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Editorial

Total work equalization: a mathematical strategy for the comparison of different exercises in clinical trials

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ABSTRACT

Greater amounts of human movement involve greater amounts of physical work and, consequently, greater metabolic energy expenditure. Therefore, when comparing the effects of different exercise interventions, it is imperative to understand, delineate, and assess the cumulative effort induced by each exercise intervention tested. However, few clinical trials use an exercise program that controls for this variable in their intervention. This methodological flaw raises an important question: is it possible to determine which type of exercise is effective (for a given outcome) without knowing which type of exercise tested produced the most total work? The answer is simple: no! Because different exercises produce similar musculoskeletal adaptations, the difference is in the total work. Therefore, we aimed to present a way of comparing different types of physical exercise: the total work equalization.

Overview

The design of experimental studies (e.g., clinical trials) is a fundamental aspect of scientific research in the health field. It enables the discovery of the efficacy and/or effectiveness of clinical interventions, such as vaccines, medications, and exercise protocols. Moreover, a clinical trial enables researchers to regulate variables, reduce bias, and obtain reproducible results for verification in disparate laboratories or geographical regions. In other words, for the results of a study using a sample to be generalized to a population, the experimental design must be representative and carefully planned.[1]

To improve the scientific and methodological rigor of clinical trials, a number of high-quality journals allow the submission of critical articles. These include letters to the editor, discussion forums, perspective articles, etc., which encourage experts around the world to identify weaknesses in published clinical trials and subject them to critical analysis. This process has resulted in a number of benefits, including the replication of studies, the initiation of new research, the identification of knowledge gaps, and the retraction of studies found to be flawed. As a result, by identifying shortcomings and random and systematic errors, researchers improve the robustness of their studies, thereby facilitating the progressive evolution of science.

Gap: identifying a methodological flaw in clinical trials on exercise

The science of exercise, as it pertains to the realms of sport and health, has undergone a gradual and continuous process of evolution. In recent years, it has been demonstrated that physical performance is contingent upon the laws of Newtonian physics. Specifically, work (of the organism) and energy expenditure (metabolic) are inextricably linked to ensure the efficacy of human movement under conditions of physical exertion.[2,3]

In other words, greater amounts of human movement entail greater amounts of physical work and, consequently, greater metabolic energy expenditure.[4] Consequently, when comparing the effects of disparate physical exercises, it is imperative to comprehend, delineate, and assess the cumulative exertion induced by each tested physical exertion.[5] Nevertheless, few clinical trials employ an exercise program that controls this variable in their intervention.

This methodological flaw raises an important question: is it possible to determine which type of exercise is effective (for a given outcome) without knowing which type of exercise tested produced the most total work? The answer is simple: no! Because different exercises generate similar musculoskeletal adaptations—the difference is in the total work.[4]

Understanding the total work of a physical exercise

The term "work" is defined as the product of the applied force and the resulting displacement.[6] In the context of human movement, work is performed by skeletal muscles, which generate force to move the body or its parts against the resistance imposed by gravity, friction, and other forces.[7] The production of muscular force necessitates the expenditure of energy, which is derived from the body's metabolic processes. Energy expenditure, in turn, refers to the total amount of energy consumed by the body during a given muscular activity.[8]

It can be observed that there is a direct correlation between the amount of work performed by the muscles and the energy expenditure. Moreover, the efficiency of human movement, defined as the ratio

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between the work performed and the energy consumed, is influenced by various factors, including movement technique, the individual's physical condition, and the characteristics of the task or effort.[9]

In accordance with the guidelines for exercise prescription set forth by the American College of Sports Medicine (ACSM) ,[10] energy expenditure represents a crucial parameter for quantifying and monitoring the dosage of physical exercise. Moreover, the ACSM emphasizes that exercise prescription based on energy expenditure enables a more precise comparison between diverse forms of exercise and can be utilized to develop personalized training objectives.[11]

These recommendations are based on scientific evidence demonstrating the relationship between energy expenditure and physiological adaptations to physical exercise, including improvements in cardiorespiratory fitness, body composition, and metabolic health.[12] Therefore, understanding the relationship between physical exercise/work and energy expenditure is fundamental to optimizing human performance, preventing and managing metabolic diseases, and conducting clinical trials.

