The Science of Health, Nutrition and Fitness

Training to Failure **Author: Carl Conroy**

One of the most controversial areas of resistance training, especially where bodybuilding is concerned, is should an athlete train to failure in order to realise muscular gains and strength improvements. This article will look at the rationale behind the premise and attempt to arrive at a scientific conclusion to the time honoured question.

Before we attempt to analyse and rationalise the science behind this theory we should first arrive at a definition of what ‘failure’ implies. Our definition for training to failure will be *‘decreased ability to generate appropriate amounts of muscle force or power during on-going contractile activity’.* At this juncture the lifter would have to be rescued by a spotter if on a bench exercise; or would have to rack the weight in a standing exercise. This inability to further perform a repetition i.e. achieve failure *could* be due to a number of physiological factors which are encompassed under the banner of ‘*fatigue*’. Such factors could include some of the following:

- **Reduced Intracellular pH** – Lactic acid builds-up in the muscle cell causing a reduced intracellular pH (increased acidity causes failure of Ca2+ release and inhibition of contractile proteins) which affects force development. (Mainwood, G.W. *et al,* 1987; Chin E.R., 1998)
- **Reduced Intramuscular ATP** – When ATP stores deplete, muscles might not have enough energy to contract. (Karatzaferi C., *et al*, 2001). ATP and PCr utilization is greater in type II compared with type I fibres (Casey *et al*, 1996) and total restoration of ATP will not occur in the first four minutes of rest for the type II fibres. However, in type I fibres four minutes are sufficient to allow full ATP restoration to occur. Therefore if a second set were carried out within a four or five minute period the type II fibres would be incapable of significant force production. (Casey *et al*, 1996).
- **Accumulation of Inorganic Phosphate** (P_i) – Concentration of P_i increases during intense skeletal muscle activity, mainly due to breakdown of PCr. High force production in cross bridges within the sarcomere of the muscle cell is hindered by this increased P_i . (Westerblad , H. ,2002)
- **Reduced Creating Phosphate** – Creatine phosphate (PCr) is a high energy compound used in anaerobic metabolism to re-synthesise ATP. There are limited stores of PCr in the muscles. This high energy ‘molecule’ is predominantly used by FTb fibres. The rate of depletion will be dictated by the intensity of the exercise. If PCr is depleted complete fatigue will occur in the working muscles. (Hirvonen, J. et al, 1992; Karatzaferi C., *et al*, 2001)
- **PNS Fatigue** – Peripheral nervous system fatigue occurs differently for low intensity and high intensity exercise. Similarly to CNS fatigue; PNS fatigue may be due to a number of complex physiological reasons. Factors such as ionic adaptations i.e. Ca2+, NA+ and K+; decreases in substrate availability i.e. PCr and glycogen; hypoxia, acidosis and accumulation of inorganic Pi might all be influential influences behind PNS fatigue. These metabolic changes can cause fatigue by acting on nerve processes that activate muscles.
- **CNS Fatigue** – Unwillingness to generate and maintain adequate CNS drive to the working muscle during exercise, is the most likely explanation of fatigue for most people during normal activities. It is believed that several neurotransmitters and the influence they exert on the brain

are influential to the fatigued state. Davis J.M. and Bailey S.P. (1997) also asserted that '*Accumulation of ammonia in the blood and brain during exercise could also negatively affect the CNS function and fatigue*'. Serotonin levels are also increased during intense exercise and these higher levels can increase perceptions of effort and peripheral muscle fatigue (Young, S. N. 1996). CNS fatigue is a highly complex area of significance.

- **Increased Heat** – As exercise ensues and intensifies, the requirement for energy will be increased. This increased metabolism and mechanical muscular effort will increase heat within the body. Indeed up to 80% of the oxygen consumed in exercise ends up as heat rather than facilitating mechanical work. If the environment is both hot and humid the core body temperature can rise significantly and this hypothermic environment can result in impedance of several physiological mechanisms including the CNS and PNS which are involved with development of muscle force. (Nybo & Secher, 2004).

