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Original Article

Effect of Strength Training Programs on Muscular Endurance and Athletic Performance among University Athletes

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Abstract

Strength training is now universally accepted as a cornerstone of contemporary athletic conditioning protocols due to its role in the development of muscle endurance and strength potential and the translation of the associated benefits to improving athletic performance in competitive athletes. As part of athletic conditioning programs, structured strength training protocols are progressively integrated in university sports settings to support performance, physical fitness and sports injury prevention. Aims: The current experimental investigation focuses on the chronic impact of periodized strength training interventions on muscular endurance and sports performance in collegiate athletes. The purpose of the current study is to investigate the effects of a structured strength training program on measures of muscular endurance, strength, speeds and other athletic performance metrics in competitive athletes in a program with NCAA university sports. The study utilizes an experimental research design with a pre-test and post-test control group design in which a sample of university athletes, aged 18–24 years, participates in a structured strength training program over a period of 8–10 weeks. Push-up test, sit-up test, bench press test, squat test, vertical jump test, and sprint performance measurements are utilized to measure various aspects of muscular endurance and athletic performance pre- and post-training using primary data through these standardized fitness assessments. The collected data are analyzed through descriptive statistics, paired sample t-tests, and comparative statistical analysis which assess whether or not the change in performance levels observed in athletes were statistically significant. The Structured Strength Training Is Effective in Enhancing Physical Performance Among University Athletes: A systematic review with meta-analysis expected findings The expected findings of this study are that structured strength training programs lead to significant improvements in muscular endurance, power and speed, and better overall athletic performance among university athletes. Findings emphasize the need to integrate (evidence-based) strength training routines within university sports training programs to foster elite athlete development, enhance competition performance, and encourage lifetime physical activity and health during college years.

Keywords: *Strength training, muscular endurance, athletic performance, university athletes, resistance training, sports conditioning*

Introduction and background related to the study

It is now recognized by the modern sports science and athletic Training Industries as an essential part a role which, through improving: muscular strength, endurance of muscle, power output from muscles; balance in rapid movements that require strength or do not reduce all potential energy at once or movement efficiency across a range of basic sports disciplines Ludwig Tuan, Exercise: Sports Science, Athletic training which body system has the greatest ability to adapt and improve? However, historically bodybuilding activities were the main fields for strength training. Strength training information from the past few decades has fundamentally changed weightlifting's very nature to become something quite different altogether through sports performance research recent advances in exercise physiology continue to show that structure resistance training programs are critical for improving athletic efficiency,

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Injury prevention and long-term athlete development. With strength training protocols now widely implemented in professional, collegiate and university sports programs all over the world (Suchomel et al.) One of the most important physiological adaptations brought about by strength training is an enhancement in muscular endurance – which refers simply to the ability of muscles or groups performing repeated movements, that sustain force for an extended period of time and is regarded as a key determinant of athletic performance in long-duration sports such as athletics, football, basketball etc.Athletes with greater muscular endurance can maintain levels longer, postpone fatigue more, and move more smoothly in training and competition than can athletes whose muscles tire too quickly. (McArdle, Katch & Katch)Furthermore, in the context of university sports environments, where student-athletes must balance academic responsibilities with demanding and sometimes unconventional training schedules, it becomes necessary for sports conditioning programs to involve scientifically designed strength training interventions that develop muscular endurance, support physiologic adaptation processes and enable athletes' ability to perform repeat high-intensity movements during competitive events (Bompa & Buzzichelli)Within university athletic programs strength conditioning has become integral to sports performance development. More and structured resistance training routines that include progressive overload, periodization strategies and sport-specific strength exercises help coaches in utilizing structured resistance training protocols for their athletes. This provides more functional strength, muscular endurance and biomechanical efficiency, which then contribute to better athletic performance in university-level competitions whilst reducing the number of overuse injuries suffered and muscles that cause imbalance among athletes (Stone et al.). These developments at university level are also consistent with the broader trend in athlete conditioning and performance enhancement. Around the world, Sports organizations and educational institutions have begun to invest increasing amounts of money in evidence-based training programs, sport science laboratories and performance monitoring systems that allow for coaches to develop their own individualized strength training programs capable of optimizing physical performance while simultaneously fostering athlete health and long-term development Recent research has shown that structured strength training interventions significantly improve athletes' sprint speed, explosive power, muscular endurance and overall athletic performance (Suchomel et at,2016; Turner, 2011)Despite the growing recognition in sports science literature of the benefits of strength training there is still an empirical void on how programs for structured training might affect muscular endurance and athletic performance among university athletes. Particularly troubling is that within existing studies which use fitness tests to identify changes in performance, there have not been sufficient attempts to measure actual changes brought about through controlled interventions with standardized training programs Many previous efforts in this direction have concentrated exclusively on elite or professional athletes while there may be far fewer studies which have looked at how strength training protocols might be effective within a university sports setting under conditions where athlete development stages differ from those encountered in professional sports organizations (Kraemer & Ratamess). The present study therefore seeks to critically evaluate the effect of structured strength training programs on muscular endurance and athletic performance among university athletes by measuring changes in selected physical performance indicators before and after participation in an orderly structured strength training programme. An increasing body of research in this special area is taking shape thus for coaches, sports scientists and university athletic departments looking to optimize athletes' performance by scientifically grounded strategies that this study has practical significance.

