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Review Article

Resistance Training (RT): A Meta-Analysis of the Existing EBM

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Abstract

Resistance Training (RT) is a category of exercise where one utilizes a tool, a piece of equipment or one's own weight to apply an external force to the body that stresses segments of the body or the entire body. The goal is to stimulate reactive improvements in support, stability, strength, symmetry and/or balance in muscle mass and strength in order to improve bone strength and stamina, the posture and performance either on one's own or with professional and/or certified training or coaching.

RT is used by millions across the globe and is recommended by the American Heart Association, sports medicine professionals, the gym, fitness marketplaces and for prehabilitation and rehabilitation.

But resistance training is poorly researched and evidence based (EBM) relying on anecdotes, expert opinion and promises of success partly because of a lack of consensus terminology and partly due to the wide range of classes and types of RT including free weights, resistance training machines, medicine balls, resistance bands, wearable resistance training tools and gravitational stimulators like weighted vests.

Using the existing evidence, science and expert opinion, this paper attempts to develop foundational terminology, uses and applications for resourcing RT that begin to develop consensus for producing high level, peer reviewed literature in the future. Simultaneously this peer reviewed addition to the literature aims to give the health minded public and the professional community an ability to develop, implement, monitor, coach and maintain custom programs that will methodically maximize the health, strength, conditioning and movement execution of the individual.

My practical life has acculturated to focus on prevention, performance enhancement, quality of life and functional adaptation rather than on the chief complaint. I have changed the questions I ask and the methods I use for researching, testing and practicing medicine as a healer to include salutogenesis and a more systemic approach.

Keywords: *Exercise; EBM; Resistance Training; Functional Medicine; Biomechanics; Fascia; Wearable Resistance Band Training ; Foot Orthotics*

In biomechanics and functional medicine, focusing on the chief complaint masks the actual foundational purpose of a healer. A healer should first do no harm and second be preemptive rather than wait for clinical expressions of pre-existing pathology. Epigenetic precursors and underpinning biomechanical and functional medicine architectural and engineering imperfections need to be aggressively and preferably diagnosed and treated. EBM is problem focused and as the population aims to be functional during a longer life expectancy it is falling short in many areas.

To paraphrase the words of Tom Myers, the structural integrationist, "I have held beliefs and teachings regarding resistance training and biomechanics that I've had to let go of. I no longer hold many iconic theories that served their purpose for me until they were destroyed by scientific and clinical facts, personal experience and logic".

Before, during and after complaints drive patient's to the clinic, we need to utilize the existing evidence at all levels when creating additions to the literature rather than to procrastinate "waiting for the evidence" to surface while making decisions regarding biomechanics and functional medicine, n = 1.

It is surveyed that 49% of all of us exercise regularly and there is a large body of evidence proclaiming trained exercise to have huge health, performance and longevity benefits but to date, we are waiting for high level evidence to surface when it comes to Resistance Training. This results in biased and misinformed information based on anecdotal, low level and often non-peer reviewed literature.

I have investigated Resistance Training (RT) for decades waiting for high level EBM to publish while manufacturers, professionals, all levels of experts and charlatans have had an open field to self-publish and market their products and methods as proven to be viable and valuable.

My mission here is to organize, create and define terminology and acronyms that are evidence based and progress logically regarding RT so as to create consensus among its users. This in turn will cultivate a foundation for further testing and researching what has become a necessary part of so many lives.

This addition to the literature involves my personal experience along with the existing low level evidence and expert opinions regarding Resistance Training (RT) and its subgroups: Free Weight (FW) Training, Resistance Machine Training (RMT) Training, Resistance Band Training (RBT), Wearable Weight Training (WWT) and Wearable Resistance Band (WRB) Training.

It attempts to give an overview of Resistance Training as a topic and then nominate Wearable Resistance Band Training as a new and useful tool with biomechanical benefit and potential for applications in functional medicine and training.

Hypotheses

- Resistance Training is a viable method of exercise that needs better defining, terminology and consensus opinion of its developers, researchers and users.
- Will a foundational Meta-Analysis of the current EBM of Resistance Training serve to stimulate higher level, valid and applicable applications of RT EBM in the future
- Is Wearable Resistance Band Training a viable, applicable and useful class of Resistance Training that deserves trial, research and clinical use?

Concession: Because RT is lacking in consensus; language and terminology needed to be invented to begin to define the subject for discussion and further research and trial. I have conceived of and defined such language for consideration and review of the reader and welcome your comments and edits.

Key Takeaway: A consistent terminology to classify and categorize resistance training and its subclasses has not been formally established and accepted in the literature and elsewhere providing interference for developing EBM.

Wearable Resistance Band (WRB) Training: Definition

Wearable Resistance Band (WRB) Training is a class/type/subgroup of Resistance Training. WRB systems utilize specially designed belts, socks, arm and chest straps, gloves and other wearables to anchor elastic resistance bands connecting two or more body segments as a hands free training tool.

Wearable Resistance Band tools, when worn, are working constantly during daily activity, exercise, sports participation, rehabilitation and training making it a useful tool for noncompliant, obese, weak, injured, young and old cohorts as well as the training of professional athletes, "weekend warriors" and average individuals.

WRB Training provides an ascending variable elastic resistance force that stresses the body at its anchored locations at variance with the g-Force of body weight. This opens up new applications for WRB Training expanding the existing body of RT.

Wearable Resistance Band systems stress the wearer at two or more locations while allowing hands free (sovereign) movement. They impact single joints and/or multiple joints on all three body planes in any and all directions uniquely.

Key Takeaway: WRB Training is a multi-vector, multi-plane, variable, ascending resistance type of resistance training that can be utilized while performing life's tasks, sports, training, movements and activities, hands free [Figure 1].

