International Journal of Yogic, Human Movement and Sports Sciences 2020; 5(1): 220-223

ISSN: 2456-4419
Impact Factor: (RJIF): 5.18
Yoga 2020; 5(1): 220-223

www.theyogicjournal.com
Received: 25-02-2020
Accepted: 08-03-2020

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Impact of maximal and submaximal resistance training on selected strength parameters among basketball players

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Abstract
The purpose of this study was to investigate the impact of maximal and submaximal resistance training on selected strength parameters among male basketball players at the collegiate level. Strength, explosive power, and agility are vital qualities in basketball performance, influencing rebounding, sprinting, jumping, and defensive actions. The present research involved forty-five college-level male basketball players aged 18-22 years, randomly divided into three groups: Maximal Resistance Training Group (MRTG), Submaximal Resistance Training Group (SMRTG), and Control Group (CG). Participants were assessed on four selected parameters: leg strength (vertical jump test), abdominal strength (sit-up test), upper body strength (bench press 1RM), and agility/explosive power (20 m sprint test). Both MRTG and SMRTG underwent an eight-week intervention program, while the control group continued regular practice without structured resistance training.
Data were analyzed using Analysis of Covariance (ANCOVA) followed by post hoc comparisons. Results revealed significant improvements in all measured parameters for both MRTG and SMRTG compared to the control group. Furthermore, MRTG showed greater gains than SMRTG across most measures, especially in leg strength and bench press performance. These findings confirm the efficacy of structured resistance training in enhancing basketball-specific physical qualities, and they highlight the superiority of maximal training in eliciting greater strength adaptations. The study concludes with implications for strength and conditioning coaches, emphasizing the need for integrating periodized maximal resistance training into basketball training regimens to optimize performance.

Keywords: Basketball, resistance training, maximal load, submaximal load, strength parameters, vertical jump, bench press, agility

Introduction
Basketball is a fast-paced, intermittent team sport characterized by rapid changes of direction, explosive jumping, sprinting, and sustained high-intensity play. Players are required to demonstrate a unique combination of anaerobic power, aerobic endurance, muscular strength, speed, and agility in order to be competitive at collegiate and professional levels (Ziv and Lidor 2010; Conte *et al*. 2021) [16, 3]. The modern game demands continuous physical exertion, involving defensive stances, rebounding battles, and offensive drives that place substantial stress on the musculoskeletal and cardiovascular systems. In this context, strength is not only a prerequisite for injury prevention but also a key determinant of competitive success.
Resistance training has long been recognized as a cornerstone in the physical preparation of athletes across sports. Specifically, basketball players benefit from increased muscular strength because it translates directly into improved jump height, quicker sprints, more forceful rebounds, and the ability to withstand physical contact during games (Ramirez-Campillo *et al*. 2020) [12]. However, the manner in which resistance training is prescribed whether through maximal or submaximal loading remains a subject of debate among coaches and researchers.
Maximal resistance training typically involves lifting loads close to an athlete's one-repetition maximum (90-95% of 1RM). This training method is associated with significant neural adaptations, increased recruitment of high-threshold motor units, and maximal hypertrophy in fast-twitch muscle fibers (Suchomel *et al*. 2018) [14].

Submaximal resistance training, on the other hand, involves lifting moderate loads (50-70% of 1RM) for more repetitions, emphasizing endurance, muscle hypertrophy, and technical refinement (Fry 2004) [6]. While both methods can enhance performance, their relative effectiveness for basketball-specific performance qualities such as jumping, sprinting, and agility requires empirical clarification.

Basketball's unique biomechanical requirements justify an investigation into the comparative effects of maximal and submaximal resistance training. For example, vertical jumping ability is directly linked to rebounding and shot-blocking success, while sprinting and agility underpin both offensive and defensive transitions. Core stability, represented by abdominal strength, ensures efficient energy transfer during dynamic movements. Likewise, upper body strength contributes to shooting range, rebounding power, and post-play dominance (Hoffman 2014) [8].

This study therefore sought to assess the impact of maximal and submaximal resistance training on four selected strength parameters in basketball players: leg strength, abdominal strength, upper body strength, and agility. By simulating a structured intervention with college-level athletes, the research aimed to provide practical guidance for coaches and strength specialists in optimizing training programs.

Review of Literature

The role of resistance training in basketball has received increasing attention in the last decade, with studies highlighting improvements in performance through various modalities, including plyometric training, weightlifting, and combined strength-power programs.

Maximal vs. Submaximal Training in Sports

Fry (2004) [6] outlined the physiological basis of maximal and submaximal loading, noting that maximal training enhances neural drive, motor unit synchronization, and peak force output, whereas submaximal training promotes muscular endurance and hypertrophy. Suchomel *et al*. (2018) [14] emphasized that maximal loading is crucial for sports requiring explosive actions, as it facilitates adaptations in rate of force development. Conversely, submaximal training is often recommended for athletes in early training phases or during injury recovery, as it reduces injury risk and fosters technique acquisition.

