

Homoeostasis Performance Model

Homoeostasis Performance Model is a synthesis between Noakes's Central Governor Model and Schmidt's Conceptual Model of Human Performance. Some of the Bernstein's conclusions about motor controller, who controls human movement, were:

- Control system is hierarchically organized on couple of levels
- There is a feed-back that connects lower parts with higher parts of control system, which is used to adjust motor commands
- Time lag between neural connections finally leads to a need of combining signals from feed-back with feed-forward preprogrammed, anticipatory signals
- Number of *degrees of freedom* of the motor system is always bigger than needed. System is redundant and the control can be viewed as the process of solving redundancy problems (finding the optimal control strategy - learning)

So basically, skill is a result of the process of searching the optimal solution for a particular motor task/problem. Abilities are the underlying (hidden, latent) factors that affect performance and skill. But abilities are also measured via performance, so there is no such thing as a crisp boundary between skills and abilities. When you want to measure strength, you can give someone to do 1RM squat. But doing squats takes skill to accomplish, especially with beginners. So, I would say that strength is a skill, rather than a some hidden, latent factor – ability. Same thing for endurance, speed, flexibility, agility and other.

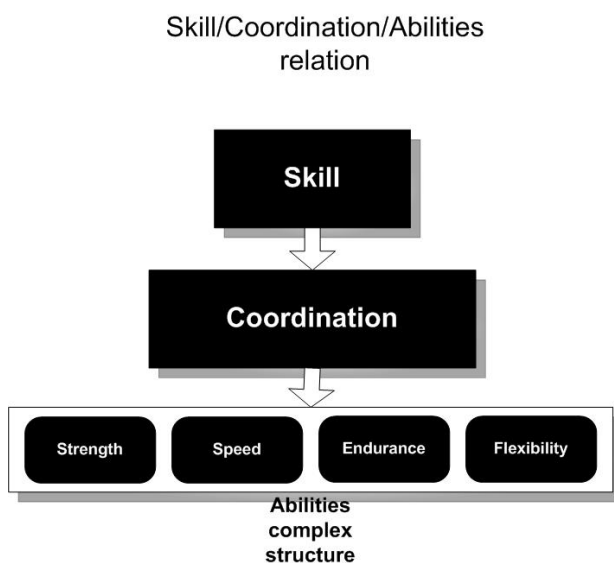
I am not saying here that there is no such thing as abilities, but I am saying that it is hard (or maybe impossible) to put the line between skills and abilities, because they are interrelated, and cannot exist by themselves alone.

It is quite helpful to look at the things that, specific skill uses specific abilities to solve specific problems. If there is no needful development of underlying specific ability, then the skill cannot be learned nor performed. It is impossible to teach someone to squat 200kg with proper skill (technique) if his level of strength (ability) is poor. Same thing with sprinting form. It cannot be learned nor reached if the underlying strengths and flexibilities (and endurance to maintain it) are not well developed. Pushing the athlete to do something he

cannot do because of the lack of underlying abilities is only frustrating and can lead to injuries.

Skill is NOT such thing as stereotype or fixed pattern (of muscular activation), but rather a dynamic, complex, continual motor problem solving. To teach some skill, you should not give answers but rather questions.

Ability structure makes things more complex, because there is no consensus about their number nor interrelation. This is also one more proof that the line between skills and abilities is hardly made. There is one general ability which correlates with every other. It is coordination. Coordination is specific ability to control movement, but there is



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also a number of types of coordination. This makes things more complex. We can look at the coordination as the connection between skill and abilities.

There is a trend in my country (Serbia) to develop coordination with youth, which can help later with learning and performing sport specific skills. The question is can coordination be developed, by the way, there is different types of coordination. I am thinking that giving kids a various exercises does not improve coordination (or it is) but rather enrich their motor space, so there is a skill transfer later in their sport development to more specific sport skills. This is not the issue here, so we are going to leave this debate for some other time.

So what the hell is new here? What new does Homoeostasis Performance Model bring to the world? This was just an introduction, so lets start...