Figure 1: *JBIT and WearBands: Examples of Wearable Resistance Band Systems.*

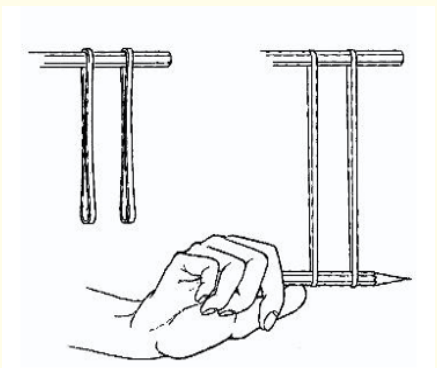

Figure 2: *Elastic Band Stretch Force*

Resistance Training (RT) [1] and Its Subgroups: Definitions

Resistance training is a category of exercise where one utilizes a tool, a piece of equipment or one's own weight to apply an external force to the body that stresses segments of the body or the entire body. The goal is to stimulate reactive improvements in support, stability, strength, symmetry and/or balance driving improvements in muscle mass and strength, bone strength and stamina, the posture and

The scientific underpinning for RT involves two physical laws of anatomy and physiology; Wolff's Law of Bone Adaptation and Davis's Law of Soft Tissue Adaptation. Both Laws govern the adaptation and compensation that exists when there is g-Force and/or elastic resistance force produced by RT.

Joseph Wolff's Law of Bone [2] states that bone will adapt to the loads under which it is placed. If the load on a particular bone increases, the bone will remodel itself over time becoming more dense and stronger in order to manage that load without injury. The inverse is true as well: if the loading on a bone decreases, the bone will become less dense and weaker due to the lack of the stimulus required for continued dynamic remodeling.

Henry Davis's Law of Soft Tissue Adaptation [3] states that muscle, tendon, ligaments, fascia or any soft tissue down to single cells when put under even a moderate degree of unremitting stress react by increasing in mass or strength and lengthen, thicken or become more dense in order to manage that load without injury. The inverse is true as well. When soft tissues remain in a state of reduced stress they will reduce in mass or strength and shorten, become thinner and less dense.

Resistance Training Categories

- **Free Weight (FW) Training**; Use of standalone weight (dumbbells, barbells, weight plates and kettle balls) that is not attached to an external apparatus that constrains it. The excess weight adds to gravity and stimulates Wolff's and Davis's Laws reaction
- **Resistance Machine Training** (RMT); Use of fixed machines (Life Fitness, Stairmaster, Free Motion and Cybex) that attach to weights, hydraulics or cables. RMT's stimulate Wolff's and Davis's Laws positively.
- **Medicine Ball (MB) Training**; Use of weighted balls that are held, thrown or caught while exercising to generating to add a synthetic g-force that posolutely stimulates Wolff's and Davis' Laws.
- **Wearable Weight Training (WWT)** – Strength training garb that holds weighted objects such as ankle weights, wrist weights and weighted vests. WWT stimulates Wolff's and Davis' Laws with an additional positive factor that the wearer is hands free.
- **Resistance Band Training (RBT)** – Use of flat or round stretchable rubber or elastic bands that when stretched provide a variable, ascending elastic resistance force to the areas of the body they are anchored to that positively stimulate Wolff's and Davis's Laws.
- **Wearable Resistance Band (WRB) Training** – Use of resistance bands attached to wearable belts, socks and cuffs that provide an ascending, variable, hands free resistance force to the anchored areas that posolutely stimulates Wolff's and Davis's Laws when stretched in many directions.

Resistance Training (RT): Science, Clinical Evidence and Research

There is overwhelming long-term research and moderately-high evidence that resistance training can be used to train and maintain skeletal muscle mass and function when the stimuli provided by daily living cannot offset the muscle engine declines that are a part of aging [4]. Adults who do not perform RT lose 0.46 kg of muscle every year from the fifth decade on and adults not performing RT experience a 50% reduction in the fibers responsible for strength, by age 80 [5]. The beneficial effects of RT on the skeletal system include preventing osteoporosis [6], sarcopenia [7] and reducing obesity [8] and falls, fractures, and disabilities [9].

The American Heart Association and the American College of Sports Medicine both endorse RT in the prevention, treatment, and control of hypertension and vascular disease [10,11].

RT has a positive effect on osteoarthritis [12]. Resistance Training has also been linked to improvement in type II diabetes [13] and Parkinson's [14]. RT is useful for healthy and higher-risk children for improving the metabolic risk profile in later life [15].

Resistance Training began in 1936 when Jack LaLanne opened the 1st profession gym in California [16]. Since that time interest in RT has grown exponentially. Better tools, certified instructors, better technology and a developing body of science and research has fostered a growing market worldwide.

Discussing and Comparing the Classes of Resistance Training

Free Weight (FW) Training

The more one weighs, the more contact force is generated upon the ground. This ground reaction force (Newton's 3rd Law) is generated up into the person. GRF stresses the body to either adapt towards remaining functional and injury free or to weaken, move less and/or injure. GRF increases as we adapt to lifting, carrying and moving free objects by the amount they weigh.

Free weight training adds force to grf in the form of weighted bars, barbells, dumbbells or weight stacks in order to oppose the force generated by muscle through concentric or eccentric contraction.

The genealogy of free weight lifting is traced back to the beginning of history to ancient civilizations where the tools were stones. This later was replaced by dumbbells and kettle balls, etc [17].

Free weight training develops a rising constant force curve (Figure 3).

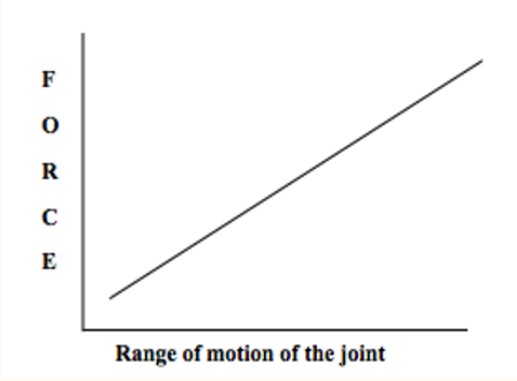

Figure 3: *Force Curve of a Free Weight Exercise.*

The basic principles of FW training involve a manipulation of the number of repetitions (reps), sets, tempo, exercise types, and weight moved to cause desired increases in strength, endurance, and size. Specific combinations of reps, sets, exercises and weights are decided on a case to case basis [18].

Free weight training involves isolated muscle engines and locations. FW Training is gravitational with the force always being directed downward. FW Training has a relatively low rate of predictable injury especially when compared to injury from sports or the rigors of living life. In college football players, time lost from injuries during weight training amounted to 1% of the time lost from injuries during football participation. The weakness of free weights is that the exercises that are performed often do not imitate those performed in natural movement.

Key Takeaway: If you are doing bicep curls with free weights, you are training the body functionally to improve the performance of doing a biceps curl and little else.

