

The Effects of Ballistic and Complex Training on Obstacle Course Race Performance among Royal Malaysia Police Athletes

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ABSTRACT

Obstacle Course Racing (OCR) is a physically demanding sport that challenges athletes to combine strength, speed, endurance, and agility to overcome various physical obstacles. For Royal Malaysia Police (RMP) athletes, OCR performance not only reflects their physical fitness but also serves as an indicator of their operational readiness and functional capability in real-field conditions. This study aims to identify the most effective training method to enhance OCR performance. Specifically, it compares the effects of eight weeks of ballistic training (BT) and complex training (CT) on upper- and lower-body strength, grip strength, vertical jump power, and linear sprint speed among RMP OCR athletes. Twenty male RMP special unit officers ($n = 20$; age: 30.4 ± 4.4 years; height: 1.75 ± 0.03 m; body mass: 66.0 ± 3.0 kg) participated in this study. Participants were randomly assigned to either the BT group or the CT group. Both groups showed significant improvements in upper- and lower-body strength and power ($P < 0.001$). However, the BT group demonstrated greater improvements compared to the CT group. No significant changes were observed in 60-m sprint performance ($P > 0.001$). The findings suggest that incorporating ballistic resistance exercises into in-season training programs can effectively optimize performance among tactical OCR athletes.

Keywords: Obstacle Run, Police, Functional Fitness

INTRODUCTION

Obstacle Course Racing (OCR) is a competitive sport that requires participants to complete a prescribed running route while overcoming a series of physical challenges or obstacles that test strength, endurance, agility, coordination, and mental resilience (Baghurt, Prewitt & Tapps, 2019). These obstacles typically include climbing, crawling, jumping, lifting, balancing, and traversing various structures, making OCR a multidimensional sport that combines elements of endurance running and functional fitness (Del Coso, J., et al., 2020). OCR events vary in distance, intensity, and obstacle complexity such as Sprint races (5 km with 20–25 obstacles), Super races (10 km with 25–30 obstacles), Beast races (21 km with 30–35 obstacles), and Ultras (50 km with 60 obstacles) (Pritchett, R. C., et al., 2021). Today, OCR is widely used in both recreational and tactical settings to assess physical capability, problem-solving skills, and performance under pressure (Pawel, Marta, Daniel & Marzena, 2023).

In recent years, there has been a noticeable rise in the popularity of OCR within the Royal Malaysia Police (RMP). The RMP OCR serves not only as a competitive platform but also as a vital component of occupational preparedness, where rapid decision-making and high levels of physical readiness are essential (Naylor et al., 2023). The RMP OCR course covers a distance of 800 meters and features 14 obstacles. These includes rope climbing, goat bridge, a 6-foot wall, monkey bars, goat ladder, spider web, cross ladder, wobbly bridge, step-over barrier, inverted ladder, water pool, tire obstacle, rope climb, and barbed wire. Upon completing all 14 obstacles, participants must shoot an 8×8 cm target plate from a distance of 25 meters (Training Division, Central Brigade, General Action Force, 2023). Despite the physically demanding nature of these challenges,

there is limited evidence identifying which specific training methods can most effectively enhance the explosive power, agility, strength, and obstacle efficiency required for optimal OCR performance especially among police personnel.

Choosing the most effective training method will benefit the RMP by enhancing officers' explosive strength, agility, obstacle efficiency, and overall performance, while simultaneously improving their readiness for operational duties that demand both physical and mental resilience. Ballistic training (BT) characterized by high-velocity, explosive movements has been widely shown to improve power output, neuromuscular activation, and sport-specific explosive actions such as jumping and sprinting (Loturco et al., 2025). Research indicates that ballistic exercises closely mimic fast, dynamic movements required in performance-based tasks, making them highly relevant for tactical and obstacle-based sports. The effectiveness of BT has been shown to enhance power based on the Post-Activation Potentiation (PAP) mechanism, which is associated with increased force production capacity (Moir & Munford, 2018). This supported by Thapa et. al., 2020, showing that combining BT with high and low velocity Stretch-Shortening Cycles (SSC) promotes greater PAP effects.

Meanwhile, complex training (CT) is a form of exercise that combines heavy resistance lifts with high-speed plyometric movements to enhance the force-velocity curve, targeting attributes such as strength-speed, peak power, speed-strength, and maximal velocity. CT has been shown to improve stretch-shortening cycle (SSC) function, motor unit recruitment, firing frequency, intra- and inter-muscular coordination, and induce morphological adaptations, all of which collectively enhance muscular force production capacity (Cormier, Freitas, Arias, & Alcaraz, 2020). Additionally, CT optimizes the post-activation potentiation (PAP) mechanism, further improving SSC efficiency and enabling greater force production with faster reaction times (Talpey, Young, & Saunders, 2016). Supporting this, Abade et al. (2019) reported that 12 weeks of CT significantly improved vertical jump height and 10-meter sprint performance in handball athletes, highlighting its effectiveness for enhancing explosive athletic capabilities.