The main thing that Homoeostasis Performance Model brings is the integral approach to study human movement. It is time to stop reductionist approach dividing motor control for creating movement and physiological metabolic/energy systems that maintain life. The human acts as a whole and thats the way it should be viewed and explored.

The main principle/concept of Homoeostasis Performance Model is that movement is allways done within the limits of homoeostasis (in healthy humans). I will first explain my point of view for „movement“, then for „homoeostasis“ and finally for their interaction.

Movement is an interplay between stability and mobility. To allow movement to happen, at the specific instant of time, some joints must be stable and stiff, while others must be mobile. Movement is an act of the whole body (not just muscles according to this model), even when you move your little finger, your whole body moves. Take an example. Stay upright with your arms by your side. Quickly rise your arms. Which are the muscles that activated first? Deltoideus? Not exactly, your leg and core muscles, because they must maintain your whole body balance and prevent you not to fall, and also, they have to maintain the stability of the individual joints (spine). This is an example of anticipatory postural adjustments. Because system is redundant, which means that there is unlimited number of solutions, motor controler must find the best/optimal way to produced desired movement and to solve desired motor task. This is a process of searching. This is the motor learning, finding the optimal control strategy to solve some motor problem. The result of this searching (motor learning) is the motor skill.

Muscles produces forces (torque) and, in the same time, stiffness (short range active stiffness) which allows them, with the pair of their antagonists, to stabilize joints and to move joints.

Movement is bigger then the sum of its components, so trying to isolate one movement (and muscle) is misleading and erroneous. As Zatsiorsky stated, we are not trying to improve our muscles but rather our movements. One my friend, when someone asked him, while doing cleans, for what muscle is that exercise, he answered: „Do you know that muscle that works when you jump to catch a ball under the basket? It is for that muscle!“.

Homoeostasis is an inner (only inner?) physiological environment that should be stable and maintained under narrow boundaries to maintain life. Take the body temperature for an example. Body temperature is about 37C, but when it crosses 44C or fall below 33C, you die! End of story. So to maintain life, your body must control its internal environment (its state). There is a lot of variables that should be controlled: body temperature, blood sugar, hydration, nutritional status of the blood, biochemistry status of blood, pressure and a lot of others. Dont forget that between them is a strong correlation and interaction, so your control mechanism have a very complex job to do to keep you alive.

To maintain homeostasis, control mechanisms have a couple of systems to help him (executables). That includes circulatory system, respiratory system, digestive system, thermoregulatory system, urinary system. Control mechanisms communicate between them via hormonal system and neural system. It is hard to find localization of the homeostasis control system, because same as motor controller (are they the same?) have hierarchical structure and it is widespread over the body. Sometimes it is said that hypothalamus is the main controller, but I think it is maybe just one (highest) part, because a lot of organs have their control systems in themselves.

To maintain life, control mechanisms have to find the optimal relation between different variables which defines homeostasis, but again, it has to find optimal way controlling-keeping them in the narrow ranges. I don't know if the human body is one state system (representative point), but something tells me maybe it can have a couple of stable states and switch from one to another as a result of training or some sickness.

If we take some parallels with cybernetics and automatics, homeostasis control mechanisms need to have defined goal of control (relation between variables – representative point) which there is maybe more of them, algorithm or optimal control to maintain it within narrow ranges (the process of searching) and gain which helps him to do it quickly and effectively. We can look at the gain as a functioning of physiological systems (heart, lungs, blood etc). Making them more efficient, creates greater gain in the systems and thus allows homeostasis control mechanisms better control and maintaining of homeostasis.

Are these two systems really separated or not? Homeostasis Performance Model states that they are not! According to this model, movement is always done within the limits of homeostasis and the homeostasis is never lost (in healthy humans). If there is a threat to homeostasis, movement is stopped or altered. Take an example of exercise in altitude. Do you expect to find more or less lactate in the blood? You expect to find more, but contrary you found less, because motor/homeostasis controller shuts down-decrease the muscle activation to maintain homeostasis. The feedback to the motor/homeostasis controller from the muscles and other organs via III and IV afferent fibers, informs it about what is happening „down-there“ – is there a threat to exit from homeostasis? This is a new concept added to classical Bernstein motor controller. Controller gets feedback information from chemoreceptors at the periphery and acts by increasing the functioning of heart, lungs and other physiological systems or by decreasing/altering muscle activation for the goal of maintaining homeostasis. Controller only permits movement within the ranges of homeostasis.