Resistance Machine Training (RMT)

Resistance Machine Training (RMT) research has shown cohorts to increase strength 115% from baseline measuring specific muscle engine groups [19]. Balance improved 245% in the RMT group and 49% in the FW group. Other studies indicate a greater improvement in RMT over FW in strength (58%), and balance (196%). Additionally, FW Training reported increased pain while the RMT Training group reported lowered pain levels [20].

RMT places the greatest amount of force where a muscle is the strongest; it can be an effective way to apply the overload necessary to stimulate muscle growth after an injury to a specific muscle engine. Resistance Machine Training specifically stresses the contractile element of muscle. They do not stress the elastic component of fascia and the connective tissue responsible for providing shape and transmitting forces from one section of muscle to another. RMT improves muscle size, strength and definition by stimulating the contractile element to generate higher levels of force. In fact, machine training is the most effective and safest for achieving this outcome.

Machines provide the most time-efficient means of performing drop sets to the point of complete fatigue. This ensures that all fibers in a particular muscle have been engaged. Machines work well for developing a custom circuit training program especially when working with a professional or trainer [21].

Unfortunately, resistance machine training often places the user in a fixed position that doesn't mimic functional movement. RMT isolates specific muscle engines and/or specific body segments. Machines force the body to move in a fixed path of motion (Figure 4). This helps muscles stabilize but doesn't offer good compound movement pattern training.

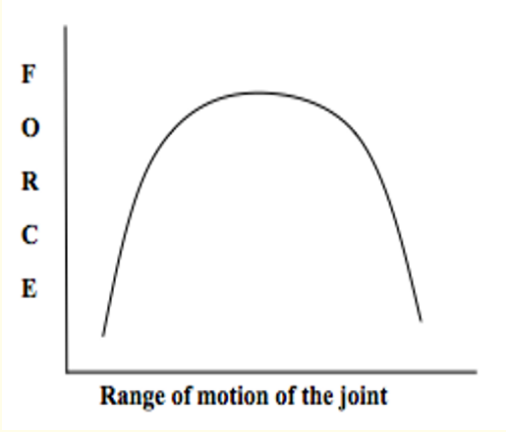

Figure 4: *Force Curve of a Machine Exercise.*

RT exercise machines take up a lot of real estate on the gym floor, are expensive and are not portable. For these reasons, they are being used less often in gyms, training facilities and homes.

Key Takeaway: Because RMT moves the body in ways that are not entirely natural they can set up repetitive motion injury. Since RMT trains you seated they do not reinforce closed chain, weighted function and "sitting may be the new smoking" [22]. RMT is gravitational with stress always directed downward.

Medicine Ball (MB) Training

Medicine Ball Training does not play an important role in this white paper and will not be discussed further [23].

Wearable Weight Training (WWT)

Historically, in 600 BC ancient Greece, Milo of Croton developed his strength by lifting and carrying a calf on his shoulders each day from its birth. As the animal grew in size, so did his strength (Figure 5). The principles used by Milo of wearing and progressively increasing weight to build strength and muscle mass has been verified in modern times as an effective means of exercise.

Figure 5: *Modern day Milo of Croton.*

The use of vests, ankle and wrist bands and belts with compartments that hold weights has existed for decades (Figure 6). By adding wearable weight, we are increasing ground reaction force demanding the body to adapt. The advantage of WWT over most other classes of resistance training is that it is portable and hands free and can exercise multiple joints and body segments while allowing the wearer to move about naturally in closed chain.

Figure 6: *Wearable Ankle Weights*

The wearer can perform specific exercises, sports and tasks allowing the added weight to provide an activity-specific or movement-specific stress to muscles, bones and the cardio respiratory and metabolic systems forcing adaptation period.

In one of the few high level peer reviewed articles relative to resistance training, in 2017, a meta-analysis of 1100+ peer reviewed articles provided 32 studies that showed that acute trunk loading with wearable weights reduced treadmill velocity, increased trunk loading, increased jump performance, maximum oxygen consumption and energy cost when running [1].

Acute limb loading increased maximum oxygen consumption and energy cost in walking and running. A literature review of WWT confirms that this form of RT is in its infancy and "future research is required into the optimum load placement, orientation and magnitude required for adaptation" [24].

Unfortunately, the injury rate of WWT is higher than most other classes of RT and wearers generally need a coach/trainer for good results [25] reducing the effectiveness of personal use.

Key Takeaway: WWT reaches a point where additional weight within the wearable slows one down, reduces productivity and can cause injury,

Resistance Band Training (RBT)

Elastic tubing equipment and resistance bands have been used for over a century as a fitness and rehabilitation tool around the world [26].

The first resistance bands were made from rubber surgical tubing in the early 1900s. They were used for body and muscle rehabilitation purposes. Resistance bands made an experiential leap in the mid 1990s when they became go-to tools of physiotherapists bringing a new freedom to total body fitness. In recent years resistance bands have grown to become fitness tools used by professionals, in gyms and personally around the world.

Resistance bands are flexible, relatively weightless, and easy to carry and set up. They are inexpensive. Most exercises can be are performed in a standing position. RBT engages more muscle mass to more places than other forms of RT.

Resistance bands are used for rehab and kinetic and plyometric training with claims that they help fitness, strength, power and flexibility. The dominant upgrade resistance bands add to other types of RT is "variable resistance" as bands used change in length, stretch and thickness.

Resistance bands come in various thicknesses and lengths providing different levels of resistance. They are usually color coded [27].

Bands, by consensus, are to be manufactured to the formula that stretching them to twice their resting length will increase resistance by 20 - 30% (Figure 7).

How Resistance Bands Work

As one stretches a resistance band with movement, stress upon the tethered locations and along the band increases. This causes muscles to build strength and increase mass. What is important is that RBT builds strength and mass to the bones and soft tissues safely and inexpensively.

