

Analysis of the Adaptability of Group Training to the Physical Fitness Improvement of College Students under the Background of National Fitness

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Abstract

Amidst China's national fitness initiative and growing health demands among university students, this study systematically analyzes the adaptability and efficacy of Cluster Set Training (CS) versus Traditional Set Training (TS) for physical fitness enhancement. Synthesizing global empirical evidence reveals that CS, through intra-set rest intervals (10-45s), facilitates phosphocreatine resynthesis and lactate clearance, significantly maintaining movement velocity and power output—demonstrated by a 5.01% increase in countermovement jump peak power and 2.57% improvement in standing long jump performance among students (Ni, 2023). By reducing pre-fatigue of type II muscle fibers, CS enhances neural adaptation and yields superior gains in upper-body strength and hypertrophy (Liu, 2022). Critically, CS lowers perceived exertion (RPE) and blood lactate concentration (20% less than TS) to mitigate metabolic stress (Cuevas-Aburto et al., 2021) while reducing cardiovascular strain (Zhao, 2022), proving safer for beginners. Its adaptability extends to special populations: CS not only improves quality of life in elderly women (Ramirez-Campillo et al., 2022) but also optimizes body composition (increased lean mass, reduced fat) in students (Xiao, 2022). The findings establish CS as an effective model that balances high-intensity loading with fatigue management, offering theoretical and practical foundations for designing university fitness programs under national health promotion frameworks.

Keywords

Cluster set training; University student fitness; Explosive strength; Fatigue management; Neural adaptation; Resistance training.

1. Introduction

Resistance Training (RT), defined as physical activity involving skeletal muscle contraction against external resistance or body weight, is widely recognized as one of the most effective non-pharmacological interventions for enhancing skeletal muscle mass and strength. This efficacy stems from its ability to activate molecular regulators within skeletal muscle, inducing positive adaptations in strength, muscle mass, and energy metabolism[1]. Given its significant health benefits, the World Health Organization (WHO) 2020 guidelines recommend that adults (>18 years) engage in moderate- or high-intensity RT targeting major muscle groups at least twice weekly [2]. Similarly, the American College of Sports Medicine (ACSM) advocates ≥ 2 weekly RT sessions to improve overall health [3]. With the expansion of the health industry and promotion of physical activity by various organizations, RT facilities and services have become increasingly accessible, establishing RT as a globally popular exercise modality[4].

University students demonstrate high interest and motivation in RT participation. This inclination arises from both a desire for improved body image—seeking muscle definition and physique enhancement—and frequent engagement in sports and athletic competitions where RT enhances performance[5]. Furthermore, growing health awareness has heightened

students' recognition of RT's role in promoting physical and mental well-being[1][8]. Consequently, investigating diverse RT methodologies to identify safer and more efficient protocols is crucial for enhancing youth athletic capacity, disease prevention, health promotion, and quality of life [11].

Classical hypertrophy-oriented RT protocols typically employ moderate intensity (60–80% 1RM), moderate repetitions (8–12 reps/set), and higher set volumes (3–6 sets/exercise), cumulatively achieving high training volume per session[5]. These protocols not only effectively stimulate muscle growth but also enhance maximal strength, power, and endurance, holistically improving muscular performance [8–10]. For individuals targeting general muscle health and function, traditional hypertrophy protocols offer significant efficacy and time-efficient benefits[11].

Set structure refers to the organizational format of repetitions within a set. The Traditional Set (TS)—characterized by continuous repetitions to failure or near-failure (manifested by incomplete concentric range of motion) followed by inter-set rest—is the predominant structure in RT research and practice [12]. Despite its widespread use, TS exhibits limitations: (1) Neuromuscular fatigue accumulation reduces movement velocity and power output, compromises motor control, elevates injury risk[13], and increases perceived exertion; (2) TS imposes substantial cardiovascular strain, evidenced by sustained elevations in blood pressure and heart rate during exercise[14], alongside transient post-exercise depression of cardiac autonomic regulation[15], potentially increasing cardiac event risk in apparently healthy individuals[16]; (3) High-volume TS protocols exacerbate metabolite accumulation (e.g., lactate), intensifying subjective fatigue and discomfort, which may undermine long-term adherence [17].