Homeostasis Performance Model brings another point of view at the fatigue. Fatigue is not a physiological impairment, but rather protective mechanism that acts as body tries to leave boundaries of homeostasis (which starts at the onset of exercise). Sense of effort (RPE, rate of perceived exertion) is a conscious perception of subconscious (underlying) integrative effort of control mechanisms to maintain homeostasis.

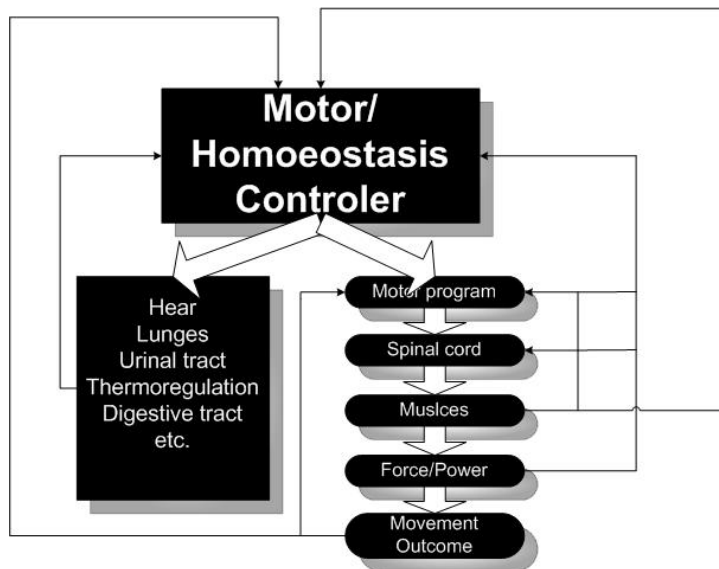
To improve your performance you must improve your motor skills and ability to maintain homeostasis. That includes improving your control strategy (learning) for both motor controller and homeostasis controller which is done by practicing. Motor controller develops skill, and homeostasis controller develops optimal control of heart, lungs, urinary tract etc. Both of these two result in pacing strategy, as an example, in running. Also, you must develop the gain in the system, as a result of training adaptation. Gain in motor controller represents motor abilities, and in homeostasis controller represent functioning level of heart, lungs etc. And finally you must improve your mental ability of „pushing“ or stimulating homeostasis controller while it de-stimulates you with sense of effort (or RPE).

It is obvious that I differentiate between learning and adaptation. Learning represent searching for the optimal control, and adaptation represent increasing the system gain. They are different but interconnected. Both have to be improved for the performance to improve.

According to Homoeostasis Performance Model, endurance is a ability to maintain homoeostasis. It is maybe most fundamental ability (?) more than strength, because also when you push 1RM bench press, it takes time, and for that time homoeostasis must be maintained. This includes joint stability, tendon integrity etc.

There is always reserve for life-threatening situations. Movement is allways done within the boundaryes of homoeostasis. Dont forget that homoeostasis controler is still learning and that internal/external enviroment is always changing, so sometimes it cannot compensate for the changes, and injuries happen! There is also a posible threats with psycho-stimulans usage, because it affects you „pushing it“ too much.

Note that for the purpose of better explanation I splitted this controler to motor and homoeostasis but really they are the same.



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Some questions?

If this controler limits maximum force to maintain tendon and joint integrity and prevent muscle injuries, why then there is a difference between concentric and eccentric force in vivo conditions as in vitro, and why there is bilateral deficit? Why those forces are not the same?

Upgrades:

12.december 2005.