Scientifically, the stretch in an elastic band occurs in all three dimensions but when resistance training, we are only interested in what would be called "normal stretch" which occurs longitudinally. The force produced by an elastic band or tube longitudinally is determined by this formula:

Force = cross sectional area x percent elongation

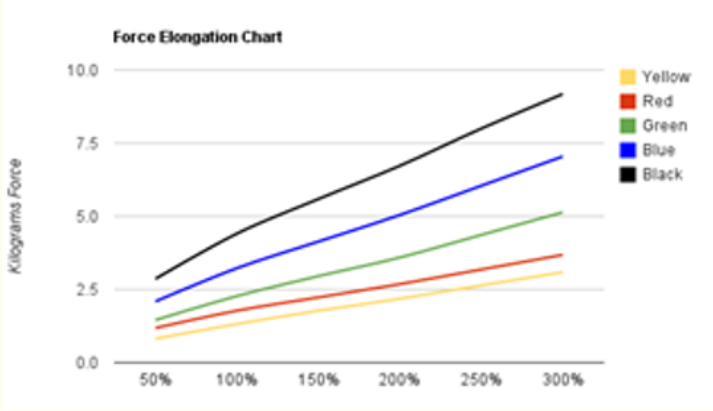

Figure 7: *Increasing force curve of colored resistance bands*

The cross sectional area is the total amount of elastic material (width x height) while the percent elongation is the percentage of change in length from the resting length. For example, a three foot length of band with no tension stretched to a final length of 6 feet has elongated 100 percent.

Since resistance bands are relatively weightless they do not rely on gravity to generate force. This suggests that they have applications and value that can stand alone in the RT space or to be incorporated with gravity based products to expand them.

In addition, resistance bands provide a stressful force that increases as the band is stretched. Summarily, RBT adds "progressive" resistance during the exercise. Resistance band force curves mimic the "strength curve' of muscles (Figure 8 and 9).

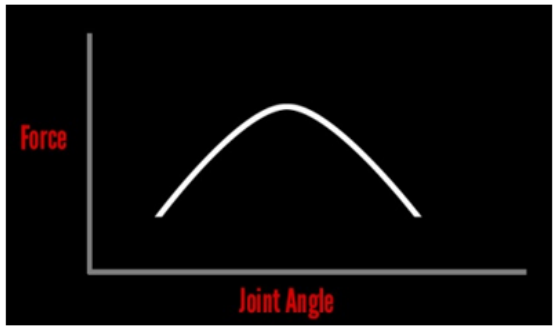

Figure 8: *Stretch Curve of Muscle.*

Key Takeaway: RBT produces energy in all directions, Since RMT Training and WFW training produces only vertical energy (isotonic resistance) to generate stressful forces, the level of success with gravity based resistance training is limited.

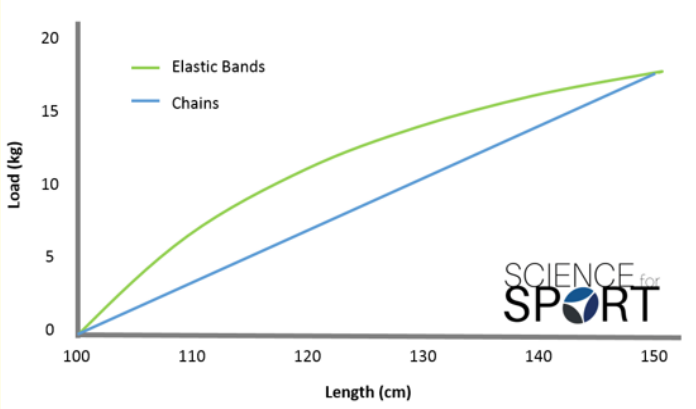

Figure 9: *Force Curve of a Resistance Band.*

Resistance Band Research [28]

Research demonstrates that resistance band training provides as much benefit in strength gains as the use of more expensive and gravity based free weight training. A 2008 study by Colado and Triplett compared 10 weeks of elastic and machine based exercise at the same intensities. The researchers found no significant difference between the groups; both the elastic and machine based groups significantly increased their strength and muscle mass. Furthermore, the researchers pointed out that the elastic resistance exercisers benefited from lower cost and immediate improvement when training compared to dumbbells [29].

RBT is categorized as Variable Resistance Training. When an exercise is performed with bands, it causes a 'variation' in the load being lifted throughout the range of movement – hence the name variable resistance training.

Even those with a sedentary lifestyle or extreme obesity can benefit from resistance bands. Healthy sedentary women using RBT decreased obesity with healthy muscle adaptations [30].

Studies have shown RBT to be effective in activating muscles compared to Resistance Machine Training (RMT) during single-joint exercises when loadings were matched [31].

RBT has proven useful in early study as a primary prevention for healthy children. Previous fears of growth plate and other injuries are being replaced by anecdotal and expert clinical success suggesting the need for higher level research. Anecdotally, claims have been made that resistance bands offer benefit for kids that other types of equipment can't match. Most drills are performed in a standing position. RBT is easier to teach, coach and monitor than other classes of RT. Exercising for as little as six weeks with elastic band resistance can increase strength 10 to 30 percent in both younger and older adults. The benefits include lowering body fat, and increasing power and endurance. Strength training of the legs with elastic resistance can improve balance, gait, and mobility [32].

Anderson., *et al*. reported no increase in muscle cross-sectional area when using resistance bands, and suggested that these improvements may be related to neural adaptations. These improvements in power output are also supported by Anderson et al., who reported large increases in average lower-body power [33].

RBT, Joints and End Range of Motion (ERM)

When training with bands, with every increase in the stretch-length, there is an increase in the tension of the band to resist the stretch. The more the band is stretched, the higher its resistance to stretch becomes. RBT provides the largest resistance where it is tethered to the body. This mean that resistance band training increases an athlete's strength at the level of the joints which is beneficial for muscle leverage when dynamic. It also means that it improves strength and performance at end range of motion which is critical to power and performance.

It is often argued that the increase in resistance towards the EROM will increase the neuromuscular demand, and thus elicit a higher force production. Theoretically, a higher force production equals an increased likelihood of strength gains. In fact, trained athletes produced both higher peak force, and higher peak power when using bands rather than free-weights alone [34].

From an engineering perspective the variable resistance of elastic bands causes larger oscillations and thus requires an adaptation towards stabilization. This suggests that if resistance bands are being utilized in untrained, weak, young or older subjects, after a short time, these cohorts would have reduced functional sway and perturbation, improving performance whil reducing injury and preventing falls. The idea that elastic bands increase agonist-antagonist muscular co-contraction would also be supported by this theory as they work to achieve a higher degree of stability when stressed at the ERM.

Elastic resistance bands may be effective tools for enhancing the concentric portion of an exercise by facilitating certain aspects of the eccentric phase (i.e. muscle activity, eccentric RFD, eccentric impulse, and the rate of loading). It is simply the recoil of the elastic bands which may enhance these aspects of the eccentric phase, as it provides an assistive/accelerative component to the movement.

