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DESIGNING WEIGHT TRAINING PROGRAMS BASED ON BASIC PRINCIPLES

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ABSTRACT

A weight (resistance) training program includes training variables, such as exercises, sets, repetitions and training frequency. A training plan describes how the variables should be modified over time. In order to be effective, both training programs and plans should be based on some basic principles, applicable to all trainees. Based on the literature review, the most important and well supported is the principle of progressive overload, which states that the stimulus should be gradually increasing over time. The principle of specificity states that the training adaptations are specific to the stimulus applied, while the principle of variation (and periodization) states that the stimulus should change (within the specificity limits) to remain challenging. Although they are not necessary to increase performance, there is evidence supporting higher improvements. The principle of individuality states that the stimulus should be adjusted based on the individual's needs. Even though overlooked, limited data indicate that it may be more important than specificity and variation. This paper discusses the basic principles, the criticism against them, and how they should be applied when designing resistance training programs.

Contribution/Originality: This study documents the principles that a weight training plan should be based on some basic principles, applicable to all trainees. This study contributes in the existing literature by clarifying the confusion and misconceptions on the topic.

1. INTRODUCTION

Weight training is commonly used to increase strength, muscle mass and even improve health (Benito, Cupeiro, Ramos-Campo, Alcaraz, & Rubio-Arias, 2020; Kraschnewski et al., 2016). The training programs include a selection of exercises, sets and repetitions. More advanced programs give details of repetition duration, rest intervals and can include advanced techniques such as negative repetitions, super sets etc. (Krzysztofik, Wilk, Wojdała, & Gołaś, 2019). Usually, the weight is increased when the desired number of repetitions has been reached. Every few months the training program changes, typically splitting the body differently and/or changing the frequency of workouts. There is a lot of research on the training variables and their effectiveness or not (Fisher, Steele, Bruce-Low, & Smith, 2011; Howe, Read, & Waldron, 2017; Morton, Colenso-Semple, & Phillips, 2019; Schoenfeld, 2016). Based on such reviews and meta-analyses there are recommendations regarding what training program should be followed, depending on the objectives (strength or hypertrophy). However, the information about long term planning is based on text-books and studies on periodization (Fleck & Kraemer, 2014). In general, the design of a training program is based on some basic principles, such as specificity, specific adaptations to imposed demands, overload, progression, progressive overload, variation, prioritization, individualization,

maintenance, reversibility (detraining) (American College of Sports Medicine, 2010; Haff & Triplett, 2016; Stone, Plisk, & Collins, 2002; Stoppani, 2015). The terminology is not standard and there is sometimes confusion (for example some training systems were called Weider principles) (Weider & Reynolds, 1983). Furthermore, the importance or the credibility of these principles has not been evaluated. Objective of this study is to summarize the principles of weight training and support and/or criticize them based on the scientific literature.

2. METHODS

"Principle" is used here as a rule of how the laws of nature are applied. The principles can be extracted by the muscle physiology and the adaptations that take place after weight training. The main sources of this overview were textbooks. In addition, these principles were searched in internet search engines and PubMed.

3. RESULTS

The basic principles are (American College of Sports Medicine, 2010; Baechle & Earle, 2008; Fleck & Kraemer, 2014; Giechaskiel, 2017; Hough & Penn, 2017; Kraemer & Ratamess, 2004; Ratamess, 2012):

- **Progressive overload:** To improve performance there must be a stimulus (workout) and this must be gradually increasing over time.
- **Specificity:** The training stimulus determines the adaptations.
- **Variation (Periodization):** For a training to remain challenging and effective, the training stimulus should change (but within the specificity limits).
- **Individuality:** The training stimulus should be based on the person and its needs. The magnitude of the adaptation (i.e., performance improvement) to the training stimulus is different for each person.

Other principles commonly cited are:

- Reversibility: The positive outcomes (benefits) of training are reversible. When the stimulus discontinues the performance decreases (detraining).
- Interference (concurrent training effect): Simultaneous stimuli of different objectives (e.g., strength and endurance) interfere with each other, slowing improvements in one or all objectives.
- Initial values and diminishing returns (trainability): The improvements slow down as one approaches the genetic ceiling.