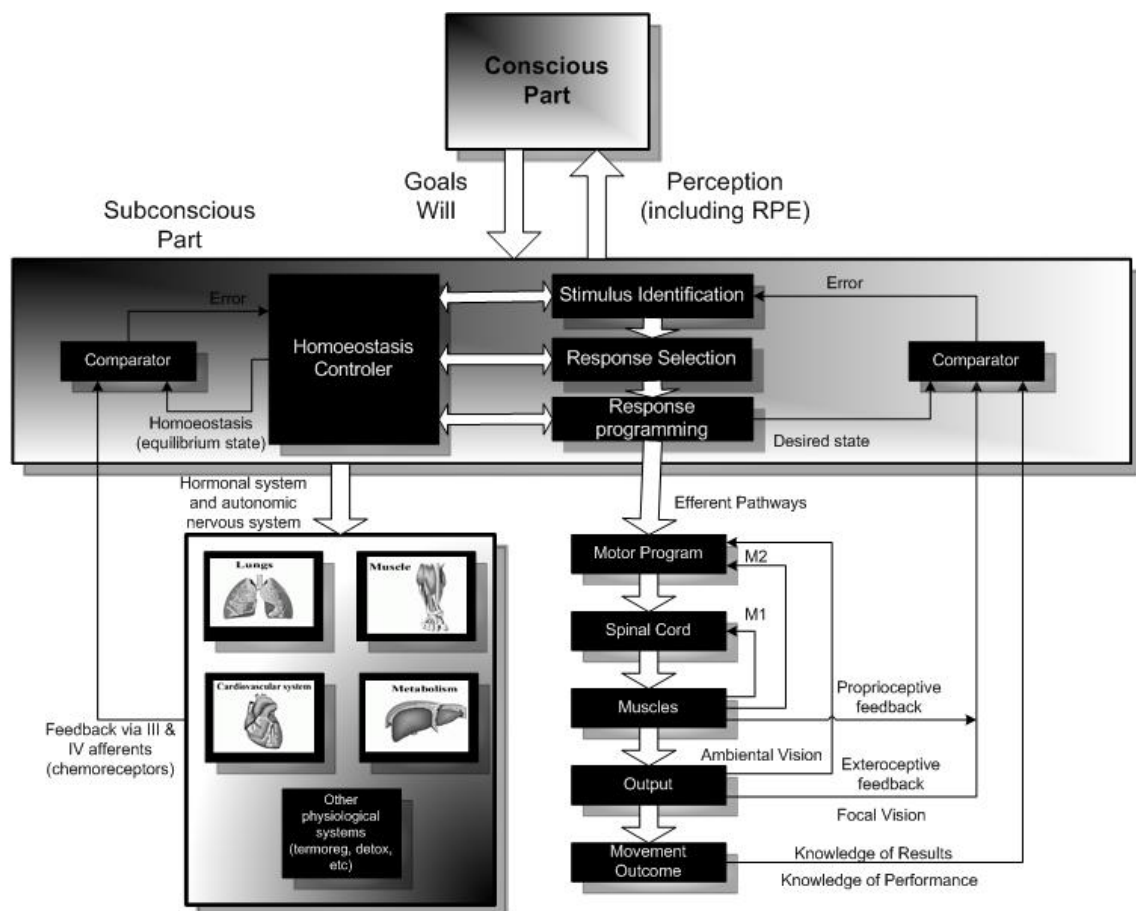
To allow best performance, as said, you must improve your skills and ability to maintain homoeostasis (and mental abilities). Homoeostasis could be more expanded into conserving joint integrity, tendon integrity, avoid muscle strains and sprains etc. So, to develop maximum performance you must develop skill and underlying abilities with specific high-intensity training, but aslo you must maintain your ability to maintaing homoeostasis by doing low-intensity general work to improve capilarization, heart and luns function, tendon and joints. From the point of Homoeostasis Performance Model, Francis HI/LI approach is highly approved and correct!

13. december 2005.

It is important to note that while organisms exhibit equilibrium, their physiological state is not necessarily static. Many organisms exhibit endogenous fluctuations in the form of circadian (period 20 to 28 hours), ultradian (period <20 hours) and infradian (period > 28 hours) rhythms. Thus even in homeostasis, body temperature, blood pressure, heart rate and most metabolic indicators are not always at a constant level, but vary predictably over time (from Wikipedia, homeostasis term).