To mitigate acute fatigue associated with TS, researchers propose modifying set structure variables. Cluster Sets (CS) represent a key alternative, integrating brief intra-set rest periods (typically 10–45 s) or dividing a conventional set into smaller subsets with shorter, more frequent inter-set rest intervals. Current evidence indicates CS better maintains neuromuscular performance (e.g., velocity, power) and induces lower metabolic stress and perceived exertion (RPE) than TS [19]. Consequently, CS may enhance RT safety and promote long-term adherence [17]. However, while CS consistently reduces acute fatigue, its efficacy varies with load intensity and exercise type [20]. In contrast, TS's proximity to muscular failure is considered by some studies a critical stimulus for hypertrophy, maximal strength, and endurance development [8], suggesting divergent adaptive pathways between TS and CS. Nevertheless, comparative research on long-term hypertrophic and strength adaptations in young males remains limited and inconclusive [12][19][20]. Systematic investigation of CS effects in this population is thus warranted to advance theoretical foundations and optimize RT programming.

2. Research Objectives and Significance

2.1. Research Objectives

This study aims to examine the advantages of Cluster Set training for enhancing physical fitness in university students, addressing limitations inherent in traditional RT, thereby informing evidence-based collegiate conditioning program design.

2.2. Research Significance

Amidst the growth of the health industry and institutional promotion of physical activity, RT accessibility has surged globally [4]. Concurrently, university students increasingly recognize RT's role in health promotion and exhibit strong participation interest [1][8][10]. By synthesizing global literature, this research evaluates CS's comparative efficacy over TS in enhancing maximal strength, power, and practical implementation feasibility. It seeks to enrich

theoretical frameworks in public fitness, address the paucity of CS research involving non-sport-specialist university students in China, and contribute novel empirical evidence to advance CS theory.

3. Primary Effects of Cluster Set Training

Domestic CS research emerged relatively late (ca. 2018), with publications increasing markedly in recent years. Chen Wenjia compared CS (30-s intra-set rest) and TS effects on strength training outcomes in 24 sports university students. Results indicated CS significantly reduced type II fiber fatigue, enhancing muscle strength and power output. Zhu Guangxin demonstrated that among four set structures under endurance loads, three CS variants outperformed TS in maintaining muscle power output. However, CS effects on hypertrophy remain contested. Liu Rui found CS offered no clear advantage over TS for increasing muscle volume in recreational trainees. Similarly, a study on female fitness enthusiasts reported no significant difference between CS and TS for lower limb girth and strength gains. Contrastingly, research focusing on the upper limbs found CS superior to TS for promoting hypertrophy and strength.

In athletic performance, CS demonstrates consistent benefits. It effectively develops lower limb explosive power in competitive aerobics athletes, enhancing competitive performance. Comparable studies show CS yields significantly greater improvements than TS in lower limb strength and power among basketball-specialized students. Furthermore, CS improves lower limb explosive power and endurance in university students. Liang Xingyue's meta-analysis **错误!未找到引用源。** suggested combined CS and TS implementation may optimize training outcomes.

International research primarily investigates acute mechanisms underlying CS effects on muscular contractile properties (power, velocity, force) and fatigue. G. Gregory Haff [30] compared cluster, traditional, and undulating set configurations, finding intra-set rest (15–30 s) enabled higher power output, peak barbell velocity, and displacement per repetition. Similar studies confirm CS's superiority over TS for acute enhancements in lower limb strength, speed, and power [31]. Direct comparison of TS and CS during loaded back squats revealed CS better maintained movement velocity and power, recommending its use for velocity-focused training [32]. Cuevas-Aburto et al. [33], using RPE, reported CS significantly reduced perceived exertion, correlating strongly with intra-set rest. Physiological studies indicate lower blood lactate concentrations post-CS vs. TS [34], a key factor in fatigue and mechanical power decline, supporting CS's efficacy in maintaining mechanical power output [34].

CS benefits extend to special populations. Rodrigo Ramirez-Campillo et al. [35] assigned older women (mean ~67 years) to control, CS (30-s rest after every 2 reps), or TS groups for 12 weeks (3 sessions/week). CS significantly improved quality-of-life scores versus TS. Keir T. Hansen et al. [36] compared four rest configurations (TS and three CS variants) during jump squats in elite/sub-elite rugby players. Intra-set rest configurations (CS) effectively enhanced movement velocity and power output.

