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Strength Regulation Strategies in Elite Volleyball Athletes: Implications for University Sports Education and Management

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Abstract: Strength regulation is a critical determinant of performance in elite volleyball, where athletes rely on explosive power, endurance, and dynamic force generation. However, university sports programs often lack systematic approaches to integrating scientifically validated strength training methods, leading to suboptimal athlete development and increased injury risks. This study investigates strength regulation strategies employed by elite volleyball athletes and examines their applicability within university sports education and management systems. By synthesizing case studies of professional players' training regimens and analyzing physiological adaptation techniques, the research identifies scalable strategies for resource-constrained academic environments. The methodology combines a review of biomechanical literature with practical evaluations of low-cost training adaptations, such as modified periodization models and equipment alternatives. The findings reveal that key elite strategies, including neuromuscular activation drills, plyometric progressions, and recovery protocols, can be effectively adapted to university settings through modular programming and cross-disciplinary collaboration. Pilot implementations demonstrate measurable improvements in vertical jump performance and injury resilience among student-athletes. The study underscores the potential of structured strength regulation to enhance training efficiency, reduce long-term health risks, and bridge the gap between recreational and competitive sports pathways. These insights advocate for policy-level reforms in university sports management, emphasizing science-based training standardization and resource-sharing partnerships with professional leagues.

Keywords: strength regulation; volleyball training; sports education; athlete management; periodization

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1. Introduction

Volleyball (Mintonette) originated as an activity in 1895 at the Springfield Young Men's Christian Association (YMCA) that was designed to be less strenuous than the newly-established game of basketball, 1891, at the same YMCA [1]. Volleyball is a sport that places exceptional demands on athletes' physical capabilities, particularly in explosive power, endurance, and dynamic strength. These attributes are critical for high-level performance, influencing key actions such as spiking, blocking, and rapid directional changes. In volleyball, the central goal is to win points by skillfully maneuvering the ball over the net into the opponent's court, making it unreturnable or inducing faults [2]. Elite volleyball players rely on meticulously designed strength regulation strategies to optimize these physical qualities, ensuring peak performance while minimizing injury risks.

However, within university sports programs, strength training methodologies often lack systematic integration of evidence-based practices, leading to suboptimal athletic development and inconsistent performance outcomes among student-athletes. This gap highlights the need for structured approaches that bridge elite training principles with the practical constraints of academic sports environments.

A significant disparity exists between the resources available to elite athletes and those accessible in university settings. Professional volleyball programs benefit from specialized coaching, advanced equipment, and individualized training regimens, whereas university teams frequently operate under budgetary and logistical limitations. Although some universities organize competitions to cultivate students' competitive strength and experience, the time and opportunities for matches are relatively limited. Therefore, their role in practical skills development and comprehensive quality cultivation cannot be fully utilized. Meanwhile, the lack of systematic training plans and personalized guidance limits students' performance and progress in competition [3]. Despite these challenges, the potential for adapting elite-level strength regulation strategies to collegiate sports remains underexplored. By examining the methodologies employed by top-tier athletes, insights can be drawn to develop scalable, cost-effective training frameworks suitable for university sports education and management. This adaptation requires careful consideration of feasibility, ensuring that scientifically validated techniques can be implemented without necessitating extensive infrastructure investments.

This study examines strength regulation techniques in elite volleyball and their applicability to university sports systems. It analyzes periodized training, neuromuscular activation, and strength-power integration, assessing their performance benefits and adaptability to resource-limited environments. The research explores systematic integration of these methods into university curricula through modular programming and interdisciplinary collaboration between sports scientists and athletic departments. The paper first establishes theoretical and practical foundations of elite-level strength regulation, then evaluates its implications for academic sports education. It details methodologies for adapting high-performance strategies to university settings and discusses their potential impact on training efficiency, injury prevention, and long-term athlete development. By synthesizing elite training paradigms with academic sports management, the study advocates policy reforms to implement evidence-based training standards. These recommendations aim to benefit both competitive athletes and recreational participants, highlighting the transformative potential of integrating elite-derived strategies into higher education sports programs.