This waves-oscillations in biorhythm affects performance. As I stated before (thread X) training should adapt to these waves (providing unloading when needed) and on the other hand athlete should adapt his waves to training (pre-planned unloadings) to allow peaking for the given moment –competition!

15. december 2005.



First of all, it is quite hard to distinguish between conscious and subconscious part. Maybe there is no line at all, but I must say that I am proponent of Descartes dualism, so I strongly believe in „something“ that is not material (soul, spirit or call it whatever you want)! I don't believe that my behaviour and my existence is just biochemical process in brain cells or some complex algorithm(s) as stated by strong AI proponents. In every motor control book, there is explanation of motor control from periphery to CNS, but I didn't find no one asking who or what triggers first neuron to fire? I don't believe it is some kind of random processes, I strongly believe in free will.... But we will leave this issue for some other time!

Conscious part is there to feel (perception) and to act or to set goals! When you move your hand, you don't voluntarily activate your muscles, but you just set goals to a motor controller what to do and it creates movement based on his ability to control it optimally (skill).

Perception from outer world is filtered through your current emotions, attitudes etc, you never get it in pure shape (only if you are enlightened :)) RPE (rate of perceived exertion) is also a perception of how hard is homeostasis controller working to maintain your state in the boundaries of life. RPE is also affected from your expectations, emotions, prior experience etc. Based on your mental strength (will power) you can push homeostasis controller to work harder, while it tries to „break“ your will with RPE feeling-perception! What is the purpose of RPE (teleology) if the fatigue is just some physiological impairment? So, according to this model, fatigue is a protective control mechanism, which shut-down or alter your performance to keep the homeostasis between boundaries. This does not exclude the possibility of peripheral fatigue, just it states that homeostasis is never lost in exercising, and that movement is altered before it is too late. Some drugs (stimulants) can change this and can lead to homeostasis lost and finally to death!

When you try to execute some movement, you give a feed-forward information to homeostasis controller so it can act much faster and not to wait deterioration of the homeostasis. To maintain homeostasis, its controller activates heart, lungs, metabolic pathways, vascular system, detoxification system and finally it alters movement execution via his connections with motor controller.

Everytime something changes in the system (human body), in most cases gain of the system or in other words function of cardiovascular, respiratory systems, muscle etc. , motor controller and homeostasis controller must find a better way to control its behaviour. It is a process of finding the best/optimal control strategy based on some criteriums. Criteriums can be various: speed of motion, energy efficacy etc. So every time you improve your abilities you must improve your skill. Take an example. If you improve your arm strength without practicing free shots in the same time, your motor controller will use same control strategy but your muscles are producing more force so you will miss the shots. You must give a time for motor controller (and homeostasis controller) to adapt, to find the best control strategy, so the best solution is to practice free shots while improving strength! For this same reason, interval training is better than continuous, because it forces homeostasis controller to find stable state more than once as is the case with continuous running. When doing continuous runs, controller finds the stable state and keeps it while with interval training he must learn to find it more quicker and more than once and to learn to use muscle more efficiently (neuromuscular coordination). This is why they always say that endurance is a skill!

17. december 2005.

Reply to Supertraining....

Let me reformulate my question Jamie.

In vitro conditions (without nerve and blood supply), muscles produce greater force during eccentric than concentric contractions measured with isokinetics apparatus in physiological liquid and with artificial electrical stimulation. Mechanism for this larger force (during eccentric contractions) are author-dependent: Jaric states that it is because viscosity in muscles (which resists movement speed, and in eccentric contraction is in same direction as actin-myosin force, thus we get larger force), and Enoka (correct me if I am wrong) states it is because changes in actin-myosin cycle!

If there is a governor that limits maximum isometric force (strength deficit) in vivo (with nerve and blood supply – normal muscle) to protect tendons, joints and muscles itself,

then why does he (governor) allows greater forces in eccentric contraction? Why doesn't he (governor) reduce muscle activation, so does muscle produce same maximum force in isometric conditions and in eccentric condition? And if the larger isometric force than allowed by governor, harms tendons, joints and muscles, why doesn't larger eccentric force create damage?