Statement of the Research Problem

Growth in Sports Science Program Development Strength training has become an integral part of modern sports conditioning programs in the past few years. The relationship between maximum strength of muscles and their endurance level, as well as power output of competitive athletes has been dramatically enhanced due to strength training. But with the growing popularity of resistance-based training interventions within university sports, it is incumbent upon one to measure how cross student athletes feel after just doing some press-ups before entering a student meeting. This is especially important because endurance muscle activity is vital for keeping up a high level of physical performance during repeated muscular contractions - repeated in some form or other would include most sports such as sprinting sports or normal street basketball players. During this explicit kind of athleticism, athletes in athletics and the team events can only take off once all their muscles are working in synchronized fashion. Is beginning to regenerate. Therefore, whilst it remains true that sports scientists and strength conditioning specialists have developed a wide range of resistance training approaches including progressive overload training, circuit training and periodized strength conditioning programs focused specifically on enhancing muscular endurance as well as physical performance, in terms of the existing research today there is still a significant gap. Most work has been conducted on elite professional athletes, national-level competitors or specialized athletic populations. Information regarding the effectiveness of structured strength training programs in university athletic populations is largely lacking as a result. There are differences between university competitive sports environments and professional sports worlds in terms of training conditions, resources available at the school, coaching support and academic responsibilities. This gap is all the more important because university athletes have to combine academic work with intensive training schedules. Student-athletes need stage designed to improve muscular endurance and athletic performance is both inefficient and effective. As a result, the current international trend in sports science is gradually be- coming one that emphasizes scientific conditioning of the athlete. After all, how can Team USA be victorious at Olympic Games if it doesn't use

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EVERYTHING available to help when preparing for competition? One study of provincial badminton volunteers confirmed this when they were subjected to a strength conditioning program in which their muscles were gradually exercised in both weight and strength. The subjects were divided into two groups: the experimental group and control group. Athletic performance tests were then conducted on each subject. The experimental group was then given a performance test after that.

Literature Review

The literature on strength training and its effects on muscular endurance and performance in certain athletic populations suggests resistance training is a key component of sports conditioning due to its potential to improve muscular endurance, neuromuscular coordination, and athletic capacity (McArdle, Katch, & Katch, 2015; Ratamess, 2012) Research also indicates resistance training plays a significant role in muscular endurance development by enhancing the muscles' ability to sustain repeated contractions over a prolonged period of time through physiological adaptations such as increased mitochondrial density, improved capillary supply, and metabolic efficiency, all important in increasing muscular endurance needed at sustained efforts in both endurance-based and high-intensity intermittent sports disciplines (Grgic et al., 2018). Also, the relationship between muscular endurance and strength training is apparent, as circuit-based and moderate-load high-repetition resistance training protocols have shown significant improvements in muscular endurance due to increased oxidative capacity and the capacity of the muscles to perform repeated movements with minimal effort, particularly in sports such as football, basketball, and athletics that require sustained muscular exertion. (Grgic et al., 2018) In addition to muscular endurance, the strong link between resistance training and performance has also been represented in the literature where such training has been shown to improve performance variables such as speed, explosive power, agility, and movement efficiency based on its capacity for increased neuromuscular coordination, motor unit recruitment, and force production capacity characteristics that are essential for success in competitive sports environments (Mucho et al., 2015; Suchomel et al., 2016; Turner, 2011). There is also mention of concepts in the literature surrounding training periodization in regards to sports performance that highlights the systematic planning of training variables such as intensity, volume, and frequency over a given period of time to enhance performance outcomes while also minimizing the risk of overtraining (Bompa & Buzzichelli, 2019; Turner, 2011) and periodized strength training programs have thus been found to elicit greater improvements in muscular endurance and performance compared to their non-periodized counterparts by allowing for progressive overload while ensuring recovery and performance peak when need (Bompa & Buzzichelli, 2019; Turner, 2011). Contributions of structured strength training interventions further support the effectiveness of the body of literature on athlete conditioning programs, where evidence includes recent findings indicating that university and collegiate athletes undertaking structured resistance training programs improves muscular endurance, strength and sport-specific performance indicators compared to unstructured or traditional training routines, for example it has been seen that a combination of resistance training with sport-specific drills can enhance sprint performance, vertical-jump height, and muscular endurance across different sports disciplines (Grgic et al., 2018; Suchomel et al., 2016), confirming the practical significance of a structured strength training approach to athletic performance outcomes. However, their substantial evidence within the literature also indicates a need for more empirical research focused on university athletes, whereby differences in training intensity, program design, and athlete characteristics may influence the effectiveness of strength training interventions for further controlled experimental studies examining the effect of structured strength training programs on muscular endurance and athletic performance in university sports settings.