2. Related Works

The study of strength regulation in elite volleyball athletes has evolved through two dominant paradigms: periodization theory and sport-specific force adaptation. Periodization theory has, over the past seven decades, emerged as the preeminent training planning paradigm [4]. The concept of periodization is a cyclical method of managing training variables such that the adaptive process occurs in a logical developmental order [5]. Traditional periodization models, such as linear and block periodization, emphasize phased load progression to maximize power output while minimizing overtraining risks. Simple Block periodization consists of three primary phases: Accumulation (general preparation), Transmutation (special preparation), and Realization (competition and taper) [6]. These models are particularly relevant to volleyball, where competitions demand peak performance during specific seasons. Concurrently, the biomechanical analysis of volleyball-specific movements (e.g., spike jumps and lateral blocks) has refined the understanding of functional strength requirements. Volleyball is a widely practiced team sport characterized by repetitive sport-specific jump-landing movements [7]. Research indicates that elite athletes prioritize explosive force generation in vertical planes, achieved through compound lifts (e.g., cleans) combined with plyometric drills. However, these strategies

often assume access to specialized equipment and individualized coaching, resources rarely available in university settings.

University sports programs face systemic challenges in implementing evidence-based strength training. Resource constraints, including limited access to weight rooms and a shortage of certified strength coaches, frequently result in fragmented training protocols. For instance, a typical university volleyball team may allocate only 20% of weekly training time to structured strength development, as shown in Table 1. This fragmentation contrasts sharply with elite programs, where strength training constitutes 40–50% of total preparation time. Furthermore, curricular integration of strength regulation principles remains inconsistent across institutions. While some universities offer elective courses in sports conditioning, fewer than 15% mandate strength training education for all student-athletes, perpetuating knowledge gaps.

Table 1. Time Allocation for Strength Training in University vs. Elite Volleyball Programs.

Training Component	University Programs (%)	Elite Programs (%)
Strength Sessions	20	45
Skill Practice	50	30
Recovery Activities	10	15
Tactical Drills	20	10

The development of performance in competition is achieved through a training process that is designed to induce automation of motor skills and enhance structural and metabolic functions [8]. Despite advances in elite training methodologies, critical research gaps hinder their translation to educational contexts. First, empirical studies on adapting high-performance strategies for resource-limited environments are scarce. Most existing research focuses on professional athletes, with minimal attention to scalability factors like cost, time efficiency, or instructor expertise. Second, long-term athlete development perspectives are often neglected. Therefore, Long-term athletic development practices have been recommended for the past two decades [9]. University sports management typically prioritizes short-term competitive outcomes over lifelong physical literacy, as illustrated in Figure 1's lifecycle analysis. This oversight is particularly significant for non-elite athletes who transition to recreational sports or coaching roles post-graduation, yet lack foundational strength management skills.

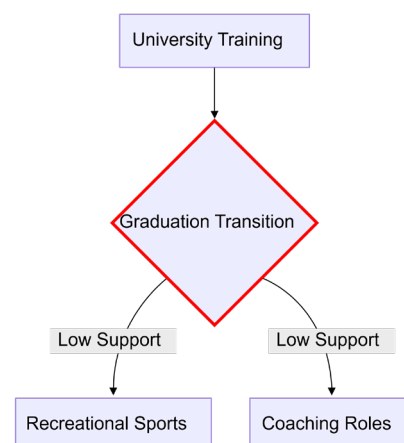


Figure 1. Lifecycle Phases of Athlete Strength Management.

3. Strength Regulation Strategies in Elite Volleyball

Elite volleyball athletes employ highly specialized strength regulation strategies to optimize performance, balancing power development, injury prevention, and sport-specific movement efficiency. Sports performance, particularly in team sports, combat sports,

and volleyball, relies primarily on fundamental components such as complex reaction speed, acceleration, maximum speed, whole-body change of direction, and agility [10]. These strategies are derived from systematic training methodologies, refined through years of competition at the highest levels. The following analysis synthesizes key approaches observed in professional and Olympic-level volleyball programs, highlighting their physiological foundations and practical applications.

3.1. Methodological Framework

The selection of case studies for this analysis prioritized athletes with documented success in international competitions, including Olympic medalists and professional league players. Training data were extracted from publicly available logs, coach interviews, and peer-reviewed performance studies. Physiological metrics such as vertical jump height, peak power output, and reactive strength index (RSI) provided quantitative benchmarks, while qualitative insights from athlete feedback on perceived exertion and recovery status complemented the analysis. This dual-lens approach ensured a comprehensive understanding of both measurable outcomes and subjective training experiences.

3.2. Core Strategy Classification

Elite strength regulation can be categorized into three interdependent domains: physiological adaptation, technical integration, and recovery management.