The last three principles are indirectly included in the progressive overload, specificity, and individuality principles respectively and will be discussed there.

3.1. Progressive Overload

Progressive overload is the gradual increase of stimulus (load or overload) placed on the body. The physiological basis is that, to induce adaptation in a muscle's motor units, the motor units should be maximally or close to maximally activated (recruited with high firing rates) (MacDougall & Sale, 2014). It originates from ancient Greece: A 6th Century BC wrestler, Milo of Croton, was lifting a baby calf every day, until eventually it became a fully-grown bull. Doing this daily, he increased his muscle mass and strength. The term "progressive resistance exercise" and the application to weights originates from Thomas Delorme, when he rehabilitated soldiers after World War II (Todd, Shurley, & Todd, 2012).

Progressive overload can be accomplished through gradually altering one or more of the training variables (Kraemer & Ratamess, 2004). The increase of the weight (for the same number of repetitions) seems the most important. The small increase of the number of repetitions (1-2) (for the same weight) is also common practice. Small increases of 1-2 kg or 1-2% are the safest that can lead to big increases in the long term. Adding sets or exercises can have positive results, if the volume is not optimal in the first place. Increasing the training frequency is another option that has been suggested to be beneficial (Dankel et al., 2017). Other methods, such as adding

negatives, reducing the rest period or the duration of the repetitions are of secondary importance (Fisher et al., 2011).

Figure 1 plots an example of the progressive overload principle, based on the super-compensation model (Giechaskiel., 2018a; Turner & Comfort, 2018). A workout depletes the resources and the body replenish them and super-compensates them (Goforth Jr et al., 2003; Selye, 1936). When the next training takes place at the right time (peak of super-compensation) and is of appropriate stimulus, the performance will improve over time (e.g. muscle mass or strength). If the next training takes place too soon or is too hard then the performance will drop and after some time will result in overtraining. More advanced techniques of overreaching and tapering to peak on specific days are out of the scope of this paper (Turner & Comfort, 2018).

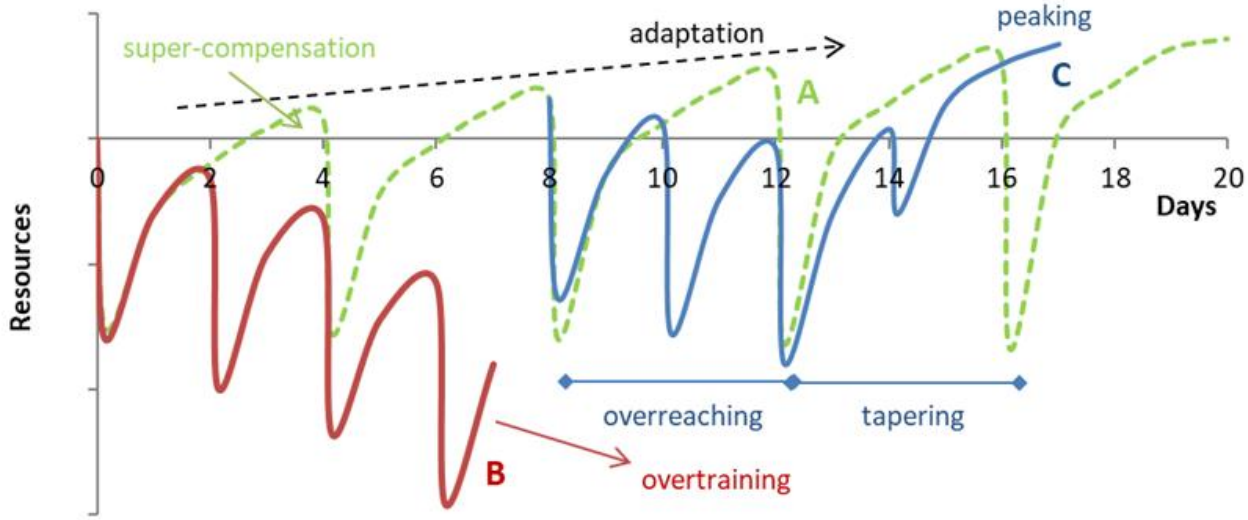

Figure-1. Hypothetical cases: (A) Workout, recovery, and super-compensation cycles that lead to hypertrophy and/or strength increase as adaptations. Note the progressive overload principle: the trainings are more demanding every time; (B) Workout and inadequate recovery cycles that lead to overtraining; (C) at day 8 the training frequency increased (overreaching), then at day 12 the volume decreased (tapering) leading to a higher level (peaking).
Source: Adapted from Giechaskiel (2017).