Resistance Band Training Advantages vs Gravity Dependent Training (FW, RMT, WWT)

Unlike FW, RMT and WWT training, RBT relies on the tension of the elastic bands rather than the pull of gravity and additional weights. While isotonic resistance exercises are limited to directions of movement in which gravity provides resistance, resistance bands offers stress in many more directions of movement for exercises (think side-to-side movements for example). This suggests that RBT stimulates a higher level of neuromuscular and myofascial control and adaptability.

Because RBT assists the CNS and the myofascial organ system in managing and adapting to the changing momentums of everyday life, movements can be performed faster and more effortlessly. RBT increases stability by reducing the end ranges of motion of movement over time. In closed chain, RBT reduces sway and perturbation. RBT maintains better balance in all directions. Workouts are never the same. Scientifically, RBT offers inherent and smoother eccentric resistance during the return phase of the movement stimulating the anti-gravity function of muscles.

Resistance Bands can be used to train multiple joints in any position including standing, weighted and moving about upright. This allows for closed chain training and control over isolated muscles (think primary vs compensatory muscle engines and active vs. passive exercising).

It's much harder to cheat with resistance band exercise because you can't use momentum to jerk the weight into position like when using free weights or machines. In addition, RBT can also be used to perform flexibility, acceleration and balance exercises for distances and long periods of time [35].

Resistance Band Training: Final Key Takeaways

- **Key Takeaway 1:** Resistance Band Training delivers a stressful force determined by the length and strength of the band, not gravity or ground reaction force.
- **Key Takeaway 2:** Resistance Bands force is generated from the movements and motions that stretch them and they act where they are tethered at the joint area and at end range of motion.
- **Key Takeaway 3:** RBT is safe, inexpensive, travels well and using color coded bands of various lengths and thickness can provide increasing resistance as one seeks optimal fitness or skilled maintenance

Disadvantages of Resistance Band Training

- Resistance bands occasionally break but advances in their manufacture continues to give them longer life.
- Resistance bands snap back and can injure the wearer if removed under tension or if poorly attached.
- Most elastic bands and tubing contain natural latex rubber to which some people may be allergic.

Wearable Resistance Band (WRB) Training

WRB Training is a new entry to the field of Resistance Training. It can be traced back to 2006 when the MASS Suit was developed as a wearable resistance band training system. Backed with testimonials, expert opinions and reviews, the MASS Suit remains without peer reviewed research. Additional products, designs and upgrades (Juke System, JBIT, Vertimax, WearBands) have entered the marketplace with options that have little or no evidence backing them up.

I have accumulated historical facts, personal clinical trials and experience, peer reviewed evidence, anecdotal testimonials and communication with health care, movement and wellness professionals that has enabled me to present a logical progression of facts and ideas on the subject of Wearable Resistance Band (WRB) Training validating its usefulness and consideration for research.

Concession: Wearable Resistance Band Training is a type/class of Resistance Training. There is no definition of WRB Training that has consensus. There is no terminology regarding WRB Training that has consensus. I have authored terminology and acronyms that will begin to define the subject more clearly for discussion, revision and eventual consensus. I ask the reader to review my language and welcome your comments and edits.

Wearable Resistance Band (WRB) Training: Taking Resistance Band Training (RBT) to the Next Level

Wearable Resistance Band (WRB) Training uses of belts, straps, socks, gloves, cuffs and other wearable garb to anchor resistance bands to two or more parts of the body that are then used for resistance training (RT).

Wearable Resistance Band Training has all of the risks and benefits of Resistance Band Training while allowing the wearer to be capable of moving about hands free.

Why Wearable Resistance Band Training?

Wearable Resistance Band Training represents a useful option for individuals, trainers, gyms, health care professionals and therapists to attach to and recommend to their clients/patients as adjuncts to their existing resistance training protocols, treatments and therapy for many applications.

Positives For Consideration of Wearable Resistance Band Training:

- WRB Training has the user independence and the ability to move about untethered
- WRB Training is not g-force or grf dependent
- WRB Training recruits muscles and movement patterns at all anchored locations
- WRB Training is variable resistance training
- WRB Training has single joint, multiple joint and integrated body applications
- WRB Training improves balance
- WRB Training reduces sway and perturbation
- WRB Training reduces falls
- WRB Training is useful in treating asymmetry (using different color bands at the same anatomical level)
- WRB Training promotes myofascial function and fitness
- WRB Training promotes strength, stamina and speed of muscle engines
- WRB Training promotes bone strength and health
- WRB Training promotes cardio respiratory health
- WRB Training promotes weight loss
- WRB Training promotes agility in all directions
- WRB Training promotes postural health and fitness
- WRB Training promotes vertical explosion
- WRB Training is more effective in exercising dual task situations (an example of a dual task situation is when someone is walking down a street and there is an obstacle in front of the walker that must be simultaneously addressed)
- WRB Training promotes speed and endurance
- WRB Training produces "real world" stresses when worn while gait training, walking, running, dancing, practicing Tai Chi or Yoga, sitting to standing that make living everyday life and performing everyday tasks therapeutic
- WRB Training allows for indoor, outdoor and constant use
- WRB Training is portable and travels easily
- WRB Training is inexpensive
- WRB Training makes the wearer a better adaptor/compensator because of CNS and myofascial stimulation.

Key Takeaway: WRB Training has the potential to create an experiential paradigm in exercise, training and therapy and is worth clinical trials that research.

Disadvantages of Resistance Band Training

- Wearable belts and straps may cause irritation, pain or injury to tethered locations (i.e. when applied too tight)
- There is a learning curve to putting on wearable resistance training systems
- Resistance bands can break but advances in their manufacture continues to give them longer life
- Resistance bands can snap back injuring the wearer if removed under tension or if poorly attached
- Most elastic bands and tubing contain natural latex rubber to which some people may be allergic.

Wearable Resistance Band Training Integrates Well with Fascia

The Fascia

Fascia is a specialized organ system of the body that has an appearance similar to a spider's web or a loosely woven sweater. Fascia interpenetrates every muscle, bone, nerve, artery and vein and all of our internal organs including the heart, lungs, brain and spinal cord at a macro and microscopic level.