Basketball-Specific Strength Training

Hoffman (2014) [8] conducted extensive analyses of basketball performance demands, identifying vertical jump, sprint speed, and upper body pressing strength as predictors of success. More recently, Stone *et al*. (2020) [13] demonstrated that basketball players engaging in structured resistance training programs significantly improved vertical jump height and sprinting speed compared to those with unstructured conditioning.

Leg Strength and Vertical Jump

Vertical jump is considered one of the most reliable indicators of lower-body power in basketball (Cormie *et al*. 2011) [4]. Resistance training, particularly with heavy loads, has been shown to enhance vertical jump by increasing muscle cross-sectional area and neural efficiency (Ramirez-Campillo *et al*. 2020) [12]. Studies by McGuigan and Winchester (2008) suggest that maximal strength levels are strongly correlated with jump height in team-sport athletes.

Abdominal Strength and Core Stability

The core acts as a stabilizing center for force transfer during dynamic movements. Behm *et al*. (2010) [2] documented that resistance training targeting abdominal strength enhances postural control, balance, and performance in multidirectional sports like basketball. Furthermore, Hibbs *et al*. (2008) [7] noted that stronger abdominal musculature reduces injury risk by stabilizing the spine under high-load conditions.

Upper Body Strength

Bench press strength correlates with upper body power and functional performance in basketball, especially for positions requiring frequent contact in the post area. Hoffman *et al*. (1996) [9] established relationships between bench press scores and overall playing ability in collegiate players. Contemporary studies confirm that maximal upper body strength contributes not only to rebounding but also to long-range shooting mechanics (Pojskic *et al*. 2018) [11].

Agility and Sprint Performance

Basketball involves frequent short sprints and direction changes. Young *et al*. (2002) [15] emphasized the link between lower-body strength and agility, arguing that resistance training improves acceleration, deceleration, and change-of-direction performance. Barnes *et al*. (2021) [1] supported this by showing improvements in agility drills following high-intensity resistance training interventions.

Comparative Findings

Research across sports shows that both maximal and submaximal training induce positive adaptations, but maximal training often yields superior gains in explosive power and maximal strength (Crewther *et al*. 2016) [5]. However, submaximal training may be advantageous for volume accumulation and muscular endurance, which also contribute to long-term performance sustainability.

Collectively, these studies underline the necessity of structured resistance training in basketball, yet they leave unresolved the specific balance between maximal and submaximal training in optimizing performance.

Methodology

Participants

Forty-five male basketball players aged 18-22 years were recruited from college teams in northern India. All participants had at least two years of playing experience at the intercollegiate level but had not engaged in structured resistance training in the previous six months. Written consent was obtained from participants, and ethical approval was granted by the institutional review board.

Design

Participants were randomly assigned to three groups (N=15 each):

- Maximal Resistance Training Group (MRTG)
- Submaximal Resistance Training Group (SMRTG)
- Control Group (CG)

The intervention lasted eight weeks. Pre-tests and post-tests were conducted on four selected parameters: Leg strength, abdominal strength, upper body strength, and agility.

Selected Strength Parameters and Tests

- **Leg Strength:** Measured using the Vertical Jump Test

(best of three attempts recorded in centimeters).
- **Abdominal Strength:** Evaluated through a 60-second Sit-Up Test (total repetitions completed).
- Upp**er Body Strength:** Bench Press 1RM (maximum weight lifted in kilograms).
- **Agility:** Measured via 20 m Sprint Test (best of two trials recorded in seconds).

Training Protocols
- **Maximal Resistance Training (MRTG):** 4 sessions per week, 90-95% of 1RM, 3-5 sets of 4-6 reps. Exercises included squats, deadlifts, bench press, overhead press, and plyometric box jumps.
- **Submaximal Resistance Training (SMRTG):** 4 sessions per week, 55-65% of 1RM, 3-4 sets of 10-12 reps. Exercises were similar but with moderate loads and higher repetitions.
- **Control Group (CG):** Continued regular basketball practice without structured resistance training.

Analytics
Descriptive statistics (mean and standard deviation) were calculated. ANCOVA was applied to test significance between pre- and post-test results across groups. Post hoc analysis (Bonferroni test) determined pairwise differences. A significance level of $p<0.05$ was used.

