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Designing effective corrective exercise programs: The importance of dosage

In this editorial, two papers that appear elsewhere in this issue, are reviewed. *One repetition maximum bench press performance: A new approach for its evaluation in inexperienced males and females: A pilot study*, by Bianco et al.; and *Muscle strengthening activities and fibromyalgia: A review of pain and strength outcomes*, by Nelson. Both papers, as is evident from their titles, discuss strength training and how it may be applied to populations of varying athletic ability or requirements.

In the design of an effective corrective exercise program (or indeed any conditioning program) an optimal outcome is dependent on training the appropriate physiological parameters. In the rehabilitation field, for many years now, there has been an over-emphasis on which exercise to do and often also the technique, with little focus on the acute exercise variables familiar to strength and conditioning coaches; the repetitions, sets, loads, tempo's, rest-periods and program periodization. The upshot of this situation is that patients may be given exactly the "right" exercise, for the wrong duration to have the desired effect. Indeed, the literature that has investigated the efficacy of motor control intervention may be skewed toward a negative outcome for this reason.

What this points to is the notion that the model of the four stages of competence in behavioral change (see Wallden, 2013a,b) fails to reach its highest peak. For clarity, when a patient presents at the clinic or a person takes up a new movement skill, such as the golf swing for example, they are rarely highly competent; instead they show a level of incompetence. Perhaps their knee is sore because they have a descending pronation pattern through their leg (see accompanying practical article titled: *Don't get caught flat footed — how over-pronation may just be a dysfunctional model*) or they keep topping, hooking or slicing the golf ball.

In these two examples respectively, they don't know why their knee is hurting, or why their golf drive is off the mark, so they are not conscious of what to do to put it right. They are what could be defined as *unconscious incompetents* (the base level of the model). It is unlikely they will improve on their knee pain or golf swing until they have seen a specialist who can identify the cause of the problem. When they do consult a specialist — perhaps a manual therapist of some description and a Golf Biomechanic, the individual can be assessed, the problem identified and they move to the next stage and become a *conscious incompetent* — they now know why they are in pain or playing badly.

The next step is to activate the correct muscles in the kinetic chain, or to change the grip on the club, or the stance, or the head position etc in order to create competence. This means that the patient or student has now reached the penultimate stage in the process by becoming a *conscious competent*; if they track their leg with biomechanical precision, their knee pain goes, if they keep their head down and their grip correct, they strike the ball cleanly... but the challenge is building in the repetitions and, in particular, the appropriate loading parameters to change the original behavior so that it becomes unconscious — the person doesn't even need to think about it. At this point a new motor engram is stored; they have reached the pinnacle of the model and can be considered an *unconscious competent*.

The issue with motor control interventions to date, is that an often inappropriate duration of loading, which targets the wrong motor fibers (usually the more phasic, type 2A fibers) is prescribed, meaning intervention outcomes are likely to be ineffective.

The issue here being that, while the type 1 fibers will activate immediately, the dominant energy systems are the type 2 energy systems — in particular the type 2A system (For clarity, it is unlikely that a patient would get much activation of their type 2b fibers unless the loading itself was very high). As can be seen in Fig. 1, the type 2A fibers will activate early and will be the dominant energy system until the 3—5 min window, when the type 1 fibers become the dominant system. This is why even what some may consider very basic low-load exercises become fatiguing so quickly — because anaerobic metabolism is being utilized in the recruitment of type 2A fibers.

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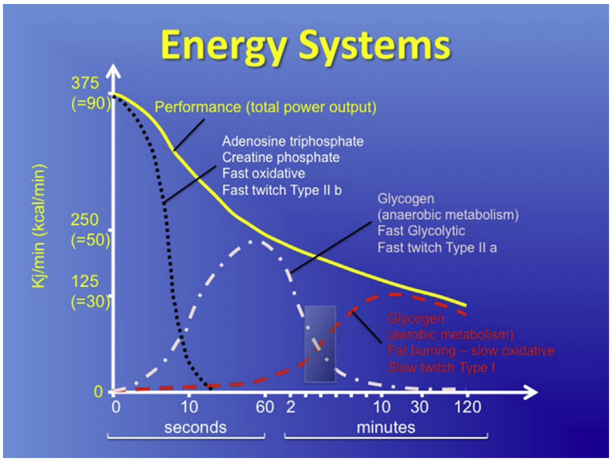

Figure 1 Energy Systems: This classic diagram, redrawn from Telle (1995), illustrates how the 3 key energy systems, which correspond with the 3 key fibre types, are utilized in performance. This helps the clinician to understand how to effectively design exercise programs to target different muscle groups and specific fibers within those groups.