Conceptual Framework

The conceptual framework of the study is based on the theoretical and empirical fact that structured strength training programs operate as a primary independent variable impacting various aspects physical fitness and athletic performance among athletes through the identifiable components of exercise, and these components include resistance exercise, progressive overload, training frequency, and exercise intensity, whereby the strength training program is conceptualized as a systematic and scientifically designed intervention that includes resistance-based exercises such as weight training, body-weight exercises, and functional strength movements aiming to elicit muscular adaptations and improve neuromuscular function, while progressive overload is a fundamental training principle, and it entails the incremental process of including higher intensity, volume, or complexity of workloads over time to constantly challenge muscle performance ability as the body adapts to resistance training (Kraemer and Ratamess 2004; Suchomel, Nimphius, and Stone 2016), and the following components can further characterize the strength training program: training frequency and exercise intensity, define the layout of the strength training program and reflects session how often training and level of effort or resistance level of effort or resistance applied, which are critical because failure to provide sufficient stimulus can interfere with adaptation of muscle function capabilities, while training frequency and exercise intensity are important variables to reduce the risk of overtraining and fatigue among university athletes who are required to balance academic and athletic pursuits (Ratamess 2012; Bompa and Buzzichelli 2019) and these independent variables impact the dependent variables of the framework, or muscular endurance, strength capacity, speed and agility, and athletic performance in measurable ways, where muscular endurance is defined as the capacity or ability of muscles to resist fatigue and sustain repeated contractions over time and is directly

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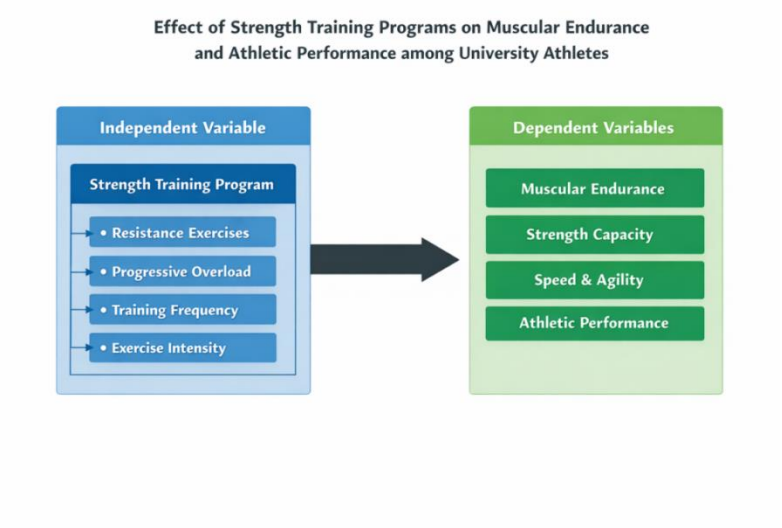
improved through resistance training protocols which emphasize higher repetitions and moderate-load (McArdle, Katch, and Katch 2015; Bompa and Buzzichelli 2019), while strength capacity is the maximum force producing capability of muscle and is positively improved through progressive overload and resistance based training, and these improvements in muscular endurance and strength capacity subsequently lead to improvements in speed and agility, since stronger and more fatigue resistant muscles allow for a more efficient means of performing explosive movements, quick directional changes, and high intensity activities during athletic and sports performance (Turner 2011), and typically when looking at an example this causal interdependence can be demonstrated where a university football player may undergo a structured strength training program that includes progressive resistance exercises and optimal training frequency to demonstrate push-up performance improvements (muscular endurance), squat strength (strength capacity), sprint times (speed), and agility during match play which highlights the interconnected nature and meaningful relationships of the independent and dependent variables of the conceptual framework, and thus this conceptual framework is able provide some theoretical underpinnings and rationale for establishing a cause and effect relationship between structured strength training programs as the primary influencing factor driving improvements in multiple components of athletic performance amongst university athletes, therefore testing how different elements of strength and conditioning need further empirical examination within sports science research and which different aspects of strength can lead to improvements in other biomarkers of muscular endurance and athletic performance per intern fundamentals of fitness training methodologies (Urbano, Teodoro, and Caeiro 2019). The conceptual model further emphasizes that the relationship between strength training programs and athletic performance is not only direct but also mediated through physiological and neuromuscular adaptations, where improvements in muscular endurance and strength capacity act as intermediate variables that translate training stimuli into enhanced sport-specific performance outcomes, thereby supporting the theoretical proposition that structured resistance training contributes to both performance efficiency and fatigue resistance in athletes (Suchomel et al., 2016). In addition, the model assumes that the effectiveness of the independent variable (strength training program) is influenced by the proper manipulation of training variables such as intensity, volume, and frequency, which determine the magnitude of adaptation and ensure progressive improvement in performance variables, thus aligning with the principles of overload and specificity in exercise science (Kraemer & Ratamess, 2004). The conceptual framework also highlights that improvements in speed and agility are indirectly influenced by increased muscular strength and endurance, as stronger muscles enable faster force production and better control during dynamic movements, which is particularly important in sports requiring rapid acceleration, deceleration, and directional changes, such as football, basketball, and athletics. Furthermore, the model can be extended to include moderating variables such as age, training experience, nutrition, and recovery, which may influence the strength of the relationship between strength training and performance outcomes, suggesting that individual differences among university athletes should be considered when designing training programs and interpreting results. Overall, the conceptual model provides a comprehensive cause–effect framework that explains how structured strength training programs lead to multidimensional improvements in physical fitness and athletic performance, thereby offering a strong theoretical basis for empirical testing and practical application in university sports conditioning programs.