When an organism is stressed beyond its physiological 'normal' capabilities; then that organism will potentially realise adaptation; to ensure that it can more fully cope with the stressor if it is experienced again. Realisation of absolute muscular fatigue i.e. repetition failure, is the stressor utilised to enforce this physiological response and thus chronic adaptation. This is the premise behind 'training to failure'.

It is theorised that when the working muscles are taken to muscular failure any or all of the following factors may be influenced. Increased muscle activation i.e. greater motor unit recruitment (Stone *et al.*, 1996 and Tan, 1999); more mechanical stressed based protein damage which would result in increased synthesis (Stone *et al,* 1996); increased anabolic hormone levels (Kraemer & Ratamess, 2005) or fibre transitioning i.e. ST fibres taking on FT fibre capabilities (Fry, 2004). Adaptation in any of these areas could result in increased strength gains and indeed increased muscle fibre cross sectional area.

Now we have established the relationships between the physiological systems and total muscular fatigue, let us now look at the evidence that supports muscular failure training.

Is training to failure effective or not? Some notable studies have supported the effectiveness of 'failure' training. In a study carried out on a number of elite basketball and football players, the researchers found that, *'Bench press training that leads to repetition failure induced greater strength gains than non-failure training in the bench press exercise for elite junior team sport athletes*'(Drinkwater *et al* , 2005). Ahtiainen *et al* (2003) asserted that '*forced repetition exercise system induced greater acute hormonal and neuromuscular responses than a traditional maximum repetition exercise system'*. Schoenfeld B.J. (2013) postulated that '*Current research indicates that low-load exercise taken to failure can indeed promote increases in muscle growth in untrained subjects, and that these gains may be functionally, metabolically, and/or aesthetically meaningful'*. The suggestion is that this low load training method closely mimics blood flow restriction training which has been shown to have positive '*marked effects on muscle hypertrophy'*. Rooney *et al*, 1994, carried out research on the roles of fatigue in weight training and concluded that, '*the processes associated with fatigue contribute to the strength training stimulus'*. Other studies have supported training to failure (Goto *et al,* 2007; Willardson, 2007) but there is also some opposing research.

The above studies have asserted that 'failure' training indeed is a positive method of training for a strength athlete or a bodybuilder. However, much of the research into this specific area is contrary to the claim that this method of training is an effective strategy for strength and muscular development. Willardson, J. (2007) stated that training to failure, *'is not essential for increases in muscular characteristics such as strength and hypertrophy'*. Izquierdo, M. *et al* (2006) also concurred with this statement when their research indicated that there was '*a potential beneficial stimulus of non-failure training for improving strength and power'*. Sanborn *et al* (2000) in a study comparing the effectiveness of multiple set training and a single set taken to failure, established that '*Body* *mass did not change significantly over time*' and that '*results generally show a superior adaptation for the multiples sets group*'. Kramer *et al*, 1997, carried out a similar research programme to Sanborn in that they compared two multiple non- failure sets to a single set taken to failure. They found that '*multiple sets not performed to failure produce superior gains in the 1-RM squat'*. Folland *et al*, 2002 established that '*Fatigue and metabolite accumulation do not appear to be critical stimuli for strength gain, and resistance training can be effective without the severe discomfort and acute physical effort associated with fatiguing contractions'*. So further compounding the premise that training to failure is not necessarily an inherent requirement where stimulation for adaptation is required.

So where does that leave the trainee who is looking for an answer to this question? The following guidelines address some of the ways in which training to failure may be beneficial if employed in a training regimen:

- Use failure training as part of a 'periodization' training year.
- Only use failure sets in one or two exercises for the last two sets.
- Allow adequate acute recovery periods between work sets when using failure.
- Allow adequate chronic recovery periods between workouts to avoid injury or overtraining.
- Use a wide expanse of repetition ranges to stimulate all muscle fibres.
- Where possible use machine based resistance to guide technique during the fatigue stages.
- Use a 'spotter' whenever possible to ensure safety.
- Do not use failure training for beginners or early intermediate trainees.

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