Collectively, CS demonstrates efficacy in reducing fatigue, enhancing power output (particularly speed and explosiveness), and shows promise for elderly populations and performance enhancement [30]. Current limitations include: (1) A research focus on strength, power, and fatigue metrics, with scarce investigation into running- or jumping-specific adaptations, aligning with Liang Xingyue's identified gap; (2) Persistent controversy regarding hypertrophic outcomes, and insufficient exploration of CS-induced fiber-type-specific hypertrophy compared to TS.

4. Advantages of Cluster Set Training for University Student Fitness

4.1. Enhancing Power and Explosiveness: Mechanisms and Evidence

Cluster Sets (CS) enhance power output and movement velocity, particularly for lower limb explosiveness, by incorporating brief intra-set rest (10–45s). The core mechanism involves facilitating phosphocreatine (PCr) resynthesis and lactate clearance, sustaining ATP production and delaying power decrement[37]. Empirical evidence supports this: Ni Yuxiang implemented an 8-week intervention (CS: 30-s intra-set rest) in 16 long-jump university athletes. The CS group exhibited significantly greater improvements in CMJ peak power (+5.01%), peak velocity (+4.06%), and standing long jump distance (+2.57%) versus TS. Similarly, Zhao Qi 错误!未找到引用源。 found basketball students using CS (85% 1RM squats, 30-s intra-set rest) for 6 weeks showed superior gains in 30-m sprint times and jump height, attributed to reduced neuromuscular fatigue and maintained movement quality. Haff et al. [40] further confirmed that 15–30 s intra-set rest significantly increases peak barbell velocity and displacement during lower-body power exercises.

4.2. Optimizing Strength and Hypertrophy: Effects and Controversies

CS potentially optimizes type II fiber stimulation and strength gains by managing fatigue under high loads. Liu Jiayu's 8-week bench press study[41] demonstrated significantly greater increases in 1RM and upper limb lean mass in the CS group (70% 1RM, 30-s intra-set rest) versus TS, resulting from reduced type II fiber pre-fatigue and sustained repetition quality. Hypertrophy outcomes, however, exhibit site-specificity. Liu Rui reported no significant advantage of CS over TS for lower limb girth increases in recreational trainees, while Chen Wenjia linked CS-mediated reductions in type II fiber fatigue to enhanced strength development. Metabolically, Cuevas-Aburto et al. observed significantly lower RPE and blood lactate in CS, reducing metabolic interference with muscle contraction. Crucially, CS enhances neural adaptations (e.g., movement consistency, motor unit recruitment), aligning with scientific RT principles [3].

4.3. Attenuating Fatigue and Maintaining Intensity: Physiological Basis

A key advantage of CS is mitigating acute fatigue accumulation, promoting long-term adherence. Zhao Qi reported significantly lower RPE in the CS group immediately post-first session (* $p < .01$) and throughout a 6-week program. Cardiovascularly, TS induces sustained elevations in heart rate and blood pressure, posing potential risks[14][15]; CS's short rests facilitate transient cardiovascular recovery, benefiting students with lower fitness baselines. Metabolically, intra-set rest accelerates PCr resynthesis and lactate clearance, maintaining ATP supply. Haff et al. [40] observed ~20% lower blood lactate in CS versus TS, directly correlating with stable power output.

4.4. Adaptability to Populations and Holistic Health Benefits

CS's flexibility benefits diverse fitness levels. Rodrigo Ramirez-Campillo et al.[45] demonstrated CS (30-s intra-set rest) significantly improved quality-of-life scores over TS in older women, attributable to lower fatigue enhancing adherence. For university students, Xiao Tao [46] found RT incorporating CS elements significantly improved body composition (reduced fat mass, increased lean mass). An investigation by Fuyang Normal University further confirmed the positive impact of resistance training on BMI. Additionally, multimodal training (including CS) may indirectly improve vital capacity and post-exercise heart rate recovery, though aerobic training remains essential for optimizing cardiorespiratory fitness.

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