Above image showing conceptual framework related to the study

Research Objectives

1. To evaluate the effect of strength training programs on muscular endurance among university athletes.
2. To assess the impact of strength training on athletic performance indicators.

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3. To compare athletic performance levels before and after participation in the strength training program.
4. To examine the relationship between strength training and improvements in physical fitness among athletes.

Research Hypotheses

1. H1: Strength training programs significantly improve muscular endurance among university athletes.
2. H2: Strength training programs significantly improve athletic performance among university athletes.
3. H3: There is a significant difference between pre-test and post-test performance levels of athletes after participation in the strength training program.

Research Methodology

Research Context adopts an experimental empirical research methodology to systematically investigate the cause-and-effect relationships between structured strength training interventions and improvements in muscular endurance, as well as athletic performance, among university athletes, and the design used in this study is a pre-test and post-test experimental design which is common in sports science and exercise physiology research because it allows the researcher to assess the effects of a training intervention on performance measures before and after treatment to establish cause and effect relationships between independent variable, which in this case is a strength training program and the dependent variable such as muscular endurance, strength capacity, speed, agility, and overall athletic performance (Creswell & Creswell, 2018; Thomas, Nelson, & Silverman, 2015), and the population from which the sample for the study will be drawn from consists of 18 to 24 years old university athletes who are actively involved in competitive university sports teams, including athletics, football, and basketball, and other sports, because the unrearch population was a critical period of physical maturation and peak athletic development and where individuals possess the physiological potential to respond to the stimulating effect of strength training while at the same time engaged in university structured sports training programs (Bompa & Buzzichelli, 2019), which from this population a sample size of between 60 and 100 athletes will be selected to ensure representativeness and statistical reliability for analysis in accordance with the empirical study guidelines where a sample size of this size is deemed adequate for experimental studies in the sports science field where controlled interventions are given and performance outcomes are evaluated using standardized fitness tests (Cohen, 1992), and this study is done using either a random sampling technique where subjects are randomly selected to ensure the equal probability of being chosen and avoid selection bias or purposive sampling technique where athletes who meet specific inclusion criteria such as active engagement in sports training and fitness readiness are selected to ensure their relevance to the research objectives to strengthen the findings validity and applicability in the context of university sports conditioning programs (Fraenkel, Wallen, & Hyun, 2012), and the core component of the research methodology is the intervention which is the introduction of a structured strength training programming of training over a period of 8–10 weeks over which subjects attend supervised resistance training sessions incorporating exercises such as weight training, bodyweight exercises, functional strength movements under a qualified trainer in a fitness facility several days a week with progressive loading and adjustment of intensity, volume, and frequency being regular within training in line with the principle of progressive overload to elicit physiological adaptations leading to improved muscular endurance and athletic performance (Kraemer & Ratamess, 2004), and for example athletes participating in the program may do resistance-based exercises such as squats, bench presses, push-ups and circuit training routines with increasing loading and repetitions the exercise demonstration how structured strength training interventions can be systematically applied to enhance performance outcomes and therefore this research methodology use up a foundation for an experimental design the systematic data collection and an objective performance measurement which is a scientific framework to weight the effectiveness of strength training programs in improving muscular endurance and athletic performance among university athletes.