In order to train the type 1, or postural muscle fibers, it is key, then, that the total time under tension is a minimum of 3–5 min (see the accompanying practical article for an example of how this can be applied).

Most motor control trainings or research studies do not take these acute exercise variables into consideration, so the type 2A fibers become trained, but they also fatigue quickly (as shown in Fig. 1), so cannot effectively stabilize the joint(s) they span for more than a few minutes. The end result is an intervention that sees the patient reaching conscious competence, but never attaining unconscious competence — or full recovery. Clinically these patients tend to present with a typically "shifty" behavior, where they fidget, lean against things, find their pain is better when moving than when still, and that it is absent first thing in the day, but comes on later when the fast twitch (or outer unit musculature) has finally run out of compensatory capacity.

The science behind program design

By far the most common number of repetitions for a patient to be given for a rehabilitation exercise is "*About 10*". If time-travel were possible and a clinic could be attended 100 years back, it is likely that the most common number would have been "*About a dozen*".

However, in the 21st Century, there is the advantage of a huge body of literature around the effect of doing an exercise, just 10 times versus 20 times (the repetitions), together with the effects of intensity, time-under-tension, number of sets, rest periods between sets, loading parameters, speed of contraction, motor sequencing, specificity and so on (Chek, 1995). It is known, for example, that 10 repetitions is a loading parameter that offers optimal hypertrophy (assuming the load is sufficient, so that the patient can *only* perform 10 repetitions before complete fatigue), but that this number of repetitions creates a lower capacity for motor learning, compared to 20 repetitions, for example (see Fig. 2).

At the high-end of performance, or even for those who are attending a gym for the first time, it is useful to know what the individual's 1-rep max (1-repetition maximum) is for a given group of exercises. In other words, the maximal load that the individual can manage involving the prescribed movement pattern (Bianco et al., 2015). This allows the trainer, or strength and conditioning coach to be able to prescribe exercise-loading parameters that will achieve the desired response.

For example, if someone is learning a new exercise, or is not well conditioned, or requires a strength-endurance stimulus, a repetition range from 12 to 20 repetitions may be desirable. To understand the approximate load required to achieve effective adaptation, this can be calculated at around 70% of the 1 rep max (or 1 RM) or 70% of the load they could lift as a maximal one-off lift. If the maximum load they could squat is 100 KG, then to target a strength-endurance response between 12 and 20 reps, this should be performed with 70% of that 1 RM — or 70 KG as load.

Reciprocally, if someone is trying to build power, without incurring too much hypertrophy stimulus then they may, for example, require a repetition range and load which can be only moved between 3 and 4 times (see Fig. 2). This range will tend to engage the faster twitch type 2B fibers, important for speed or power athletes; but also important in some activities of daily living and as part of a thorough rehabilitation process, as outlined in Wallden (2013b). To calculate these loads, it is useful to know the 1 RM. Taking the same example of someone who can squat 100 KG as their maximum one-time lift (their 1 RM), they would now pick a load equivalent to 90% of their 1 RM — in other words, 90 KG — and this should be an effective training stimulus to train them in the 3–4 rep max range for power (Chek, 1995).

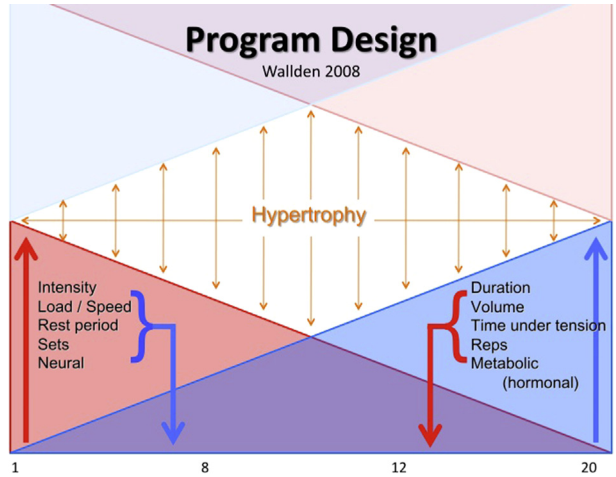

Figure 2 Program Design Summary: This image encapsulates some of the key tenets of program design; illustrating how there is typically an antagonistic relationship between repetitions and sets, between duration and intensity and so on, when designing effective conditioning programs; and the relationship to hypertrophy, which may, or may not be desirable. The numbers along the base of the diagram indicate the repetition range the patient is likely to be working in, with 8–12 repetitions being the classic range considered optimal to induce a hypertrophy response (Wallden, 2008).