Knowing the types of physical exercise

The practice of physical exercise has been demonstrated to induce a series of adaptations within the musculoskeletal system. These include an increase in muscle mass, a rise in the density of mitochondria within muscle cells, and an enhancement in the body's capacity for oxidative metabolism.[13] These adaptations are the consequence of augmented energy expenditure and mechanical stress imposed on muscles during exercise.[14]

Regular physical exercise has been demonstrated to enhance insulin sensitivity, augment fatty acid oxidation capacity, and optimize the efficiency of carbohydrate metabolism. These adaptations are directly correlated with the increase in energy expenditure and the necessity to optimize the utilization of energy substrates.[15] The release of hormones such as cortisol, adrenaline, insulin, and growth hormone are influenced by physical exercise. These hormonal responses are regulated by energy expenditure and are crucial for maintaining metabolic balance and facilitating physiological adaptations.[16]

Clinical trials have been conducted with the objective of identifying the effects of different types of physical exercise on public health (e.g., rehabilitation) and human performance (e.g., sport). However, it is often overlooked that the type of exercise is determined by metabolism, rather than by the specific program.[8] One method for identifying the types of exercise is through metabolically analyzing the predominant energy contribution during the activity.[8] For example, there are activities that exhibit oxidative, glycolytic, and phosphagen predominance, which are classified as aerobes, lactic anaerobes, and alactic anaerobes. In terms of the level of exertion, these can be classified as low, medium, or high intensity, which ultimately determines the duration of the activity.[8]

Many research groups have published data on different types of exercise. However, most comparisons are between different types of exercise without equalizing the total work, which makes study findings unreliable. Therefore, in order to avoid this methodological error, as well as to increase the possibility of reproducibility of the results obtained in clinical trials on exercise, we aimed to present a way of comparing different types of physical exercise: the total work equalization.

Clinical trial on exercise: comparing different types of exercise

Studies on exercise have identified energy expenditure as the most important marker of response to physical training. The systematic reviews by Skelly et al. ,[17] Scribbans et al. ,[18] and Schoenfeld et al.[19] showed that greater exercise volume represented by energy expenditure (regardless of exercise intensity) is a determinant of improved health outcomes.

In turn, Wewege et al.[20] showed that when energy expenditure is equalized between different exercise modalities, different types of training produce similar improvements in the outcomes studied, reinforcing that different exercises produce similar musculoskeletal adaptations—the difference is in the total work.[4]

In other words, the above meta-analyses support the statement that energy expenditure is the most important marker of response to physical exercise (regardless of the type of exercise) when the goal is the prevention and/or management of metabolic disease. The findings have important implications for exercise prescription in clinical routine, as the focus should be on the total volume of exercise (total work) rather than on the individual volume or load of the exercise program. They also have important implications for exercise prescription in clinical trials, as total work equalization is a way to compare the effects of different types of exercise, since energy expenditure during exercise has been shown to be the determining factor for physiological adaptations.[21]

Total work equalization

A basic requirement for clinical trials investigating the effects of exercise is the recording of total work to verify the real effects of exercise on the pathophysiology of various diseases affecting a sample/population or to control for responses to exercise performance. To this end, it would be of great importance for the growth of the field of exercise science if the energetic cost of interventions could be accurately measured so that we could improve the comparative aspects of clinical trials.

Caloric cost (total work) can be measured using laboratory gas analysis techniques and equipment. However, the accuracy of energy cost analysis is limited to equipment that is inaccessible to clinical and research routines in underdeveloped countries, as this equipment is expensive to purchase and maintain and is often found only in sophisticated scientific laboratories. For clinical aspects and for application purposes in simpler clinical trials of comparison between metabolic predominances, we propose the use of the following mathematical models.

For aerobic exercise (e.g. walking), the total work can be calculated using the duration and activity load variables: aerobic volume = duration (minutes) × speed × body mass (kg). For example, if a 100 kg individual exercises for 30 min at 10 km/h, the aerobic training volume would be: aerobic volume = 30 min × 10 × 100 = 30.000 arbitrary units (i.e., total work = 30.000).

For strength training, the total work can be calculated using the number of sets, the time under tension (time devoted to the duration of the repetitions of each set), and the load lifted for each exercise: Total work = Sets (number) × Time under tension (seconds) × Load (kg) .[5] For example, if an individual performs 3 sets of 20 s with a load of 50 kg in squats, the work done in this session would be: total work (squat) = 3 × 20 × 50 = 3000 kg (i.e., total work = 3000 kg).

Finally, it is important to emphasize that in order to compare different exercises, it is necessary to adjust the total work (proposed in this article) and the predominant metabolic pathway.[22]

Ethics approval

N/A.

Consent to participate

N/A.

Consent for publication

N/A.

Availability of data and materials

N/A.

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CRediT authorship contribution statement

André Pontes-Silva: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **André Luiz Lopes:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The Prof. André Pontes-Silva serves as a reviewer for the *Brazilian Journal of Physical Therapy*. The authors declare no further competing interests.

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