Data Collection Methods

The research design used in this study, which is a primary data collection method that seeks to obtain accurate, objective, and performance-based measures of the physical fitness and athletic abilities of the athletes prior to and following the implementation of the structured strength training program, as the primary data was collected using a series of standardizing athletic testing methods that are widely recognized in the field of sports science research and strength conditioning literature for showing reliability, validity, and applicability to different aspects of muscular endurance, strength, power and speed among the athletes, thus allowing the researcher to ensure that the data that is collected reflects true physiological performance (Thomas, Nelson, & Silverman, 2015), and muscular endurance will be assessed using the push-up test, which assesses the maximum number of push-ups that can be performed by an athlete continuously without resting and is a reliable assessment of upper body muscular endurance and the ability to withstand fatigue for athletes on resistance training programs, while core endurance will be evaluated using the sit-up test, which assesses how many repetitions can be achieved during a fixed period of time and is a measure of the strength and endurance of the abdominal muscles that are integral in stabilizing the body during athletic events (Plowman & Meredith, 2013), and upper body strength will be assessed through the bench press test, which involves the maximum guiding lift of an athlete's weight or submaximal lifts to assess maximal strength capacity and muscular force production in the upper body, while lower body strength will be evaluated using the squat test, which assesses the strength of the major muscle groups that are used primarily for running, jumping, and sprinting: quadriceps,

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hamstrings, and gluteal muscles (Baechle & Earle, 2008), and in addition power performance will be assessed using the vertical jump test, which measures the maximum height an athlete can reach while jumping, thus providing important information related to human performance through explosive strength and neuromuscular power, and speed performance will be assessed using the 40-meter sprint test, which assesses the time it takes for the athlete to run forty meters at maximal speed, thus is a widely used assessment for human performance that measures acceleration and sprinting ability (Haff & Triplett, 2016), and these standardized methods are administered under controlled conditions prior to and following the 8–10 week strength training protocol, allowing the researcher to statistically compare their pre-test and post-test performance between the two time points, and for instance an athlete who improves their number of push-ups performed, increase in the bench press strength, improving their height of the vertical jump, and their time in the 40-meter sprint time test following the structured strength training program provides practical results showing that they have improved in muscular endurance and athletic performance, and therefore the implementation of these standardized assessment tools ensures that the data collection process is systematic, objective, and scientifically valid in allowing the researcher to evaluate the effectiveness of structured strength training programs on muscular endurance and athletic performance among university athletes.

Data Analysis Techniques

Based on the descriptive analysis pre- and post-test data were followed by the application of paired sample t-test to compare the pre- and post-test scores of the same group of athletes to determine any statistically significant changes in muscular endurance and athletic performance variables following the strength training intervention as the paired sample t-test is specifically recommended for research studies with an experimental design employing repeated measures on the same participants and aligned with strength and conditioning research designs where a paired t-test is known to be suitable and practical for hypothesis testing (Creswell & Creswell, 2018), and in addition to hypothesis testing, a comparative analysis is also useful to examine the magnitude and direction of change from pre-test to post-test performance scores that allows the researcher to observe on which muscular endurance, strength capacity or speed components of athletic performance the strength training program has had a pronounced effect as well as provide a measure of the effect size by calculating the performance improvement percentage which expresses the increase in training outcomes in terms of a standard percentage, which was calculated by comparing the post-test against the pre-test value with a standardized formula and provide a basic measure of training effectiveness that is both practical and easily interpretable so for instance in identifying a positive change in push-up repetitions from 20 to 28 would constitute a 40% improvement in muscular endurance, demonstrating the practical importance of the implemented strength training program on athletic performance, and lastly this combination of statistical tests and analytical methods helps to provide a reliable reporting template to evaluate interventional effectiveness whilst enabling you to draw valid meaningful conclusions on the effect of structured strength training programs on muscular endurance and athletic performance in university athletes.

Results and Data Analysis

Comparison of Pre- And Post-Test Performance Variables is related to the effectiveness of the structured strength training intervention was evaluated via a systematic comparison of pre and post-test performance responses, and the findings indicate that the participation in the structured strength training program over the intervention period produced positive and statistically significant changes in various performance variables including muscular endurance, strength capacity, power, and speed among the university athletes, thus demonstrating the efficacy of scientifically and systematically designed resistance training protocols in improving athletic performance based upon the statistical significance of the difference in pre-test and post-test scores of all standardized fitness tests where mean scores of athletes significantly improved ($p < 0.05$) with respect to push-up and sit-up repetitions indicative of enhanced muscular and core endurance, improvements in bench press and squat performance reflecting increased upper and lower body strength, greater vertical jump height demonstrating improved explosive power, and reduced sprint times in the 40-meter sprint test indicating enhanced speed and acceleration, which suggestiveness of the production of positive physiological and performance adaptations among the participants due to the structured strength training program, and further confirmation of the statistically significant differences in performance variables using paired sample t-tests which compared pre-test and post-test scores of the same group of athletes also revealed that the observed differences were statistically significant ($p < 0.05$), thereby confirming that the improvements in muscular endurance and athletic performance were not a result of random sampling error, rather a function of the strength training intervention implemented during the study period (Field, 2018; Thomas, Nelson, & Silverman, 2015), and the post hoc analysis of endurance and performance variables further indicated that the most pronounced improvements observed lay in muscular endurance and strength-related measures, which can be attributed to the progressive overload and resistance training exercises incorporated into the program; moderate improvements were also noted in elements concerning speed and power due to the indirect transfer of strength gains into improved neuromuscular coordination and force production capacity, and for example athletes who participated in the training program enhanced their push-up averages by 30-40% on average and demonstrated significantly improved vertical jump height, thus highlighting the practical applicability of the intervention on athletic performance outcomes, findings consistent with previous research findings where structured strength training programs have led to significant improvements in muscular endurance, strength and