Physicists recognize four fundamental forces: gravitational, electrical, weak nuclear and strong nuclear. Gravitational and electrical forces are the two forces of importance affecting the human body. Electrical force is important at the molecular and cellular levels, e.g., affecting the binding together of our bones and controlling the contraction of our muscles. Gravitational force is weaker than electrical force by a factor of ten. There is less known about the electrical force of fascia than its gravitational force.

When the human body is upright and moving, the fascial network must adapt to the bottom-up forces of ground reaction (grf) and top-down forces of gravity (g-Force). Fascia is the primary system for controlling these forces [36].

Anatomically, fascia is the glue that connects every cell, structure and organ together. Composed of collagen, elastin and water based gelatinous ground substance, it is our morphostasis. Fascia is responsible for our form, stability and movement and has been underappreciated in Resistance Training (Figure 10).

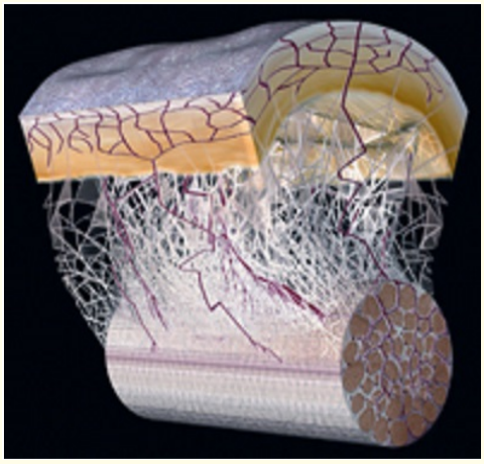

Figure 10: *Dermal and Deep Fascia.*

When we think about and work with fascia it is helpful to conceptualize coherence and integration in order to appreciate its unique and often unrecognized importance. Without fascia, the 80%+ of us that is water would be a puddle on the floor.

Research suggests that non-contractile connective tissue is the richest sensory organ in the human body, containing up to ten times as many free nerve endings than the contractile elements of muscle [37]. Put another way, there are ten Golgi Tendon Organs, Paciniform pressure receptors, Ruffini shear detectors, or interstitial nerve endings in the fascia surrounding every muscle fiber for every one that exists within the muscle [37].

The fascial system connects us from head to toe. As an illustration, pick up a part of a sheet and twist it. You can see tension lines and folds that endlessly spread out from that point (Figure 11).

Fascial health depends upon:

- Hydration,
- Having variety in our movement,
- Having rest and recovery periods (think interval training)
- Being healthy and fit.

Figure 11: *The Ripple Effect of Pulling On a Sheet*

Wearable Resistance Band Training is more coadjuvent to myofascial fitness and function than other forms of resistance training. In fact, many of the other classes of RT dampen facial activity and health due to their isolation effect.

Fascia is a biochemical/electrical pathway for signals and information to be carried to and from every cell in the body. Fascia is more sensitive to chemical hypertonic stimulations than the underlying muscle and overlying sub cutis. It is theorized that compression of tissues results in a piezo-electric effect. This causes the electrons, which are associated with the chemical bonds in the involved tissues, to generate a form of intrinsic current.

The Facial Lines [38]

When it comes to fascia, there is not much high level evidence on either side of its importance and consensus remains divided.

On one side are those finding benefit in working with fascia contending that there are lines of connective tissue that run throughout the body called fascial lines (Figure 12).

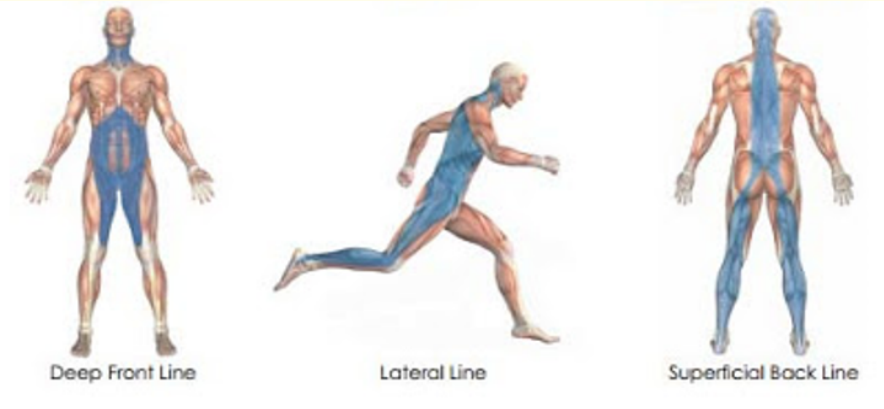

Figure 12: *The Fascial Lines.*

They believe that these lines hold the body together and help coordinate the body to move as a unit repetitively. If this can be proven it would mean that myofascial lines are integral in functional movement training, as well as coordination and stability.

Research is showing that a single muscle can have some fascicles that are lengthening while other fascicles are shortening suggesting the existence of fascial integration [38].

Fascial lines help explain the kinetic chain when it comes to the standing and dynamic posture where an event in one location of the kinetic chain affects others in all directions. By understanding this kinetic line of events, you can better understand injuries, movement limitations, and the need to target weaker areas to increase performance that research has failed to explain. Think about how tight hamstring and calves could cause lower back pain, or even something like Planter Fasciitis can result in hip or even lower back functional limitations.

The CNS gets to decide what muscles fire, how strong and fast they are, how far they will elongate, what motor patterns and postures you adopt, and whether you will experience pain – in short, everything that matters that can be controlled and habitualized.

The myofascial system is an auto-regulatory system that makes rapid, momentary adjustments chemically and mechanically to allow the body to adjust to the never ending changing movement patterns in order to maintain stability, support, strength, balance, symmetry.

The central nervous system (CNS) sends signals via electrical impulses that lack the speed necessary to control movement and adaptation in real time. The fascia and connective tissue systems communicates much faster than the CNS using chemo-mechano-transduction to initiate a biochemical response. It is estimated that mechanical vibrations travelling the myofascial network move three times faster than the signals sent by the CNS [39].

On the other side of the decades old debate are EBM zealots having no logical progression or evidence to explain the many unproven conditions presented here. These experts and researchers call for evidence explaining the importance of the myofascial system but offer little counter in defense. This paper is meant for the former.

This paper is meant for the former.

It is now understood that a muscle does not have to cross a joint to create movement at that joint. For example, the soleus does not cross the knee. As the body is walking forward during gait and the right leg is on the ground, the right soleus limits the tibia-on-talus dorsiflexion, helping the knee move into extension.