3.2. Specificity

Specificity states that the training adaptations depend on the stimulus applied, including (ACSM, 2009; Ratamess, 2012; Reilly, Morris, & Whyte, 2009):

- Muscle groups trained.
- Muscle actions involved.
- Speed of movement.
- Range of motion.
- Energy systems involved.

Even though there is some carryover of training effects, the weight training should focus on the specific training goal. Training for very different targets (e.g., both endurance and strength) (concurrent training) will compromise the results (interference effect) (Turner & Comfort, 2018; Wilson et al., 2012). The strength-endurance continuum (actually repetition maximum (RM) continuum) states that lifting heavy weights leads to greater gains in strength, while lifting light weights leads to greater gains in muscular endurance (Campos et al., 2002). Thus, for those interested in strength, few repetitions with high loads should be used (Schoenfeld, Grgic, Ogborn, & Krieger, 2017). The RM continuum was recently criticized (Fisher et al., 2020). The relative increases of strength at the repetition range of 2RM to 10RM translates to similar relative increases of the 1RM (Carpinelli, 2011). However, this is not necessarily true for higher than 30RM (Mitchell et al., 2012). For those interested in hypertrophy the principle of specificity is of lower importance as a wide range of weights (or repetitions) have been proven to be

effective for stimulating muscle protein synthesis and increasing muscle mass (Schoenfeld et al., 2017; Wernbom, Augustsson, & Thome, 2007).

Figure 2 gives a hypothetical example of the specificity principle by plotting the effect of a set on body's metabolic and mechanical systems (Giechaskiel, 2017). Short duration efforts of maximum intensity (e.g., sets of 1-5RM) demand energy from the phosphagen system, activate the whole pool of fibers, and result in myofibrillar hypertrophy. Sets of long duration use energy from oxidation of glycogen (or glucose) and fats, activate mainly Type I fibers, and induce mainly mitochondrial hypertrophy (Grgic & Schoenfeld, 2018).