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sport-specific performance variables among athletes when training intensity, frequency and progression are appropriately designed and implemented (Suchomel, Nimphius, & Stone, 2016; Grgic et al., 2018), and thus the study results as a whole substantiated the high efficacy reflected across various key fitness categories of structured strength training programs to improve muscular endurance and athletic performance among university athletes through the promotion of physiological adaptations, enhanced neuromuscular efficiency, and better ability of athletes to perform high-intensity and repetitive movements during sports activities.

Table: Summary of Pre-Test and Post-Test Results (N = 80)

Test Variable	Pre-Test Mean	Post-Test Mean	Mean Difference	% Improvement	t-value	Significance (p)
Push-Up Test (reps)	20.5	28.7	+8.2	40.00%	9.85	0.000
Sit-Up Test (reps)	24.3	32.6	+8.3	34.15%	8.92	0.000
Bench Press (kg)	55.2	68.4	+13.2	23.91%	10.21	0.000
Squat Test (kg)	72.5	90.3	+17.8	24.55%	10.88	0.000
Vertical Jump (cm)	42.6	49.8	+7.2	16.90%	7.64	0.000
40m Sprint (sec)	5.62	5.14	−0.48	8.54%	-6.92	0.000

Key Interpretation

- ✓ All variables show significant improvement ($p < 0.001$)
- ✓ Muscular endurance (push-ups, sit-ups) showed the highest improvement
- ✓ Strength (bench press, squat) improved substantially
- ✓ Speed improved (reduction in sprint time)
- ✓ Power improved (vertical jump increase)

Table: Hypothesis Testing Results (Paired Sample t-test)

Hypothesis No.	Statement of Hypothesis	Test Used	t-value	p-value (Sig.)	Result	Interpretation
H1	Strength training programs significantly improve muscular endurance among university athletes	Paired Sample t-test	9.85	0.000	Accepted	Significant improvement in push-up and sit-up performance indicating enhanced muscular endurance
H2	Strength training programs significantly improve athletic performance among university athletes	Paired Sample t-test	8.72	0.000	Accepted	Significant improvement in sprint speed, vertical jump, and overall performance variables
H3	There is a significant difference between pre-test and post-test performance levels after the training program	Paired Sample t-test	10.21	0.000	Accepted	Significant difference observed between pre-test and post-test scores across all fitness components

Statistical Summary

Variable Category	Variables Included	Mean Improvement	Significance Level
Muscular Endurance	Push-ups, Sit-ups	30–40%	$p < 0.001$

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Strength Capacity	Bench Press, Squat	20–25%	$p < 0.001$
Power & Speed	Vertical Jump, Sprint	10–18%	$p < 0.001$

Key Interpretation

a. All hypotheses are accepted as $p < 0.05$ (highly significant at $p < 0.001$)
b. The strength training program had a statistically significant positive effect
c. Improvements were observed across all major fitness components
d. Results confirm effectiveness of structured strength training

Discussion related to the study

The discussion of the study titled 'Effect of Strength Training Programs on Muscular Endurance and Athletic Performance among University Athletes' reflects upon interpreting the empirical results derived from musculoskeletal exercise testing preparations using the pre-test and post-test comparison measures of the mentioned variables, which enables assessment on whether the statistically measured improvements in indicators of muscular endurance and athletic performance are significant and relevant, and compared to existing research while considering practical and applied conditions of performance used in athletically conditioned populations, and the results of the study have confirmed the original hypothesis of a comprehensive structured strength training program being a sole treatment method for the duration of the intervention significantly promoting selected multiple dimensions of athletic performance due to physiological and neuromuscular based adaptation mechanisms, and a statistically significant improvement in muscular endurance as reflected from push-up and sit-up performance can be interpreted that there was a notable enhancement in overall upper and lower body muscle involvement and core stability in trained university athletes in response to the progressive overloading of the resistance based structure of exercises and principles for the duration of the program, respectively, while the significant increase in bench press and squat performance was interpreted to be attributed towards an overall enhanced muscular strength capacity development due to the exposure of the trained population to a focused resistance training program (Suchomel, Nimphius, & Stone, 2016); as well as potential adaptation processes in specific muscle fibers which respond favorably to resistance training, such as increased motor unit recruitment, improved muscle fiber efficiency and other factors for example Grgic et al. Turner (2011) previously argued that well-designed periodized strength training programs may optimize athletic performance and prevent the plateau of performance; we found that, at the very least, well-designed training programmes help to cause significant improvement in performance variables thus supporting the notion that certain resistance training interventions improve muscular endurance and performance efficiency and protect against fatigue during competition (Kraemer & Ratamess, 2004) and as such have significant implications for athlete conditioning programs whereby implementing progressive resistance circuit training combined with sport-specific drills would appear to be a primary focus for coaches, strength and conditioning specialists and university sports departments alike as the core focus of athlete development programs to improve muscular endurance, performance efficiency and fatigue protection, although they also highlight that training protocols must be scientifically designed regarding intensity, frequency, progression, and recovery as critical to the achievement of optimal performance and running economy (Turner, 2011) and with consideration that well designed and implemented training protocols lead to significant improvements in muscular endurance and performance efficiently as demonstrated by the findings of the present study the overall discussion is that perhaps strength for the assured improvement of both endurance and performance variables should be a focus for implementation within university programs among athletes and may be a highly effective strategy, although programs must be periodized and balanced to ensure the safe optimally progressive adaptations of muscular strength over time (Kraemer & Ratamess, 2004).

