \alpha$  = the angle between  $F$  and movement direction),

and  $P = \frac{Lm}{t} = \frac{F * d * \cos \alpha}{t}$ , whereas  $P$  = power,  $Mw$  = mechanical work,  $t$  = time,

then from the formulas of mechanical work and power it may be deduced that  $F$  force is not only the common factor but also the principal factor that generates movement.

If the resultant of the applied forces is null at all times, the kinetic energy of a material point is preserved: a material point may not modify its kinetic energy unless a force is applied on it. Namely, the kinetic energy equals the  $Mw$  spent in order to get the material point from stop to  $V$  speed or the  $Mw$  necessary to stop the material point, or, at last, with the  $Mw$  returned by the material point when it is stopped. The kinetic energy is a scalar quantity (temporal type) of movement. The existence of the physical quantity KE and of the physical law of KE conservation is related to the property of time homogeneity (time translation symmetry).

From a physical point of view, speed may be an expression of acting force dynamics with all the movements' characteristics: *duration, trajectory, acceleration, inertia, deceleration* etc. Per se, speed is a movement quality and not at all a conditional attribute. In fact, it is unanimously accepted that speed is more of an ability that has the central nervous system and the dynamics of the fundamental nervous processes - excitation and inhibition, with all their expression characteristics: force, mobility and balance, as morphofunctional support. A human individual may be born with this aptitude under different manifestation degrees, insomuch as he/she can be born with one temperamental constitution or another, according to these characteristics. The speed manifestation support is the cerebral cortex and it acts according to the dynamics of the fundamental nervous processes, excitation and inhibition, relating to the characteristics of the above mentioned. Insomuch as a temperamental constitution generated by the genetic matrix may not “progress”, we believe that this aptitude of the human individual also cannot “progress”.

Therefore we consider that it is wrong to state that “speed may progress”. We believe that the movement speed may only be optimized and this optimization may take place, mainly, by two means: movement rationalization (learning, improvement and automation) and increase of the maximum force. Moreover, we cannot assert that the theoreticians and practitioners in the field of physical training underlie programs for “speed development”. From our point of view, all these programs that contribute to the “speed development” are only addressed to the

<sup>12</sup> Idem - quoted work, p. 52

<sup>13</sup> Idem

<sup>14</sup> DUPONT, G., BOSQUET L., *Metodologie de l'entrainement*, Ellipses, 2007, p.19

<sup>15</sup> HRISTEV, ANATOLIE, *Mecanică și acustică*, Ed. Didactică și Pedagogică, București 1982, p.58

manifestation of force in a certain movement regime, singularized by the energetic requirements of the reference sports discipline, by the typology of technique and tactics, metabolic modeling to which the human individual was conditioned during the training, correlated with the competition requirements of a certain discipline etc.

On the other hand, a motric capacity can be exclusively developed by stimuli activity on the morphological and functional pattern. How many specialists are there, that act on the dynamics of fundamental nervous processes for increasing speed through intense training, regardless of speed's form of expression?

In any type of activity moving speed can be exteriorized through the muscle ability to overcome external resistance. Thus, the speed of movement depends on the types of muscle strength manifestations and does not appear isolated in sports as an independent quality.

According to VERKHOSHANSKY I., "speed occurs as a functional attribute of the human body, but it is manifested individually only when the outer resistance is not higher than 15% of the maximum muscle force, which is not characteristic to most of the physical exercises."<sup>16</sup> It results that in these cases the maximum force does not have a decisive influence over the movement speed, but even for these movements, force is required to overcome the inertia and the intrinsic resistive force of the segments and of the entire body, which is at rest or moving.

Moreover, VERKHOSHANSKY considers that "...there are no certain special mechanisms that are responsible only for the speed, force or resistance of the athlete. The various motric abilities are enabled by some and the same functional systems of the body. However, as a result of the specialized training these systems are improved in compliance with the objective particularities of the sport branch."<sup>17</sup> The case analysis may reveal that there were athletes who obtained remarkable results during different events: athletics, swimming etc.

To us, the muscle force is a fundamental parameter of the effort capacity which an individual can express while performing the movements. The magnitude of the muscle force depends on the modality in which its making was conditioned (training and adaptation), and also on internal (muscles and tendons rigidity) and external (time, position, speed) factors. These only customize various particular modalities of applying of (a potential of) the muscle force.

Moreover, different approaches in the methodology of force development in the performance sport are differentiated according to the specific modality of manifestation/ action of athletes in obtaining different types of performance, specific to different sports disciplines.

