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point-of-view

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When duration matters: rethinking resistance training load through time under tension

Quando a duração importa: repensando a intensidade no treinamento resistido por meio do tempo sob tensão

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Abstract – The traditional volume × intensity model in resistance training, defined as sets × repetitions × load, fails to account for the duration of muscular effort. This oversight neglects the importance of Time Under Tension (TUT)—the total time a muscle is actively contracting during exercise—which significantly influences hypertrophic, metabolic, and neuromuscular adaptations. Recent studies have demonstrated that manipulating repetition tempo alters muscle activation patterns, regional hypertrophy, and fatigue accumulation, regardless of total load. For instance, prolonged eccentric tempos increase muscle damage and protein synthesis, while faster concentric actions may enhance power. Furthermore, TUT provides a practical strategy for delivering sufficient mechanical tension using lower loads, making it particularly valuable for older adults, clinical populations, and athletes during deloading phases. Despite natural tempo deviations under fatigue—especially in later repetitions—approximately 70% of repetitions are typically performed with the intended cadence, supporting the viability of TUT-based programming. This viewpoint advocates for the inclusion of TUT in load quantification models and proposes a revised equation that integrates duration: Volume = sets × reps × load × time per rep. Incorporating TUT may improve the precision of training prescriptions, enhance individualization, and provide a more complete understanding of internal training load and adaptation.

Key words: Resistance training; Muscle contraction; Exercise therapy.

Resumo – *O modelo tradicional de volume × intensidade no treinamento resistido, definido como séries × repetições × carga, não considera a duração do esforço muscular. Essa limitação ignora a importância do Time Under Tension (TUT) (Tempo sob Tensão – TST) – o tempo total em que o músculo permanece ativamente contraído durante o exercício –, que influencia significativamente as adaptações hipertróficas, metabólicas e neuromusculares. Estudos recentes demonstram que a manipulação do tempo de repetição altera padrões de ativação muscular, hipertrofia regional e acúmulo de fadiga, independentemente da carga total. Por exemplo, tempos excêntricos prolongados aumentam o dano muscular e a síntese proteica, enquanto ações concêntricas rápidas podem favorecer o desenvolvimento de potência. Além disso, o TUT é uma estratégia prática para fornecer tensão mecânica suficiente com cargas mais baixas, sendo especialmente útil para idosos, populações clínicas e atletas em fases de recuperação. Apesar de desvios naturais no tempo sob tensão nas últimas repetições – devido à fadiga –, cerca de 70% das repetições costumam ser realizadas com a cadência prescrita, o que reforça a viabilidade do uso do TUT. Este ponto de vista defende a inclusão do TUT nos modelos de quantificação da carga de treino e propõe uma equação revisada que integra a duração: Volume = séries × repetições × carga × tempo por repetição. Incorporar o TUT pode melhorar a precisão das prescrições de treinamento, aprimorar a individualização e proporcionar uma compreensão mais completa da carga interna de treinamento e da adaptação.*

Palavras-chaves: *Treinamento resistido; Contração muscular; Terapia por exercício.*

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INTRODUCTION

Resistance training prescription traditionally relies on the volume × intensity equation, in which volume is commonly defined as the product of sets, repetitions, and absolute load. While this approach has proven effective in various settings, it carries a notable limitation: the absence of a temporal component. In other words, it overlooks *how long* the muscle remains under tension during an exercise—a factor that can substantially influence neuromuscular adaptations[1]. This viewpoint aims to critically analyze the role of Time Under Tension (TUT) as a complementary marker of intensity and an essential component of total training load. My arguments are that TUT should be incorporated into volume quantification, particularly in contexts focused on muscular hypertrophy, local endurance, and metabolic adaptations.

Traditional models of resistance training (RT) prescription have long emphasized the manipulation of load, sets, and repetitions to modulate intensity and volume. These variables have proven sufficient in numerous contexts, including strength development, hypertrophy, and muscular endurance. However, a growing body of literature suggests that these parameters do not fully account for the total mechanical and metabolic stress imposed on the muscle-tendon unit during training[2]. The omission of temporal dynamics—namely, how long a muscle remains under tension—may lead to an incomplete understanding of the internal load experienced by the musculature.

Time Under Tension (TUT) captures this dimension by quantifying the duration of muscular contraction across concentric, eccentric, and isometric phases of a lift. This parameter has gained attention due to its influence on intracellular signaling pathways, metabolite accumulation, and fatigue profiles, which in turn affect training outcomes[3]. Furthermore, recent advances in electromyographic and imaging techniques have provided evidence that distinct cadences can result in region-specific hypertrophy, varied recruitment patterns, and differences in neuromuscular efficiency, independent of total load lifted[4]. For instance, slower eccentric tempos appear to induce greater muscle damage and hypertrophic signaling, whereas faster concentric tempos may optimize power development.

These nuanced effects cannot be captured by traditional volume calculations alone. TUT also has implications in exercise prescription for specific populations, such as older adults, individuals undergoing rehabilitation, and athletes in off-season or deload phases. In these contexts, TUT provides a method for maximizing mechanical tension without necessitating high external loads, thereby reducing joint stress and the risk of injury while still promoting anabolic adaptations[5]. Given the multidimensional impact of TUT on resistance training outcomes, it is imperative that its role be reconsidered in load quantification models. This viewpoint aims to expand the conceptual framework of training volume by integrating TUT as a key component of internal load and to encourage further empirical exploration into its practical utility across diverse training contexts.