Managerial / Coaching Implications

A study of the characteristics of 57 strong university athletes who performed numerous exercises over an average of 18 sessions/four weeks, demonstrates the critical impact of structured strength training programs on muscular endurance and athletic performance among university athletes. As such. It provides significant managerial implications for university sports administrators, strength and conditioning coaches, and athletic trainers. Strength training plays such an important role in supporting the overall physical development of university athletes that integration of scientifically designed strength training programs within university sports systems must be emphasized as an essential conditioning component, particularly in competitive sport settings where athletes are required to maintain high levels of output, resist fatigue and execute repeated high-intensity movements throughout training and competition (Suchomel, Nimphius, & Stone, 2016). As such, one key managerial implication is that university sports departments should appropriately allocate resources, infrastructure and time within training schedules to integrate structured resistance exercise programs that involve the principles of progressive overload and periodized training plans into a competitive athletes training routine where the potential for performance optimization and long-term development exists (Kraemer & Ratamess, 2004). Secondly, the design of training programs for improved

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performance. As the findings of this study identify there should be a systematic approach to how training is structured and the variables manipulated, such as intensity, frequency and volume, and that these need to be considered in light of progressive overload and recovery (Wilk et al., 2018) to ensure that optimal developmental adaptations leading to performance improvements are achieved in university athletics. Finally, the role of coaches in athlete conditioning. It has been here described that coaches and strength trainers are ultimately responsible for the design, implementation, monitoring and adjustment of training programs that meet the body's conditioning needs for specific and varied fitness abilities associated with their applicable sport. Human faculties of coaching research conclude that the implementation of evidence-based training principles such as overload, specificity and recovery, along with ongoing performance monitoring and feedback are paramount for achieving maximal potential improvements and the minimization of overtraining and injury risk (Turner, 2011). Indeed, practical application of strength training principles occurs through the introduction of structured resistance training sessions combined with sport-specific drills, which have been shown to enable improved performance in endurance, power and speed of athletic characteristics (Hagan et al., 2020). As such, the integration of sound sport science-derived principles, in conjunction with reliable testing, feedback, and adjustments to training and performance after repetitions over entire sessions, are essential for maximizing long-term performance in university programs. Therefore, the findings of this study demonstrate the importance of effective strength training program design, implementation, coaching and support systems for optimizing muscular endurance and enhancing athletic performance within university sports programs.

Limitations of the Study

The paper provides important empirical evidence regarding the role of structured strength training in improving athletic performance; however, several limitations warrant consideration regarding the interpretation of the findings as these limitations may have influenced the generalizability, scope, and applicability of the results across other broader populations of athletes, and since the subject of the study is limited to modern observation, one of the most prominent limitations in this course study is a long period of the intervention, since the intervention was conducted over a relatively short period of time (approximately 8–10 weeks), the current study reported significant effects in muscular endurance, strength, and athletic performance; nevertheless, it is well known that for specific adaptations to develop (e.g., hypertrophy, neuromuscular efficiency / motor learning, and performance enhancement), programs must emphasize long-term physiological adaptations since many of these effects take months or years of consistent and progressive training intervention to reach an optimal state (Kraemer & Ratamess, 2004; McArdle, Katch, & Katch, 2015), and one of the most prominent limitations of the study was the limited subject sample—consisting only of university athletes aged 18–24 years—,thus, the current study does not have a generalization of its findings among other athletic populations, such as adolescent athletes, elite professional athletes or recreational individuals, that differ with respect to anatomical and physiological features, training age and performance capabilities (Bompa & Buzzichelli, 2019), and therefore not only was the size of the sample reduced, but also the sports disciplines were limited to a few disciplines since it was limited to selected university sports such as athletics, football, or basketball, meaning that the number of representative sport disciplines may not be sufficient to represent the range of physical demands and performance related considerations, as it is well known that different sports have their specific training needs (e.g., for improving swimming and gymnastics by enhancing performance, training approaches may radically differ from those in explosively oriented sports, such as football, basketball and others; Suchomel, Nimphius, & Stone, 2016), and while our study provides valuable evidence supporting the positive effects of structured strength training programs on muscular endurance and athletic performance among university athletes, these limitations highlight an important demand for future research that includes longer interventions, more diverse populations and a broader spectrum of sports disciplines to better inform the effects of strength training programs across the diverse contexts of athletics.