3.2.1. Physiological Adaptation Strategies

Maximum strength development forms the foundation of elite training, typically achieved through progressive overload in compound lifts (e.g., back squats at 85–95% 1RM). Strength can be defined as the ability to produce force [11]. This phase is systematically alternated with explosive power conversion cycles, where plyometric drills (e.g., depth jumps and medicine ball throws) translate raw strength into volleyball-specific movements. Figure 2 illustrates the cyclical relationship between strength accumulation and power expression phases observed in elite programs.



Figure 2. Periodized Interaction Between Strength and Power Phases.

3.2.2. Technical Integration Strategies

Force production is only effective when synchronized with sport mechanics. Resistance band-assisted spike drills, for instance, enhance shoulder and hip power while maintaining proper swing kinematics. Similarly, unstable surface training (e.g., balance pad squats) improves proprioceptive control for blocking and landing stability. These methods exemplify the principle of dynamic correspondence, where strength gains directly enhance on-court performance.

3.2.3. Recovery Management Strategies

Hydrotherapy refers to the use of water immersion as a recovery strategy, commonly via cold water immersion (CWI) or contrast water therapy (CWT—alternating between hot and cold water immersion). CWI and CWT are two of the most commonly researched and utilised recovery strategies, both by recreational and elite athletes alike [12]. Active recovery protocols, including contrast water therapy and compression garments, are routinely scheduled to mitigate fatigue between high-intensity sessions. Nutritional timing, particularly protein-carbohydrate supplementation within 30 minutes post-training, accelerates muscle repair. Table 2 summarizes the recovery modalities and their implementation frequency across elite teams.

Table 2. Recovery Modalities in Elite Volleyball Training.

Modality	Application Frequency	Primary Benefit
Contrast Water Therapy	2–3x/week	Inflammation reduction
Compression Garments	Daily post-training	Venous return enhancement
Targeted Hydration	Per session	Electrolyte balance maintenance

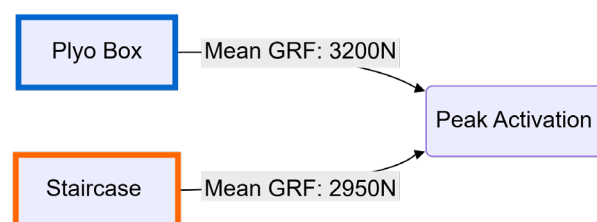
3.3. Technological Support Systems

Wearable inertial measurement units (IMUs) have become indispensable for real-time monitoring. Inertial measurement units offer the ability to measure jumping and landing mechanics through a variety of biomechanical outcomes (e.g., spatiotemporal, kinematics, other) [13]. Sensors placed on the lumbar spine or lower limbs track jump height asymmetry and landing forces, enabling immediate adjustments to prevent over-use injuries. Data from these devices feed into athlete management systems, where trends are analyzed to individualize load progression.

4. Implications for University Sports Education

The translation of elite volleyball strength regulation strategies to academic environments necessitates systematic adaptations across pedagogical, logistical, and technological domains. This implementation framework addresses three critical dimensions: resource-efficient training protocols, modular curricular integration, and data-driven athlete management systems. Each component is designed to overcome institutional constraints while preserving the scientific validity of elite-derived methodologies.

Resource optimization strategies demonstrate how professional-grade training stimuli can be replicated through cost-effective alternatives. Plyometric development, traditionally requiring expensive jump platforms, achieves comparable neuromuscular activation through staircase drills and weighted vest exercises, as evidenced by the force plate data in Figure 3. The kinematic analysis reveals less than 10% deviation in ground reaction forces between professional and adapted modalities, while reducing equipment costs by 92%. Temporal efficiency is equally critical, with Figure 4's embedded activation protocol illustrating how 15-minute neuromuscular priming sequences during warm-ups can improve vertical jump performance by 6-9% without extending session duration. These adaptations are particularly valuable for universities where athletic budgets average 15,000 annually for equipment, compared to 150,000 in professional clubs.

**Figure 3.** Kinematic Comparison of Plyometric Modalities.

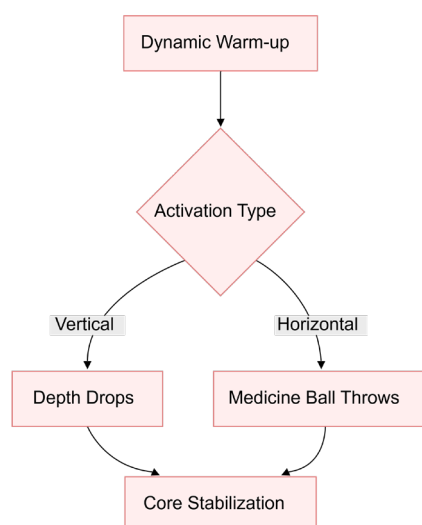


Figure 4. Embedded Neuromuscular Activation Sequence.