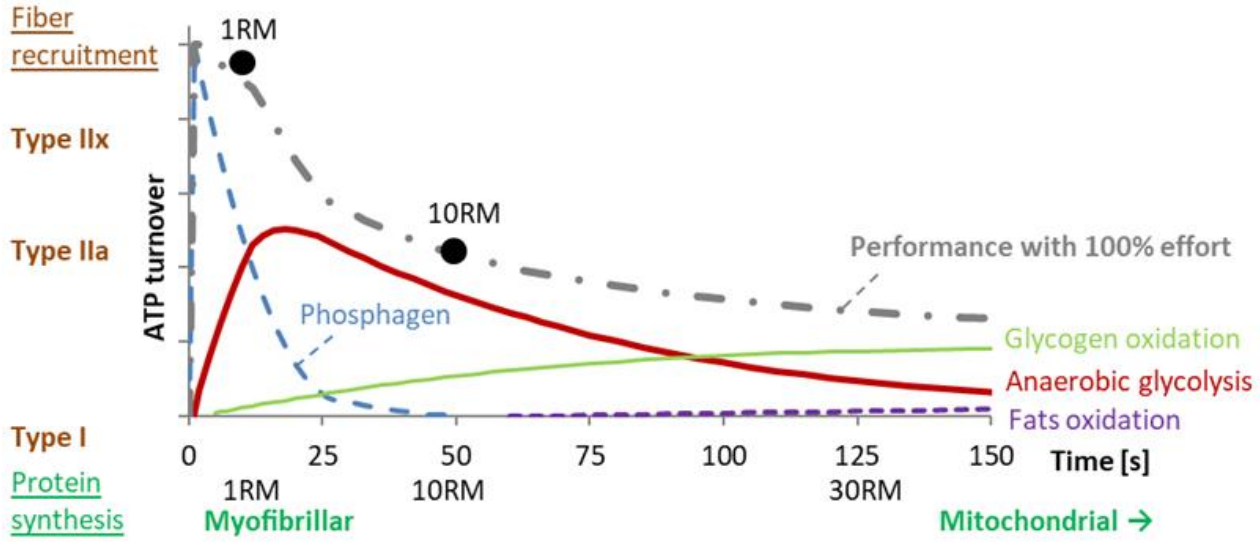

Figure-2. Hypothetical effect of a set on a body's systems (metabolic and mechanical). Short duration efforts of maximum intensity (e.g., sets of 1-5RM) demand energy from the phosphagen system, activate the whole pool of fibers, and result in myofibrillar hypertrophy. Sets of long duration use energy from oxidation of glycogen (or glucose) and fats, activate mainly Type I fibers, and induce mainly mitochondrial hypertrophy. RM=Repetition Maximum.
Source: Adapted from Giechaskiel (2017).

3.3. Variation and Periodization

Variation is the systematic change of one or more program variable(s) over time to allow for the training stimulus to remain challenging and effective. A change may also increase motivation and provide mental stimulation. Random variation might be suitable for persons with busy and relatively unpredictable lives (for instance those going on frequent business trips). Inappropriate increases of the variables (e.g., volume or intensity) might result in overtraining and/or injury. Also, too much variability could reduce the opportunity for the body to adapt to the given stimulus. It should be mentioned that the changes have to be within some limits in order to respect the principle of specificity.

Periodization is the logical, sequential, phasic method of manipulating training variables in order to increase the potential for achieving specific performance goals while minimizing the potential for overtraining and injury through the incorporation of planned recovery (DeWeese, Hornsby, Stone, & Stone, 2015; Williams, Tolusso, Fedewa, & Esco, 2017). The concept of periodization was mainly developed for athletes to achieve peak performance in certain, pre-specified period in time. However, periodization can be effective for everyone and not only for athletes (Evans, 2019; Strohacker, Fazzino, Breslin, & Xu, 2015). The foundations of the theory of periodization were first proposed in the former Soviet Union, where textbooks for coaches and physical education students called for the division of the entire preparation process into separate periods of general and more specialized training (Issurin, 2010).

Reviews and meta-analyses comparing periodized and non-periodized strength-training programs concluded that periodized structures were more effective for both males and females, individuals of varying training backgrounds, and a range of age groups (Rhea & Alderman, 2004; Williams et al., 2017). A review concluded that

the appropriate sequence and combination of training variable manipulation is what produces superior results, and not simply the amount of work or number of repetitions accomplished (Stone, et al., 1999).

It has been criticized that the science and practice of periodization is largely based on anecdotal evidence, and short-term research (Cissik, Hedrick, & Barnes, 2008), especially the theoretical framework that is based upon, the general adaptation syndrome (Buckner et al., 2020). Furthermore, meta-analyses of the topic of periodization are particularly challenging since they attempt to include studies with considerable heterogeneity in the research design and variables considered (Fisher, Steele, Smith, & Gentil, 2018). Finally, the possibility to optimally prepare programs in advance has also come into question (Kiely, 2012).

3.4. Individuality

According to this principle individual responses to a training stimulus depend on the genetics and consequently the stimulus should be adjusted based on the individual and its needs. Any program should consider parameters like (American College of Sports Medicine, 2010; Giechaskiel, 2017):

- Genetics and physical status (age, training age, initial fitness level).
- Specific needs (e.g. prioritization based on strengths and weaknesses, or the demands of the sport or activity).
- Health or injury concerns which may limit the exercises performed or the exercise intensity.
- Desired effort and motivation (is the program recreational, or is "maximal performance" desired?).
- Time availability (per workout and week).
- Availability and preference of equipment (e.g., free weights, machines, elastic bands).
- Environment conditions (rest, stress).