Similarly, hypertrophy may also be a desirable phase in both rehabilitation and performance conditioning (Wallden, 2013b) and, for this, training with loads at around 80% of the 1 RM is appropriate. These loads should allow the individual to complete 8–12 repetitions which is right in the middle of the hypertrophy zone (see Fig. 2).

In the accompanying paper which describes a novel way to assess the 1 RM in the bench press, Bianco et al. (2015) use a percentage of body mass to calculate the load an individual should lift (up to 25 repetitions) entered into an equation to help calculate 1 RM. This novel approach helps bodyworkers and movement therapists to safely and effectively predict their patient or athletes' 1 RM.

As Bianco et al. (2015) explain, this may have important ramifications both for the athlete and for those inexperienced in the gym, such as the patients with Fibromyalgia (FM) as described in the Nelson (2015) paper.

Nelson (2015) provides compelling evidence that, not only is exercise important, but specifically that resistance training, or muscle strengthening activities can be of great benefit to the Fibromyalgia population. It is possible, therefore, that patients with similar and related conditions may also benefit., chronic fatigue and post-viral fatigue.

There may be many reasons why muscle strengthening activities work well for the patient with Fibromyalgia. Just as it's more aerobic counterpart, muscle strengthening (or resistance training) can facilitates circulation, especially to the working myofascial chains; it can improve breathing pattern either reflexively through improved biochemistry (described below) or with additional coaching – especially if this is worked on in recovery as a strong parasympathetic rebound after activity can facilitate the rest/digest abdominal breathing pattern and can push the body into a repair mode (Chek, 1995). However, in addition to these benefits of general exercise muscle strengthening activities may have other benefits, which include increasing growth hormone output, reducing circulating inflammatory markers, minimizing adrenal stress and, importantly, teaching the patient that pain is not always a negative indicator; that it can be a part of growth and development, and that it will ease with time.

It should be stressed that there are still many people – including bodyworkers and movement professionals – who believe that resistance training is primarily for aesthetic gains and brute strength, but has no place in health. This may be a view that is skewed by an era of fixed-axis machine training, which probably caused more issues than it solved biomechanically. But functional exercises are those exercises that serve the function for which they are intended; and for most people that would be exercise that increases their sense of well-being, their performance capabilities and their overall health. Anyone in pursuit of such an objective would, therefore, be likely to include muscle strengthening exercises as part of their program.

Nelson (2015) concludes her paper by stating that "Future studies must provide explicit details with regard to frequency, intensity, duration and type of muscle strengthening exercise", and he is right. One of the theories behind Fibromyalgia has its basis in a dysfunctional interplay between growth hormone (Chaitow et al. 2005) and other anabolic hormones, including IGF-1 and ghrelin (Tander et al. 2007). Poliquin (2006) explains that if resistance training is conducted using optimal acute exercise variables, serum growth hormone levels can increase by as much as 20-fold. Since growth hormone is key in entering the deep, restorative, delta-wave phase of sleep usually compromised in FM, it is entirely possible that the muscle strengthening activities assessed by Nelson (2015) helped to drive GH levels higher. Similarly, Ratey & Hagerman (2008) explain that simply partaking in steady-state exercise, such as cycling or treadmill running (classic "cardiovascular" exercise) results in more of a catabolic effect, whereas including some high-intensity sprints into the cardiovascular training (a form of interval training) increases growth hormone secretion dramatically. Adding a single bout of sprinting (high-intensity exercise) to a run or ride, for as little as 30 s, generated a 6-fold increase in GH. Poliquin also describes how the release of cortisol with cardiovascular exercise tends to ramp up dramatically after 20 min of activity; inducing a fight-flight, catabolic state and, for those with breathing pattern disorders, adrenal fatigue or anxiety, an increased risk of exacerbation. Looking at it from the opposite perspective, research into gym-based functional movement assessment showed that Individuals who exhibited biochemical and biomechanical signs of BPD were significantly more likely to score poorly on movement screening tests (Bradley and Esformes, 2014). Overall then, it seems plausible and likely there may be a bidirectional effect of exercise on breathing pattern and breathing pattern on exercise pattern; and since BPD may be both a component of and causative in FM this may help to explain why the results of Nelson's (2015) enquiry into resistance based training interventions were so positive.