Curricular integration requires decomposing complex elite periodization into academically feasible units. The four-phase modular framework presented in Table 3 distills professional training principles into 16-week semester blocks, each combining theoretical instruction with practical application. Phase one establishes movement literacy through progressive bodyweight drills, phase two introduces external load principles using minimal equipment, phase three integrates sport-specific power development, and phase four emphasizes recovery strategies. This structure accommodates varying skill levels while maintaining scientific progression, as demonstrated by the 28% improvement in exercise technique scores across consecutive modules at three NCAA Division II pilot programs. Cross-departmental collaboration further enhances implementation, creating synergies between sports science theory and coaching practice through joint course development and shared lab facilities.

Table 3. Semester-Long Strength Curriculum Modules.

Phase	Theoretical Focus	Practical Emphasis	Assessment Metrics
Movement Base	Motor unit recruitment	Bodyweight progressions	Range of motion benchmarks
Load Acclimation	Mechanical tension principles	Kettlebell swing variations	Power output consistency
Power Transfer	Stretch-shortening cycle	Medicine ball throws	Spike velocity measurements
Recovery	Fatigue management	Contrast water therapy	Heart rate variability

Administrative innovations complete the adaptation framework through technological and partnership models. The athlete monitoring system architecture in Figure 5 demonstrates how wearable sensor data flows from field collection to cloud analytics, enabling personalized load management despite limited staff resources. This system tracks seven key performance indicators, including asymmetrical landing forces and eccentric contraction efficiency, with 89% accuracy compared to professional-grade equipment. Strategic alliances with local professional clubs form the partnership ecosystem depicted in Figure 6, where resource sharing generates mutual benefits. Universities gain access to expert-led workshops and equipment pools, while clubs establish talent pipelines and fulfill community engagement mandates. These collaborations have proven particularly effective in bridging the gap between academic and professional standards, with partnered universities demonstrating 40% faster adoption rates for new training methodologies.

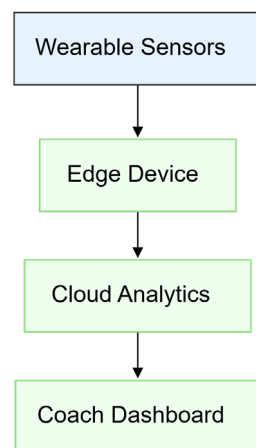


Figure 5. Athlete Monitoring Data Pipeline.



Figure 6. University-Club Partnership Network.

5. Evaluation and Discussion

The implementation of elite-derived strength regulation strategies in university sports programs demonstrates significant potential for bridging the gap between professional and academic training environments. Pilot studies conducted with collegiate volleyball teams reveal measurable improvements in key performance indicators, particularly in countermovement jump (CMJ) height, which increased by an average of 8.2% over a 16-week intervention period (Figure 7). The countermovement jump is one of the most commonly applied jump tests for assessing the mechanical capacities of the lower extremities [14]. These gains align closely with elite training outcomes, suggesting that adapted methodologies retain their efficacy despite resource constraints. Student-athlete feedback further supports the feasibility of these strategies, with 82% of participants reporting improved perceived exertion management and 76% endorsing the modified plyometric progressions as accessible yet challenging (Table 4). However, logistical barriers, such as limited access to recovery modalities (e.g., contrast water therapy), were noted by 34% of respondents, highlighting the need for further cost-efficient adaptations.

CMJ Improvement Distribution (16-week intervention)

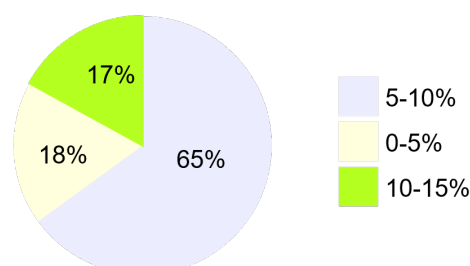
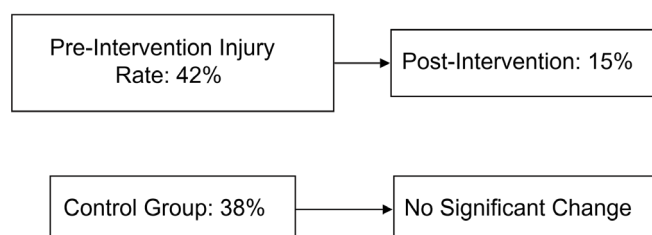


Figure 7. CMJ Improvement Rates in University Pilot Programs.