For example, the training program of a person in his 20s with no obligations and stress focusing on strength would be very different to a program for a person in his 50s with many obligations and stress focusing on health. The expectations should also be different.

In particular for genetics, a meta-analysis performed on twins showed that genetic factors explain most (63%) of the variance in handgrip strength (Schutte, Nederend, Hudziak, De Geus, & Bartels, 2016). Heritability estimates are typically >50% for muscle mass (Hsu et al., 2005; Roth, 2012), and 40-50% for the proportion of Type I fibers in human muscles (Simoneau & Bouchard, 1995). The heritability of personality is around 50% (Krueger, South, Johnson, & Iacono, 2008). Even when participants engage in carefully controlled exercise training regimens, the nature of the training response is remarkably heterogeneous, allowing the classification of non-, low-, and high-responders (Ahtiainen et al., 2016). Typically, 20-25% subjects exhibit a very limited hypertrophic response, and another 20-25% show robust muscle hypertrophy (Petrella, Kim, Mayhew, Cross, & Bamman, 2008). Another study found that high responders were predominantly athletes that the training matched the genotype and low responders were mainly from the mismatched group (Jones et al., 2016). In another study with different training protocols, all participants demonstrated a positive response in at least one variable suggesting that the existence of true non-responders to exercise training is unlikely and that different training protocols should be considered when optimizing individual exercise prescription (Bonafiglia et al., 2016). This means, if a training program does not lead to the expected results after a few months, it should be changed in order to match better the genetics of the trainee.

4. DISCUSSION

Designing training plans should be based on the basic principles of progressive overload, specificity, variation and individuality. Figure 3 summarizes the relationship of the principles with a theoretical example. The strength-endurance (or RM) continuum is presented in function of training duration (time) or RM (repetition maximum). Training with low repetitions significantly improves strength, but not endurance. Similarly, training for long duration improves endurance but not strength. Hypertrophy is optimized somewhere in the 8-12RM region.

The principle of specificity states that depending on the goal, the appropriate time or RM should be selected. Thus, one should decide the main objective (e.g. strength, hypertrophy or endurance), because the choice of the training variables will depend on this objective. For example, a program targeting on strength needs to focus on low number of repetitions. Targeting endurance at the same time will slow down the strength improvements (principle of interference or concurrent training effect).

The principle of individuality states that the goals should be realistic based on the current situation (see the two hypertrophy curves for two trainees). Although the curves are similar for all trainees, the optimum RM range and the magnitude of the results will vary. Custom based programs, depending on the genetics of the trainee, will have better results. Of course, the program has to be based on the available time, equipment, health status, injuries, age, training age, etc. Individuals with low initial fitness levels will show faster improvement and greater relative gains. As individuals approach their genetic ceilings, the rate of improvement slows down (principle of initial values and diminishing returns).