Or put another word:

Maximum maximum isometric strength (via artificial stimulation) = 100N

Maximum isometric force MVC = 70N

MVC force during eccentric contraction (at some predefined speed) = 90N (or more)

Is the maximum isometric MVC force limited because of protection, then why MVC force during eccentric contraction IS NOT limited, and why doesn't it produce any damage?

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25. January 2006. (Altitude training vs. below sea training)

When you perform, there is a tendency to perturb body homeostasis. This perturbation strongly depends on your skill/abilities, or to say your muscle power, economy, elasticity etc. Your body wants to maintain homeostasis, so it reacts by activating (in greater degree) the mechanisms for their maintenance (heart, lungs, temperature regulation, etc.). As stated before, movement is an interplay between stability/mobility, and if we draw a parallel, performance is the interplay of perturbation/maintenance of homeostasis (can you see the similarity with Yin/Yang concept and dualism?).

According to Homeostasis Performance Model, to improve performance, one should improve:

- Sport Specific Skills and Underlying Abilities (including morphotype)
- Ability(es) to maintain homeostasis
- Mental abilities

Your body never exits from homeostasis limits, and if you tend to do it, your Central Governor reduces muscle output and increases RPE.

So, improving skills/abilities tend to increase homeostasis deterioration during performance (except improving economy, elasticity etc). There is an interesting concept in Lore of Running book from Tim Noakes (which I started reading before a couple of days), that when you want to improve muscles' abilities (in long distance running) you should engage in oxygen enriched environment, rather than altitude training!!!! On my opinion this oxygen enriched environment allows you easier maintenance of homeostasis, and thus greater stimulus for the muscles (you can achieve greater performance values). On the contrary, if you want to train your homeostasis maintenance abilities, you should get into oxygen depleted (altitude) environment. But this kind of training will not optimally develop muscle factors..

Thus, the solution is that distance runners should engage in below sea training (oxygen enriched environment) to stimulate muscle factors, and in altitude training to stimulate homeostasis maintenance abilities....

25. January 2006. (integrating Homoeostasis Performance Model with Conjugate Sequence System)

As stated in the Model update from 12. december 2005, if we expand concept of homoeostasis to joint integrity, bone health and structural integrity of the body, we will soon see, that to achieve peak performance one should not only train Sport Specific Abilities and Skills, but also, an ability to maintain homoeostasis, or body integrity. This means, that during sport specific training, one should allow some time for training of joint integrity and overall integrity, thus minimizing muscle imbalances etc.

According to conjugate sequence system, one should train abilities in sequential manner, but in the same time maintain non-specific abilities (and already developed specific ones), or in other word, one should maintain/improve their GPP (general physical preparedness) levels to allow improvement in SPP (special physical preparedness). For example, to achieve better performance in shot-put, one should train mostly for developing greater power in arm/legs, but in same time, one should also include minimal time training for non-dominant hand, back muscles etc. This is because development of greater power in arms tend to create greater stress at the arm joints, and if you don't have also developed back muscles (rotator cuff, lats, traps etc) your joints tend to be pulled/clenched during performance, because you have not developed ability to maintain their integrity (homoeostasis).

15. June 2006.

The Human Performance Model (HPM) basically states that any kind of performance is limited by balance/harmony between two processes: homoeostasis break-down process (HBP) and homoeostasis maintenance process (HMP). If HBP is more powerful than HMP then the performance will eventually stop because of developed fatigue. So, fatigue is not physiological impairment, but it is rather a control mechanism that prevents ruining of body-homoeostasis which can lead to injury and death. The body is smart... it is not just a machine listening to our motor commands...