Summarily: Incorporating free movement and elastic variable resistance force in the form of WRB Training can improve the ability of the body to develop more efficient movement habits. Wearable Resistance Band Training incorporates tri-planar, multidirectional movements including both slow and fast-paced tempos that ensure adequate stimulation of all layers of the myofascial network.

The Fascia and Biotensegrity

Tensegrity, the integration of tension and integrity, is an architectural term used to describe a structure that is self-supporting through a combination of tensile (lengthening) and compressive (shortening) forces. Given that the myofascial system is a balance of compression and tension, biotensegrity is an effective term to describe how the body has a natural, structural tendency to balance forces. Following the model of biotensegrity, it is more accurate to say that skeletal structures float within a three-dimensional matrix of muscle and connective tissue [40-42].

Pedal Stability, Support, Strength, Symmetry and Balance: The Foundational Key to All Action

When co-existing with gravity, it is universally accepted that unless the foundation of the body (the feet and lower legs) are stable, supported, strong, symmetrical and balanced, the body will wear and tear, degenerate, deform, injure and/or underperform. Foot Centering Theory, Restorative Foot Orthotics and Wearable Resistance Band Training is compatible with modern lower extremity biomechanical research in that they improve stability, support and strength, while correcting asymmetry and making muscle engines more balanced and trainable.

The Four "SSSS' and a "B" of The Feet

The body, from the ground up, needs to maintain enough stability, support, strength, symmetry and balance to counteract g-force and grf at all times and have enough in reserve to stand and move about efficiently and injury free. Our feet need to have reserve stability, support, strength, symmetry and balance to perform life's tasks and activities optimally for a lifetime.

Key Takeaway: Lower extremity instability, weakness, asymmetry and muscle engine imbalance predictably will provoke genetic underpinning biomechanical pathology and/or epigenetic pathology to suffer repercussions. Acute or chronic deformity, neurological or musculoskeletal complications, metabolic maladies, debilitating weakness, injury, deformity and overuse syndromes are the resulting cascade of "The four "SSSS" and a "B" of the Feet" (Figure 13).

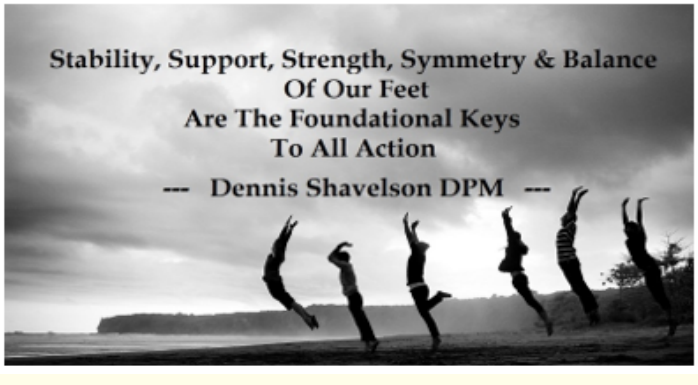

Figure 13: *The Four "SSSS" and A "B" of the Feet.*

Examples of this foreseeable chain of events that are accepted as part of senescence are; "I used to dance; now I collect stamps" and "as I get older, I expect to walk slower and take shorter steps" can be reversed or improved with improvement in The Four "SSSS" and a "B".

The Complexity of Lower Extremity Biomechanics & Human Movement Is Preventing RT Research

The complexity of maintaining and moving the human bipedal structure should not be underestimated. One of the main reasons that there is so little peer reviewed evidence with respect to the material covered in this paper is the fact that there are so many variables in developing cohorts within the percentage of error that would drive valid and applicable evidence. In order to begin to understand the factors on both sides of this equation, I have developed "The Optimal Functional Mobility Equation".

The Optimal Functional Mobility Equation: Why EBM is Difficult to Produce

There are ten or more variables that must be considered and controlled on the degenerative side of the equation as well as 10 or more factors on the other side of the equation that effect one's ability to develop cohorts and valid results when studying closed chain function and performance.

When considering Resistance Training as a topic for clinical trials and research investigators seemed to fail to consider that RT is only one part of the Optimal Functional Mobility Equation. This fact makes it difficult to create research protocols with RT as an isolated variable and even more demanding to generate cohorts that are not being impacted by the other 19+ variables (Figure 14).

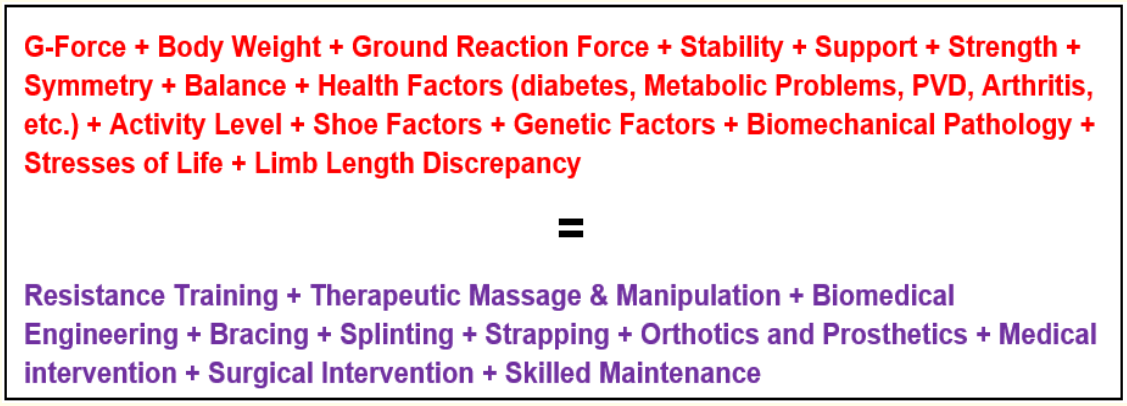

Figure 14: *The Optimal Functional Mobility Equation.*

The Importance of Gravity: The Constant Mobilizing, Strengthening and Crippling Force

All objects on Earth are outweighed by gravity. All of us oppose gravitational force whenever we lift a weight or move about. G-force at the surface of the Earth is 9.8 meters per second per second. Any object on the surface of the Earth experiences this acceleration due to the vector sum of non-gravitational forces acting per unit of the object's mass. It is gravity that allows us to stand and move about and we must be well-adapted to the physical conditions at the surface of the earth, dynamically [43]. It is also gravity that creates stress within the human body creating subclinical and clinical breakdown and collapse.