Results

Table 1: Pre-Test and Post-Test Means (±SD) for All Groups

Parameter	SMRTG Pre	SMRTG Post	MRTG Pre	MRTG Post	CG Pre	CG Post
Vertical Jump (cm)	48.6±4.1	54.7±4.3	49.1±3.9	58.9±4.5	48.2±4.2	49.5±4.1
Sit-Ups (reps/60s)	30.1±3.2	34.3±3.0	29.9±3.1	36.9±3.4	30.3±3.0	30.9±3.2
Bench Press (kg)	72.4±6.5	79.6±6.1	73.1±6.7	85.7±6.2	72.8±6.4	73.9±6.5
Sprint (20m, sec)	3.41±0.20	3.26±0.18	3.40±0.21	3.18±0.17	3.42±0.19	3.39±0.20

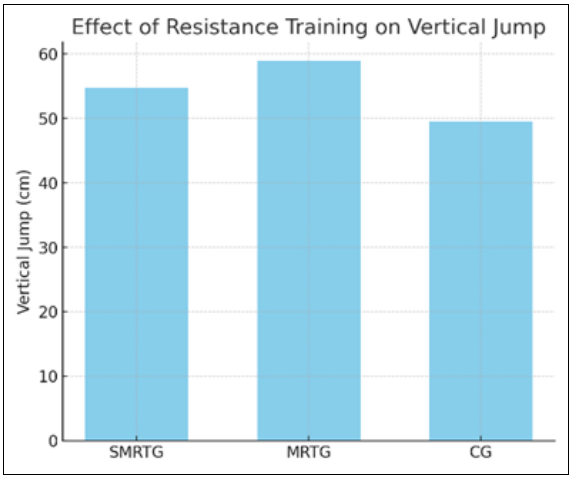

Fig 1: Vertical Jump Performance (cm)

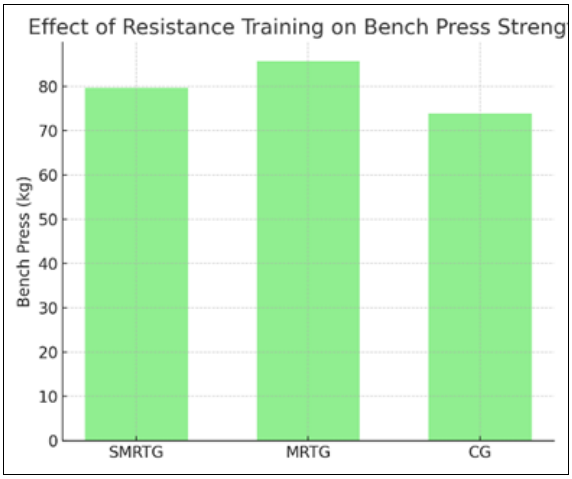

Fig 2: Bench Press Strength (kg)

Statistical Findings
- ANCOVA showed significant group differences for all four parameters ($p<0.05$).
- Post-hoc tests revealed both MRTG and SMRTG improved significantly compared to CG.
- MRTG improvements were significantly greater than SMRTG for vertical jump (P=0.01) and bench press (P=0.02).
- Differences in abdominal strength and sprint performance were also greater in MRTG, though the gap was smaller.

Discussion
The findings support both hypotheses, showing that resistance training whether maximal or submaximal enhances strength performance in basketball players, but maximal training leads to superior adaptations.

Leg Strength and Jumping Ability
Vertical jump improvements were most pronounced in MRTG, consistent with studies by Cormie *et al.* (2011) [4] and Ramirez-Campillo *et al.* (2020) [12], which highlighted heavy-load training as more effective for improving explosive power. For basketball players, this translates into enhanced rebounding and shot-blocking capabilities.

Abdominal Strength and Core Stability
Both MRTG and SMRTG showed improvements in sit-up performance, though gains were larger in MRTG. This supports Hibbs *et al.* (2008) [7], who emphasized the role of core strength in athletic performance. Improved abdominal strength likely contributed to better posture control during high-intensity play.

Upper Body Strength
Bench press performance improved significantly in MRTG compared to SMRTG, echoing findings by Hoffman *et al.* (1996) [9]. Increased upper body strength enhances rebounding, screening, and post-play dominance, providing a competitive advantage.

Agility and Sprinting
Although gains in sprint performance were modest, MRTG still outperformed SMRTG and CG. This indicates that maximal training enhances rate of force development, which is essential for acceleration and agility (Young *et al.* 2002) [15].

Practical Implications
These findings suggest that basketball coaches should integrate maximal resistance training into conditioning

programs, particularly during off-season or preparatory phases. Submaximal training, while effective, may be better suited for beginners, rehabilitation, or maintenance phases.

Conclusion

The study concludes that both maximal and submaximal resistance training significantly improve strength parameters among basketball players. However, maximal resistance training is more effective in enhancing leg strength, upper body strength, and overall explosive performance. Coaches and strength specialists should incorporate maximal training protocols into basketball conditioning schedules, while carefully monitoring load progression to avoid overtraining or injury. Future research should expand sample size, include female athletes, and explore long-term effects across competitive seasons.

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