In running, muscle action that creates GRF and actually propels you forward (and up) tend to perturb homoeostasis (joint stress, metabolites, stretch-shortening fatigue, tendon strains, usage of energy fuels – liver and muscle glycogen etc), and if your functional organs are unable to maintain homoeostasis there will be fatigue build-up and eventually decrease in running speed or stopping. Thus, running performance is limited by (a) ability of muscle system to produce power for running and (b) homoeostasis maintenance ability (which depends on various factors)

If we expand concept of homoeostasis to joint integrity, we will soon see that HPM is applicable to resistance training. If your muscles are not in balance your main lifts will suffer. Although your body have ability to lift 150kg on bench press it will not allow you this performance if your shoulder stability is poor due weak rotator cuff muscles (for example). Trying to lift more will eventually lead to injury if you succeed to by-pass control mechanism. Thus, the strength is limited by (a) potential strength ability and (b) homoeostasis control (muscle balance, structural integrity, joint stability/mobility etc.)

Another comparison is the following. You have Ferrari that have very powerful engine and can go 400km/h. But, his brakes are poor. The question is how much will you push the gas pedal? How much will you allow yourself to go fast? 400? I don't think so... maybe 100km/h max. Thus, your security is more important than the powerful engine. To go faster you must first fix your brakes. Considering this for some athlete, he should (a)improve engine power and/or (b)improve braking system.

Another example is puch in boxing. You would love to speed up the puch and thus improve your ability to knock-out opponent and pass his defense. So, you start improving explosive strength of prime movers (triceps, deltoideus, pecs etc), but after some time you start to stagnate... You try to develop even more explosive strenght in prime movers but with no succes. The solution is to improve antagonist muscles that actually decelerate the moving limb. Your body will allow only the speeds of movement that will not cause injury to joints. Event if you have potential to move limb faster, you will be not allowed to do so until you „fix the brakes“.

17. jun 2006

Basically, the *body** has two main goals/tasks

- Create the actions directed by the *Owner*** which basicaly tend to perturb body homoeostasis
- Provide the *frame* for life of the Owner by trying to maintain its own homoeostasis within boundaries of life

Thus, the body is allways deciding between these two processes. The body is smart. It will allow actions but only within the boundaries of maintenance of homoeostasis.

Training improves both processess. It improves actions (homoeostasis perturbation) by improving abilities and skills. It also improves the ability of the body to maintain homoeostasis by improving the functional systems and their control and also skills (more skillfull athletes are more efficient and thus create less perturbation in homoeostasis). Training should provide BALANCE between these two processess, becасue if emphasising only one there will not be any improvements and it can actually lead to decrease in performance. Both processes should be improved to improve performace. Note that those two processes are not split-able, they are integrated into a whole! Also, the body must provide a feedback from Material World to the Owner. This is called perception and is also affected by current states, emotions etc and is also affected by training. Everything is affected by everything.

If you (Owner) force the body to provide actions, it will give you feedback about the work done to maintain homoeostasis – RPE (rate of percieved effort; which is a „combination“ of action effort and homoeostasis maintenance effort). This is one of the mechanisms of the body to tell you where are you heading (perception, and as such it is affected by your expectations, prior experience, emotions etc). If your Will Power is very strong and keep pushing it, the body will ultimately use the second protective mechanism – fatigue. The body will try to alter the activity by „fatiguing“ itself (reducing CNS output and impairing physiological processes at the periphery), so you must push it harder (which will induce greater RPE) which ultimatelly lead to greater fatigue until fatigue is greater than your Will Power and this is when fatigue starts to become visible by altering/reducing performance. Note that fatigue starts at the onset of exercise/action as a control mechanism.

This was my short teleological (purpose) aspect of fatigue and RPE.

I hope I didn't confuse anyone, but I doubt :)

* Under the term *body* I consider the body-mind complex

** Under the term *Owner* I consider the Consciousness, Soul or whatever you like to call it. I am strong proponent of Descartes Dualism and I strongly believe in Free Will. Also, I don't

believe that Consciousness is located in the brain, it is something that is not material and cannot be explained by physical laws and algorithms. The brain/mind is just a „transducer“ or a machine. I didn't want to go into philosophical discussion but it seems that we cannot do anything without considering it.

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12. decembar 2005.
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