As performance potential, the force of the human individual is, among others, dependant on the functioning of the metabolic pathways for producing the energy required for the contractions. These are based on two characteristics: **power** and **capacity**. Both these terms refer to the fundamental characteristics of energetic systems (channels) running. Therefore it is useful to set out these characteristics.

**Power** respects the availability of the considered energetic pathways. It is measured in kJ. The image of a container out of which a liquid flows is often used. We can imagine that the container tap represents the power and expresses the output and the speed of producing/ using the energy per time unit. It is known that each of the three energetic processes are limited by certain highly specific characteristic factors, as follows:

- the alactacid anaerobic power depends on the ATP content and the ATPase enzymes amount;
- the lactacid anaerobic power depends on the glycolytic enzymes content;
- the aerobic power depends on the oxidative enzymes content of the striate muscle fibers, on one hand, and on the cardiac output, on the other.

**Capacity** is represented by the time in which this energetic system (the container's volume) can work.

Like *power*, *capacity* has limiting factors:

- for the anaerobic alactacid energetic pathway, the capacity depends on the amount of creatin-phosphate from the skeletal muscles;
- for the anaerobic lactacid energetic pathway, the capacity depends on the importance and efficacy of the buffer systems (neutralization of H<sup>+</sup> ions of the lactic acid).

The capacity of the aerobic system depends on many factors. These factors are:

- the rate of muscle and hepatic glycogen;
- preferential use of lipids;
- thermolysis capacity;

For the science of corporeal activities, from our point of view, the force is a fundamental category, similar to, for example the matter in philosophy. Inasmuch as matter - fundamental philosophic category - manifests through

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<sup>16</sup> VERKHOSHANSKY, I., quoted by DAHNOVSCHI, V., S., LESCENKO, S. S., *Подготовка борцов высокого класса*, Zdorovia, Kiev, 1989.

<sup>17</sup> Ibidem

substance and field in “n” particular shapes, the force may also have a variety of manifestation forms or aspects, according to internal and external movement parameters.

Regarding the problem of supporting our hypothesis, from the practitioner’s point of view force may be developed through the repeated stimulation of the morphofunctional support, leading to biochemical, physiological and structural regulations, which potentiates/ maximizes, more or less, action complexes either in the sense of aerobic demand, or that of combined and/or anaerobic demand.

For this purpose, “every physical effort produces modifications in the human body, defined by Volkov as direct, gradual and cumulative”<sup>18</sup>, being related to the volume, intensity, density and duration of the stimulus action.

The force is dependant to the ATP amount that the human individual is able to release in order to perform the physical effort.

At the beginning of effort, the body has a certain amount of ATP available, which is consumed during the physical activity. The ATP molecules are resynthesized by the human body through the conversion of ADP and AMP through all the available energetic channels. “The energy production is not performed at the expense of just one metabolic pathway activation (i.e. the phosphagen system, glycolysis and oxidative phosphorylation) but through an interrelation of these systems, dictated by the intensity and duration of the effort.”<sup>19</sup>

According to PERONNET and FERGURSON<sup>20</sup>, the three energetic processes (aerobic, lactacid anaerobic and lactacid anaerob) recombine the ATP molecules and differentiate by their capacities, their maximal power and by their moments of intervention and response.

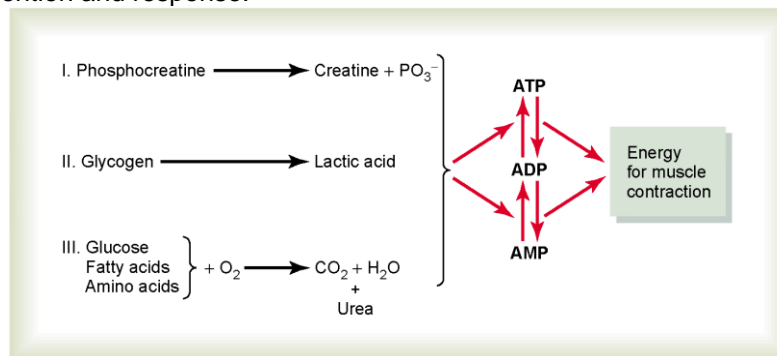


Figure 2. Important metabolic systems that deliver energy for the muscle contraction<sup>21</sup>

Biochemically, the only trade good for energetic exchange is the ATP molecule, regardless of the energetic process to recover it and especially regardless of the required motric abilities combination.

If the ATP recovered through the metabolic processes based on phosphocreatine (PC) and glycolysis depletion, contributes to the manifestation of maximum force and combined force qualities, is it normal to think that the ATP which results from the aerobic energetic processes cannot underlie the manifestation of muscle contractions that develop a force, regardless of its magnitude? Our opinion is that the energy from the ATP recovered through the oxidative processes and implicitly the contraction force are lower because the body has access to a smaller ATP amount per time unit. Regarding the final product, namely the ATP recovery, concerning the energetic channels, one of the significant differences is probably in the speed at which the sequences run.