The Volume × Intensity Equation: A Limited Perspective

In resistance training practice, volume has been traditionally calculated as: *Volume = sets × repetitions × load*. This model assumes that 10 repetitions at 100 kg elicit the same physiological stimulus regardless of execution tempo.

However, it is unreasonable to assume that a set completed in 15 seconds offers the same neuromuscular stress as another performed over 45 seconds, even with identical external load and repetition count[6]. This discrepancy becomes more evident in hypertrophy-oriented protocols, where time under sustained tension directly impacts motor unit recruitment, metabolite accumulation, and local fatigue[7]. Nevertheless, most studies and training prescriptions continue to overlook this variable.

Time Under Tension as a Physiological Marker of Intensity

Time Under Tension (TUT) refers to the total time a muscle remains actively contracting during a given set. It is determined by the repetition tempo (e.g., 2 seconds concentric, 0 isometric, 2 eccentric) multiplied by the number of repetitions. Thus, a 10-repetition set at a 2:0:2 tempo yields a TUT of 40 seconds.

Evidence suggests that manipulating TUT significantly alters training adaptations. Prolonged TUT protocols tend to enhance metabolic stress, activate anabolic pathways such as mTOR signaling, and increase hypertrophic response—even with moderate loads[8]. For instance, Burd et al.[9] demonstrated that low-load resistance exercise with prolonged TUT resulted in greater protein synthesis than high-load with short duration under tension.

Additionally, literature indicates that when hypertrophy is the primary goal, sustained mechanical tension may be more relevant than absolute load alone[7]. This supports the inclusion of TUT as a meaningful intensity marker—especially in non-athlete populations or clinical scenarios where high external loads are contraindicated[10].

Practical Implications and TUT-Based Prescription

Incorporating TUT into training prescription can enhance both effectiveness and control of the training stimulus. Consider the following practical examples:

Example 1:

3 sets of 10 reps at 70% 1RM with a 1:0:1 tempo → TUT ≈ 20 seconds per set.

Example 2:

3 sets of 10 reps with the same load at a 2:0:2 tempo → TUT ≈ 40 seconds per set.

Although it is well recognized that in practical settings individuals tend to accelerate movement during the final repetitions of a set—especially under conditions of fatigue—there is still merit in considering TUT as a prescriptive variable. Despite this common deviation from target cadence, evidence and anecdotal observations suggest that approximately 70% of the intended repetitions are typically performed with the prescribed tempo, especially during the initial portion of the set. Therefore, integrating TUT into the training framework remains a valuable strategy for enhancing stimulus control, even if slight deviations occur toward the end of the set.

Despite identical "classic" volume (30 repetitions × 70% 1RM), the neuromuscular and metabolic demands differ substantially. An alternative is to revise the traditional volume formula to integrate TUT: *Functional Volume = sets × reps × load × average time per repetition.*

Under this point of view, It should be considered functional volume for equalized volume comparation within experimental protocols. Following I will demonstrate that a real date based on experiment aimed to compare resistance training conditions for healthy people, group A versus group B, Figure 1.

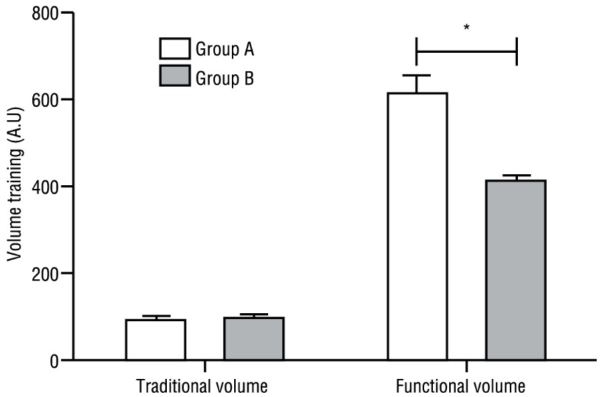

Figure 1. Real date analyzed under two conditions for training volume: Traditional volume: load x set x repetitions; Functional volume: load x set x repetitions x TUT, in this configuration, group A had 6s of TUT, and group B had 4s of TUT. * Express statistical difference.

This adjusted formula offers greater precision in prescription, protocol comparison, and training stimulus control.

TUT applicability extends across diverse populations:

Older adults: high TUT with low loads promotes adaptations while minimizing joint stress[11].

Aesthetic hypertrophy: controlling TUT maximizes tension time in target muscles[8].

Athletes: TUT manipulation allows for the development of muscular endurance without necessarily reducing external load[12].

FINAL CONSIDERATIONS

The traditional volume × intensity equation, while widely accepted, fails to account for key components of physiological overload. TUT introduces a critical temporal dimension for more accurately quantifying muscular effort during resistance training.

Its use not only expands our understanding of adaptation mechanisms but also provides practitioners and researchers with a valuable tool for individualization, monitoring, and optimization of training loads.

If load reflects "*how much*" and repetition reflects "*how many times*," then TUT tells us for "*how long*" the system was challenged. Therefore, when duration matters, repetition count alone is no longer enough.

COMPLIANCE WITH ETHICAL STANDARDS

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Ethical approval

This research is in accordance with the standards set by the Declaration of Helsinki

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: N/A; Performed the experiments: N/A; Analyzed the data: N/A; Contributed reagents/materials/analysis tools: ESB; Wrote the paper: ESB.

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