In an experiment performed in the 1970's designed to see the effect of adding more g-force (or in the case of RT, more weight), 23 generations of chickens were placed in a hyper g-force centrifuge that raised g-force 10-15%. The offspring had lower body fat, larger muscles, denser bones, and a very robust and powerful cardiovascular system. They had few health problems, and in many ways were arguably healthier [44,45]. The added g-force had caused positive adaptation (and so would the added weight of RT).

Jupiter, with 2.4 times the gravity of earth would have you weighing 480 pounds if you weighted 200 pounds on Earth. Imagine the effect of wearing a vest with 280 lbs of weight on your body and imagine the impact it would have on your posture, your functional life and your longevity.

Key Takeaway: Weighted resistance training using kettlebells, kettle balls, free weights, sleds, weight machines and other devices in order to simulate 10 - 15% hyper g-force will cause positive adjustments as in the 1970 chicken experiment.

The formula for Weighted Resistance Training is g-Force + Additional Weight Force = Total Force of Training.

Combining Resistance Band Training (RBT) or Wearable Resistance Training with (+) Gravity Dependent Training (FWT, MRT and WWT)

There has been little clinical trial and virtually no research directed towards the risks and benefits of combining RBT/WRB Training with gravity dependent training (FW Training, RMT and WWT). There is some anecdotal evidence and expert opinion that there may be advantages in combining RBT/WRB Training with gravitational RT. In reported clinical experiences, adding resistance bands to standard free weight workouts such as the squat provides additional benefits. It seems plausible that a single rep of a single exercise such as the free weight squat may have added benefits if resistance bands were added to the exercise providing its unique characteristics into the equation (Figure 15) [33].

Figure 15: *Combined RBT and FWT.*

As the bands generate their maximum force at end ranges of motion and free weights generate their maximal force at the middle of the rise and fall, the effect of the combined exercise is greater than either performed separately. Resistance band squats additionally stretch and remodel the myofascial due to their variable, multi-joint, multi-directional impact [33,46,47].

Key Takeaway: Hybrid exercise that combines g-force and resistance band training seems to have symbiotic value and applicability in well selected applications but most likely needs a professional attached to monitor educate, coach and maintain.

Combining Resistance Band Training (RBT) with Wearable Resistance Band (WRB) Training

There has been little clinical trial and virtually no research directed towards the risks and benefits of combining Resistance Band Training with Wearable Resistance Band Training. There is some anecdotal evidence and expert opinion that there may be advantages in combining RBT with WRB Training but no peer reviewed literature on this subject. In reported clinical experiences, combining wearable resistance band training with resistance band training workouts such as the vertical squat provides additional benefits. It seems plausible that a single rep of a single exercise such as the free weight squat may have added benefits if resistance bands were added to the exercise providing its unique characteristics into the equation [47]. It remains to be seen if similar results will surface when combining RBT with WRB training.

Wearable resistance band training works best for multiple joint and full body exercise applications as well as when free movement is preferred. Resistance band training generally works well for both single joint exercise and multiple joint applications. Both forms of exercise generate their maximum force at end ranges of motion and perform at the tethered joint area.

Key Takeaway: Hybrid exercise that combines resistance band training and wearable resistance band training may have symbiotic value and applicability in well selected applications but most likely needs a professional attached to monitor educate, coach and maintain.

Discussion

RT is well represented in the peer reviewed literature but mostly dealing with free weights and machine resistance training and after injury or disease. These studies remain disconnected and of little clinical value [48]. In spite of over 100 years of research on this topic, fundamental questions remain unresolved [49].

Resistance Training's guiding principles are based in ancient times. Through its history they have not changed significantly. What we have experienced is a revolutionary development of the machinery and equipment used and the science, technology and experiences that continue to be developed, tested and driven to new heights [47].

As we add science, clinical trials, research and expert opinions into the mix of the available evidence; nomenclature, additional clinical pathways and peer reviewed literature will surface.

I have tried to present an accurate, evidence based, presentation of Resistance Training (RT) and its various types/classes.

My personal experience has focused upon the Wearable Resistance Band (WRB) Training type of RT and so that is where my level of bias must be disclaimed.

Wearable Resistance Band Training is all about functional movement, agility work, outdoor fitness on the move, group fitness classes, boot camps, real-time sports training, walking, hiking, yoga, Pilates and dance to name a few applications. It can be a standalone therapy but it also can be used as a hybrid training source combined with other forms of RT such as free weight training and resistance band training.

Being portable, mobile and hands free, WRB Training strengthens, balances and stabilizes by allowing the body to move in closed chain under the influence of elastic variable resistance. For static exercises and for working isolated muscle groups one or a handful at a time without any significant movement or cardio demand, other classes of RT are currently more preferable.

Summarily, WRB Training is worth researching and applied in clinical trial and error as a potentially valuable type of Resistance Training.

Conclusion

This paper, by stimulating interest in the science and EBM of RT is designed as a matrix from which future research will surface regarding Resistance Training. As with all EBM, the theory, statistics and conclusions drawn here contain personal bias that should be discussed and tempered where necessary.

By proving that Resistance Training (RT) and its subgroups are poorly represented in the peer reviewed literature and deprived of consensus when it comes to terminology, validity and applicability the findings here suggest directions for researchers, professionals and the foot, postural and movement challenged sufferers of mankind to find ways to repair some of the myths and inaccuracies that exist in the marketplace and elsewhere.

I have provided baseline terminology (to be adjusted until consensus) that can be used in research and practice for RT and its types. I have listed a bibliography that includes peer review, non-peer reviewed published, self-published and anecdotal blogs and articles published by experts in the field as references. These should assist to refresh or broaden the foundational knowledge base regarding the many topics covered here.

It is my belief that creating a peer reviewed and clinically organized infrastructure on the subject of Resistance Training, the subgroups of Resistance Training, Free Weight Training, Machine Resistance Training, Resistance Band Training and Wearable Resistance Band Training will be better researched and practiced in the future.

Unfortunately, if EBM remains problem oriented the ability to research prevention, performance enhancement and quality of life upgrades with remain mostly without peer review [33,34,48-55].

Conflict of Interest

Dr Shavelson is the Medical Director of WearBands, a wearable resistance training tool.
Dr Shavelson is the CEO of WearBands Therapeutic LLC.

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