We believe that if there is only one energy trade good, why wouldn't there be a single conditional motric attribute, since speed and resistance are manifested according to force or can be considered as particular modalities of applying the force in different work regimens?

<sup>18</sup> VOLKOV quoted by WITT, A., *Power changes depending on the sport*, translated in: Sportul de Performanță, Nr.281, CCEFS, București, 1988, p.83

<sup>19</sup> URSTA, M., *Cuantificarea metabolismului energetic în timpul efortului fizic*, [http://www.medicinasportiva.ro/medicina%20sportiva/fiziologie/Cuantificarea%20metabolismului%20energetic%20in%20ti mpul%20efortului%20fizic.html#articol\\_specialitate](http://www.medicinasportiva.ro/medicina%20sportiva/fiziologie/Cuantificarea%20metabolismului%20energetic%20in%20ti mpul%20efortului%20fizic.html#articol_specialitate)

<sup>20</sup> PERONNET, FERGURSON, quoted by DRAGNEA, C., A., Mate-Teodorescu Silvia, *Teoria sportului*, FEST, București, 2002, p. 139

<sup>21</sup> GUYTON A., C., *Textbook of Medical Physiology*, eleventh edition, by Elsevier Inc., 1600 John F. Kennedy Blvd., Suite 1800 Philadelphia, Pennsylvania 19103-2899, 2006, p.1057

If we analyze the *marathon* from the point of view of the dominant motric attribute that determines the performance, the specialized literature is consistent in asserting that the long time resistance is a common place for the vast majority of specialists. If we analyze the event biomechanically, running represents a succession of jumps from one foot to the other, with a floating phase. For each of these jumps, muscle contraction is required, and out of it muscle force results as primary manifestation.

Moreover, the runner in the marathon event, even if he performs a tremendous physical exertion during the race, he runs the last stadium tour in less than 1 min., achieving an average speed of  $\approx 5.71$  m/sec<sup>22</sup> (almost 60% of the maximum speed!) throughout the 42.193 km. That is, if the athlete would run only on the classic running track the average speed would be  $\approx 70$  sec per each tour. We believe it is true that starting with the moment of the first contraction, no matter how long it lasts, in the human body there are spontaneously triggered all the metabolic energetic processes that ensure the energy required for the recovering of ATP molecules<sup>23</sup>, with the remark that there is a different inertia for each of the energetic pathways, according to the location of the energetic substratum reserves, the breakdown modality, the pause of action, the efficacy etc.

The physical training seeks, through adequate methods, to improve the *power* and *capacity* of athletes for each sports discipline, adequately to the specific requirements generated by the competition for each branch.

The effects on the human body produced through training are individualized not as much from the reactivity of the athletes, but from the effort dosing during training and competition. By temporal projection of the training effort, the individuals selected to be professional athletes will develop from childhood to maturity different types of reactivity as adaptations to competence requirements. By disregarding the “*technical field*” of each sports discipline, “*the engine*” of the performer will release the required energy in accordance with all the requirements that determined over time the power and capacity. Currently a series of specialists are still searching empirically, not knowing for many sports disciplines which is the best “*engine*”, what sort of “*fuel*” it uses, what is the “*optimal speed of revolutions*” regimen. Biochemically, the only trade good for energetic exchange is the ATP molecule, regardless of the energetic process to recover it and especially regardless of the required motric abilities combination. And if there is only one energy trade good, why wouldn't there be just one conditional motric attribute, the force, as long as the other conditional attributes are manifested according to the force or might be considered particular modalities of force implementation in different work regimens?

## CONCLUSIONS

The consequences of this study are difficult to anticipate. From our point of view there may occur a series of mutations and reconsiderations in the field of the science of theory and practice of physical training and consequently in the understanding of the performance phenomenon and the concept of performance in a series of sports branches. We also believe that some mutations and changes may occur in the “center of gravity” in the methodology of preparing the performance in some sports branches, according to the new meanings that these ideas will have in the reassessment of the performance concept for those branches.

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11. <http://www.powerdevelopmentinc.com/?id=34> *Fundamentals of the Theory and Adaptation of Sports Training*, SE Pavlov Russia State Medical University, Moscow Russia State Medical University, Moscow

<sup>22</sup>The quoted example takes into consideration the actual record of “marathon event” which is 2:03.59, set by Haile Gebrselassie, Berlin, 2008.

<sup>23</sup> The ATP molecules recover constantly from the moment when the body begins using them to perform physical effort.