Indeed, in Fig. 2 this phenomenon is illustrated, showing how the higher the number of repetitions, the greater the hormonal (catabolic) stress. The lower the repetitions (and therefore heavier the load), the more the neural stress. Hence, for those in a state of fatigue, resistance training programs may be very effective; and more-so the more they tend to stay towards the higher-intensity left side of the diagram.

Since exercise can be effective in managing anxiety (Ratey and Hagerman, 2008) and this can be effective in managing BPD (Chaitow, 2004) this could set up a positive feedback loop to also benefit patients with FM. Additionally, as Chaitow (2004) explains, the general deconditioning often associated with BPD and with fibromyalgia (Nelson, 2015) results in a lower aerobic threshold, meaning that patients enter a state of oxygen debt sooner. This may initiate a cascade of events resulting in anxiety, hyperventilation and increased production of lactic acid, pyruvate and other waste metabolites within the muscles, thereby increasing pain, soreness and the tender point/trigger point development that defines fibromyalgia.

Beyond growth hormone, there is also evidence that higher intensity exercise increases ghrelin production in an intensity dependent manner (Fathia et al. 2010) and that low levels of ghrelin are associated with some of the symptoms of FM (Tander et al. 2007).

You can only train as hard as you rest

In athletic conditioning, the concept of over-training or pattern-overload has been broadly accepted for some time;

and in clinical practice, its counterparts repetitive strain injury and cumulative trauma disorders (Check, 2000; Solomonow, 2012) are also well-established phenomena.

In 2003, this author proposed a model to help explain why some people with poor posture, or poor technique, or poor lifestyle choices (as examples) may seem to get by just fine, while others seem to fall prey to such minor, but repeated, misdemeanours (see Fig. 3). This model proposes that the cumulative stressors on the system (biomechanical, biochemical or limbic emotions) naturally increase as the individual passes through life; but that these stressors are always responded to by the healing rate, which typically starts high as a child, but declines as we age. For example, according to Poliquin (2006), growth hormone levels decrease by 14% per decade from the age of 20 years onward. The stressors are manageable largely by optimizing the biomechanical profile — and other lifestyle choices, to some degree. The healing rate, is manageable primarily through lifestyle choices, but also through optimizing biomechanical function.

The role of the rehabilitation specialist is to optimize both the healing rate (which means encouraging what can be done to increase it) and the damage rate (which means encouraging what can be done to decrease it). It is only when the rate of damage exceeds the rate of repair that the tissue (or organ) will fail.

This understanding can be useful in getting clarity on the subheading of this section; *You can only train as hard as you rest*. The purpose of training is typically to create a positive stress causing controlled damage, which initiates a healing response for that tissue to re-grow stronger. Too much positive stress (overtraining) can result in too much damage (the rate of trauma has exceeded the rate of healing) and an inability to recover, injury or illness may ensue. From this perspective, the rest between training sessions is important to consider; as well as the resting of certain movement patterns or muscle groups.

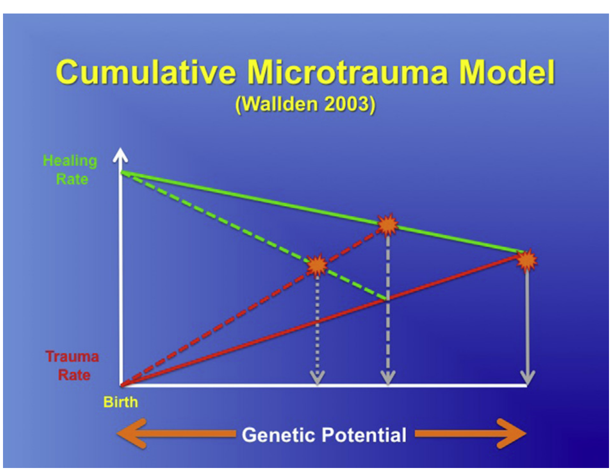

Figure 3 Cumulative Microtrauma Model: Cumulative microtrauma, by its nature, accumulates throughout life. However, it is always competing with the body's ability to repair. When the rate of damage exceeds the rate of repair, this is when the tissue, organ or system fails. Ideally, this occurs only at the end of the individual's genetic potential. However, if biomechanics are compromised (such as length-tension relationships), the rate of cumulative microtrauma will increase and may exceed the body's ability to repair itself earlier than the genetic potential (dashed line). This would be common in the patient base. If the nutrition & lifestyle habits of the patient are compromised, the repair rate will drop sooner, meaning that tissue break-down would occur even sooner (dotted line) (Wallden, 2003).