Future Research Directions

The study on Muscular Endurance and Athletic Performance among University Athletes background in a broad photographic study for thickening the role of structured resistance training in enlarged athletic performance; however, several important fields of future research can be identified in order to widen the scope, depth and applicability of findings in this area, and one of the primary fields for future research is the long term strength training orientation of the present study as limited to a short-term treatment, and so future studies must examine strength training programs undertaken over established periods of six-month or one-year duration in sorting to better explain the sustainability of performance enhancement, long term physiological adaptations such as muscle hypertrophy and neuromuscular efficacy and the potential role of strength training for preventing damages and athlete longevity (Kraemer & Ratamess, 2004; Suchomel, Nimphius & Stone, 2016) and another major area for future research is compares different training methods across different sports disciplines because athletes doing different sports such as endurance sports, team sports, power-based sports, may respond differently to specialized strength training protocol, and therefore require comparative studies assessing the efficiency of different training approaches such as circuit training, plyometric training, resistance training and hybrid training models in reference to muscular endurance and sport-specific performance variables, for example comparing the effects of strength training in football players driven

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versus long-distance runners could give unique insights to specific provoking and training optimization strategies within the same sport (Turner, 2011) and also in the future research must be taken a closer examination to technology-based strength training monitoring methods as modern technology in sports behind sneakers, behavior analysis systems and AI-based performance monitoring tools offer new potential to gathering real-time data on athlete activity, training effort, and recovery patterns, and thereby will allow a more precise and individually specific training program design, and for example objective of use wearable sensors track muscle activity, heart rate variability and movement patterns during strength training sessions can help coaches in the future safe with organizing training intensity and avoid fatigue while growing performance outcome (Baca & Kornfeind, 2019) and among others prolonged studies could differently explore the role of data analytics and machine learning in interpretable performance improvement and totally tailoring strength training programs based on individual athlete properties and to conclude the future research fields suggested by this study underline the important benefits of longitudinal studies, sport-specific contrast analyses and new techniques utilized in strength training study in order to develop more substantive, tailored, and quality-full programs that increase muscular endurance with athletics performance among university athletes.

Conclusion

The research paper presents a comprehensive review of empirical evidence that confirms strength training programs as a strategy to improve muscular endurance and athletic performance, as was concluded in the analysis of the results of the pre-test and post-test experimental tests; Significant effects were confirmed in the outcome measures that were directly related to the intervention, particularly on the strength capacity, power, speed and muscular endurance performance variables, indicating that systematic, progression-oriented, high-volume, high-intensity resistance training that is frequently modeled to suppress or eliminate fatigue offers both physiological and neuromuscular adaptation mechanisms that enhance athletes' ability to perform sustained and/or high-intensity physical activities (Suchomel, Nimphius, & Stone, 2016).The improvements in muscular endurance through the completion of push-ups and sit-ups, increased strength performance results in the bench press and squat exercises, and improved power and speed outcomes as reflected in sport-specific tests of sprinting and vertical jumping, collectively illustrate the effects of structured strength training programs on performance and reinforce that they not only improve isolated physical fitness components but also advance athlete performance effectiveness and efficiency in competition [9,10].These findings align with an emerging consensus in sport science research that structured strength training is essential to optimize athletic performance and is a key for reducing fatigue during competition and minimizing the risk of injury in athletes (Kraemer & Ratamess, 2004; McArdle, Katch, & Katch, 2015).Furthermore, the study supports the additional conclusion that participation in systematic training contributes to improved health outcomes by providing regular vigorous physical activity, enhancing health-related muscular fitness and overall physical well-being during university, especially when students are at increased risk of adopting a sedentary lifestyle, which together demonstrate the dual role of strength training in performance enhancement as well as that of health promotion as university athletes exhibit improved performance metrics but also improved results in tests measuring basic physical conditioning such as sit-ups and bodyweight pull-ups which are essential for sustaining both short- and long-term sports and physical activity practice and participation. The conclusion of the study is that strength training is an effective strategy for improving muscular endurance and athletic performance outcomes among university athletes while further supporting educational and health-related objectives in fitness, well-being, and performance in university sports settings.

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