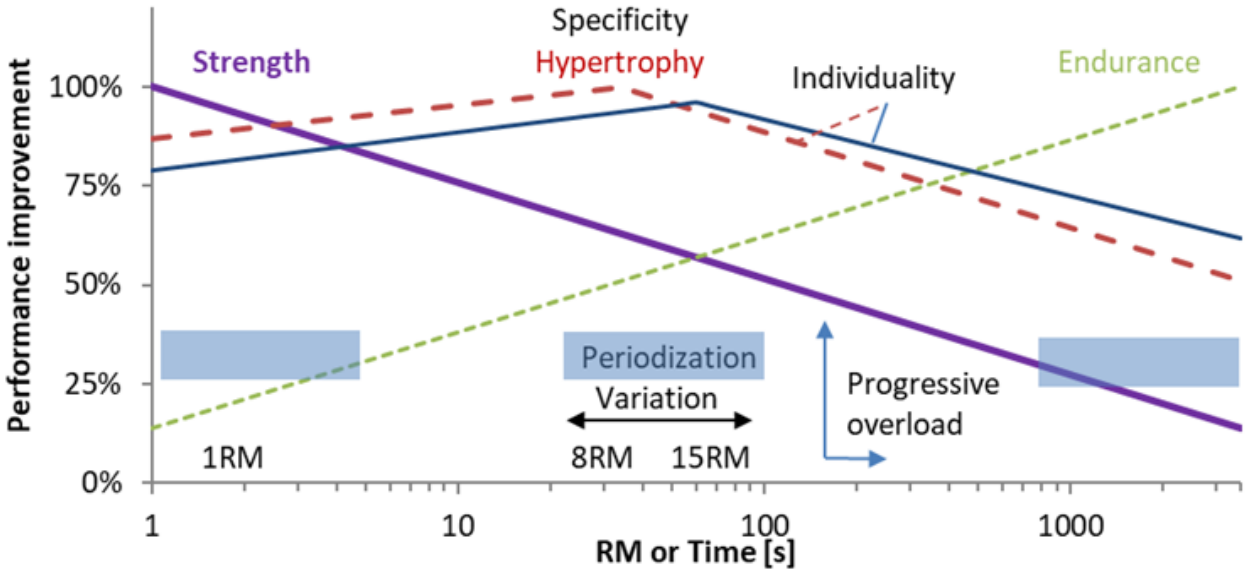

Figure-3. A simplified explanation of the training principles based on theoretical curves of the strength-endurance (RM) continuum. The curves are shown linear in the log-linear plot for simplicity reasons. RM=Repetition Maximum.
Source: Adapted from Giechaskiel (2017).

Whatever the training program, progressive overload is the most important principle to ensure results over time. This is usually achieved by increasing the weights at every workout, or after a specific number of repetitions has been reached (e.g., 10 repetitions). Small increases of 1-2 kg or 1-2% are the safest that can lead to big increases in the long term (Giechaskiel, 2018b). Self-regulated short-term targets can also be useful, as research has demonstrated that self-regulatory progressive resistance exercises resulted in greater improvement in 1RM strength compared to a pre-determined linear progression (Mann, Thyfault, Ivey, & Sayers, 2010). On the other hand, when individuals discontinue their exercise programs (detraining) performance decreases (principle of reversibility). Maintaining the gains is relatively easy and less effort is necessary. Decreased frequency and number of sets can maintain approximately the majority of the gains (Tavares et al., 2017).

Changing the program to maximize the performance responses (variation or periodization) is also recommended. How often changes are needed depends on the targets of the trainee (strength, endurance, hypertrophy). Assuming that the trainee has only one goal (hypertrophy), there is no real need to change the program. A program should go on until it stops being effective and delivering results. On the other hand, decrease of performance is alarming. Monitoring can be done simply writing down the weights and the repetitions or with more complicated techniques (e.g. blood markers such as creatine kinase) (Giechaskiel, 2020a; Giechaskiel, 2020b; Turner & Comfort, 2018). When there are 3-4 weeks without progress, it is time to change the program. This could

mean a small change in the frequency, or the number of sets. But it could also mean a completely different program (e.g., different split of muscle groups and exercises). For persons that like changes, the periodization principle might be suitable: There is a structured variation of intensity, volume and frequency over the time. However, this structured approach requires the trainee to possess better organization capabilities.

As Figure 3 shows, the principle of variation states that, within the boundaries defined by the principle of specificity, small changes can further increase improvements. The periodization is an extension of the variation when other goals are necessary (e.g. strength and endurance). With periodization the training focuses on different goals at different periods in time.

5. CONCLUSIONS

This short overview summarized the basic principles that should be applied when designing a weight training program and plan. Clearly, the most important and well supported is the progressive overload that requires gradual increases of the stimulus over time. The principle of specificity states that the adaptations depend on the training stimulus, while the principle of variation states that in order to keep the stimulus effective it should be varied within the specificity limits. The periodization is an organized variation to accommodate different, and sometimes conflicting objectives, over different time periods. Even though there is enough evidence to support the principles of specificity and variation/periodization, there are also many indications that they are not necessary for the increase of the performance. Their application though, might help the trainee to get faster and closer to the genetic limit. An overlooked principle is the one of individualization. Any program should be tailored according to the needs and genetics of the trainee. Although the data are still limited, it could be even more important than the principles of specificity and variation/periodization.

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