Beyond this, the rest periods utilized between the sets of any given exercise will also dictate the effect that the exercise has. Fig. 4 illustrates how the 3 core fiber types (there are many more than 3, but there are 3 accepted "general" fiber types) react to work.

- The fast twitch type 2b fibers react to work by fatiguing very rapidly — indeed within around 8 s their capacity is all-but spent, which is why it is said the fastest sprinter across the 100 m finish is not the athlete who is accelerating fastest, but the athlete who is decelerating slowest. These muscle fibers require a minimum of 5 min to recover.
- The fast twitch type 2a fibers react to work by fatiguing within 60–120 s of work (depending on intensity and conditioning level), but will recover quicker — within 2–3 min in general.
- The slow twitch muscle fibers (those most targeted in early-phase rehabilitation) will recover very rapidly — almost fully within 1 min.

The key difference in training these muscle fibers is that, in general, to target the faster muscle fibers, *sufficient* rest periods are required. But in order to target and condition the slow twitch, type 1 fibers, *insufficient* rest is

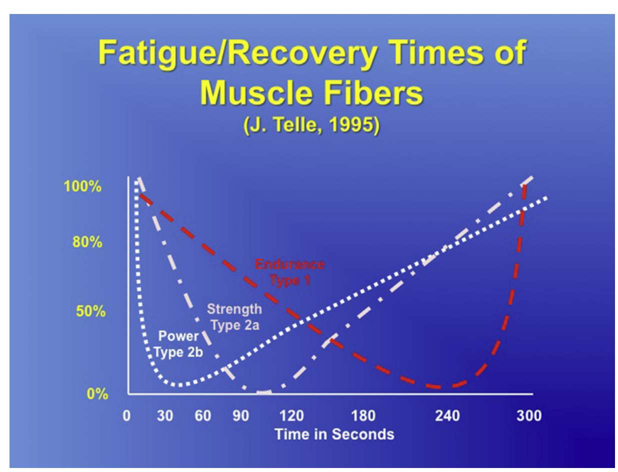

Figure 4 Fatigue & Muscle Recovery Times: This image, redrawn from Telle (1995) illustrates how rapidly the 3 key fiber types reach fatigue and how long it takes for them to recover from this point. This can inform the clinician in designing conditioning programs. In general, the rule is that faster twitch fibers must be given the time to fully recover (otherwise the body defaults to slower twitch fibers — defeating the object of training), whereas slow-twitch fibers should not be allowed the time to recover fully, in order to create a training stimulus (Chek, 1995).

required. Of course, there are myriad nuances and permutations but, as a basic rule in rehabilitation and conditioning, this is worth bearing in mind.

Conclusion

Understanding the possible applications of acute exercise variables can be complex and, like any field of specialty, can be taken to great depths of exploration. The program design summary slide (Fig. 2 above) was created to help condense some of the key tenets of strength conditioning into one diagram. Looking from the left, the triangle (coloured red in the digital version of the journal) running from left to right of the illustration shows how when exercise intensity is high, it's counterpart — duration — tends to be low. When load or speed are high, the volume is low. In this instance, rest periods need to be high, the number of sets of the exercise performed should be high, and the key stress is neural.

Reciprocally, looking at the triangle from right to left (coloured blue in the digital version) when the duration of an exercise is high, the intensity (in strength conditioning terms) is low. The volume is high, and the loads or the speeds are typically low. For this kind of exercise the rest period between sets should be kept short — perhaps as little as 30 s to prevent full recovery between sets. The repetitions are typically high (although isometric holds are potentially an exception to this rule) and therefore the sets are low. This kind of exercise tends to be more stressful to the hormonal system — in particular increasing cortisol secretion.

From a strength conditioning point of view, the number of repetitions typical to fall toward the left side of the table are 1—6 repetitions; often considered the "power" zone, where hypertrophy gains are relatively small (as depicted by the diamond "hypertrophy zone" in the centre of the image). There is a zone between 6 and 8 repetitions often termed "maximum strength", but loads that can be lifted a maximum of 8—12 repetitions tend to be prime candidates for building muscle bulk; which may be desirable in some situations, and in others undesirable. Finally there is the 12—20 repetition range (and beyond) where hypertrophy gains are not so strong, and hormonal stress is increasing. This is often termed the "strength-endurance zone" and can be useful in base-conditioning, for specific endeavours or sports requiring this quality, and for honing technique in a certain movement pattern, due to the number of repetitions.

Resistance training and, specifically, the acute exercise variables is often poorly understood in rehabilitation field, yet its application could benefit many patients; not just those specializing in biomechanical rehabilitation, but those working with more complex and chronic health conditions.

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