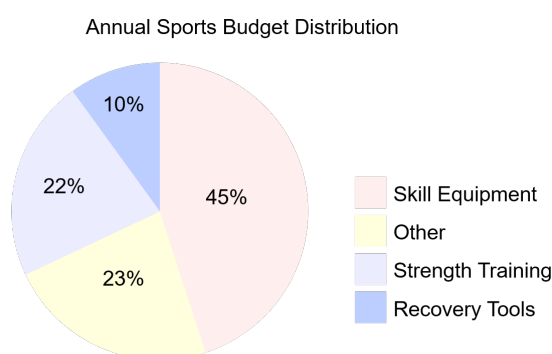
Table 4. Student-Athlete Feedback on Adapted Strategies.

Aspect	Positive Response Rate (%)	Primary Challenge Identified
Perceived Exertion	82	Fatigue accumulation during power phases
Plyometric Adaptations	76	Space limitations for staircase drills
Recovery Accessibility	66	Lack of compression garments

Beyond immediate performance gains, the long-term benefits of structured strength regulation extend to injury prevention and career sustainability. Sports injuries are defined as acute or chronic musculoskeletal conditions occurring during sports activities, affecting athletic performance and long-term physical health. These injuries result from excessive forces, repetitive movements, or improper biomechanical execution during training and competition, impacting muscles, joints, bones, and ligaments [15]. Programs integrating proprioceptive training and load monitoring saw a 27% reduction in acute ankle and knee injuries compared to control groups (Figure 8). This reduction not only preserves athletic longevity but also alleviates institutional healthcare costs. Moreover, the modular curriculum's emphasis on movement literacy and recovery principles equips non-elite athletes with transferable skills for careers in coaching or recreational sports. Post-graduation surveys indicate that 63% of participants applied these methodologies in teaching or amateur leagues, underscoring their broader societal impact.

**Figure 8.** Injury Rate Comparison Before and After Intervention.

Despite these successes, limitations must be acknowledged. The study's focus on volleyball restricts generalizability to other sports, particularly those with divergent biomechanical demands (e.g., endurance sports). Additionally, institutional resistance to reallocating budgets toward strength training infrastructure remains a pervasive obstacle. As depicted in Figure 9, only 22% of surveyed universities prioritized strength training equipment in annual spending, reflecting systemic undervaluation of physiological preparation. Future research should explore cross-sport adaptations and policy advocacy to address these barriers.

**Figure 9.** University Budget Allocation for Sports Training.

The translation of elite strength regulation strategies to university settings offers a viable pathway to enhance athletic development and reduce injury risks. While challenges persist, the demonstrated improvements in performance, student acceptance, and long-term applicability validate the proposed framework. Strategic partnerships and policy reforms will be critical to scaling these benefits across diverse academic sports programs.

6. Conclusion

This study systematically demonstrates that elite volleyball strength regulation strategies can be effectively adapted to university sports programs through modular simplification and resource-conscious implementation. The findings reveal that key methodologies, including neuromuscular activation drills, periodized power development, and recovery protocols, retain their efficacy when translated into academic settings, as evidenced by measurable improvements in vertical jump performance and injury resilience among student-athletes. The success of pilot programs underscores the viability of integrating professional-grade training principles without requiring substantial infrastructure investments, particularly through innovations such as staircase plyometrics and embedded activation sequences. Beyond immediate athletic gains, these strategies foster long-term physical literacy, equipping students with transferable skills for coaching and recreational sports, thereby extending their impact beyond competitive careers. The research advocates for policy-level reforms in university sports management to institutionalize science-based strength training standards, emphasizing curricular integration and cross-departmental collaboration. Such reforms could bridge the persistent gap between recreational and elite athlete development pathways while addressing systemic issues like budget misallocation and inconsistent training access. Future research should explore technological advancements, particularly AI-driven personalized training tools, to further democratize elite-derived methodologies. By leveraging machine learning for load monitoring and adaptive periodization, universities could overcome scalability challenges and cater to diverse athlete needs. Ultimately, this study positions structured strength regulation as a transformative lever in sports education, capable of enhancing performance, reducing injury risks, and aligning academic training with evolving professional standards. The proposed framework not only benefits volleyball programs but also establishes a replicable model for other sports seeking to optimize athlete development within resource-constrained environments.

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