Although numerous studies have examined BT and CT independently, limited research has focused on their combined or comparative effects on OCR performance, especially among tactical populations whose physical demands differ from traditional athletes. Current OCR-related literature primarily focuses on endurance, general strength, or isolated physical components, with minimal emphasis on integrated high-velocity training methods such as BT and CT. Research among RMP personnel remain scarce, despite their unique occupational requirements and frequent participation in police-based OCR competitions. There is a lack of evidence identifying which training method is more effective for enhance OCR-specific performance outcomes. Given the physically demanding nature of OCR events and the need for RMP athletes to maintain high levels of operational readiness, it is essential to identify evidence-based training strategies that optimize performance while aligning with job-specific physical requirements. Therefore, this study is warranted to determine which training method provide greater benefits for OCR performance also to provide practical recommendations for coaches, police trainers, and tactical conditioning programs within the RMP. Therefore, this study aims to identify the most effective training method to enhance OCR performance.

Specifically, it compares the effects of eight weeks of BT and CT on upper- and lower-body strength, grip strength, vertical jump power, and linear sprint speed among RMP OCR athletes. It was hypothesized that both training methods will produce significant improvements in OCR performance, but one training method will improve on overall outcomes.

METHOD

Research Design

This study employed a quasi-experimental design with a quantitative approach to investigate the effects of BT and CT on the RMP OCR athletes. A pretest was employed one week before the commencement of training and post-test after the 8-week intervention. The test included One-Repetition Maximum (1RM) for Bench Press and Half Squat, Vertical jump performance, Static handgrip strength (flexor strength), and 60meter sprint acceleration.

Participants

A total of twenty male participants ($n = 20$; Age: 30.4 ± 4.4 years; Height: 1.70 ± 0.07 m; Body Mass: 60.0 ± 10.2 kg) from the Special Operations Unit of the RMP were purposively recruited for this study. The participants were randomly assigned to BT group ($n = 10$) or the CT group ($n = 10$). The study was conducted at the Special Task Force (Unit Tindakhas, UTK) Bukit Aman Gymnasium. All participants gave their written consent prior to the study. None of the participants had any history of injury or chronic illness. Additional medical clearance was also obtained from the Northern Brigade Clinic of the General Operations Force (PGA). They were instructed to refrain from taking dietary supplements or engaging in any additional training programs during the study period. Ethical approval for this study was obtained from the University Ethics Review Committee.

Training Protocols

The 8-week training program consisted of 16 sessions, with the exercise intensity increasing every four weeks. Training sessions were held twice per week, with at least 24 hours between sessions to allow for recovery. Each session began with a standardized 10–15-minute warm-up and concluded with static stretching for cooldown. Training intensity was prescribed based on pre-test 1RM values, and the load was reduced by 5% of 1RM if participants were unable to complete the required number of repetitions.

Instrumentation

1RM Upper Body (Bench Press)

Upper body maximal strength was evaluated using a standard barbell bench press protocol with guideline from the National Strength and Conditioning Association (NSCA, 2016). Participants completed a standardized warm up consisting of 5 repetitions at intensities ranging from 40 %-60% of their previously estimated 1RM. Participants performed a warm up using set followed by progressive loading until the 1RM was achieved within three to five attempts. A 3-minute rest interval between trials was given for each successive attempt. The 1RM bench press has shown high test–retest reliability, with reported intraclass correlation coefficients (ICC) ranging from 0.95 to 0.99 in trained and untrained individuals.

Table 1: Training Protocol

Training	Training Intensity	Exercise		Set & Repetition	
Ballistic Training	80 – 90% of 1RM	i. Horizontal Leg Press ii. Bench Press		i. Session 1 : 3 sets/ 2- 6 reps/ 80% of 1 RM ii. Session 2 : 3 sets/ 2- 6 reps/ 90% of 1 RM	
Complex Training	30 – 50% of 1 RM	iii.	90° Half Back Squat	i. ii.	Session 1 : 3 sets/ 4- 8 reps/ 30% of 1 RM Session 2 : 3 sets/ 4- 8 reps/ 50% of 1 RM
		iv.	Squat Jump		
		v.	Medicine Ball Throw		

1RM Lower Body (Half Squat)

Maximal strength was assessed using the half squat test with knee angle 90° on a smith machine. Participants completed a standardized warm up consisting of 5 repetitions at intensities ranging from 40 to 60% of their previously estimated 1RM. Three minutes after warm up, participants were allowed up to 5 attempts at approximately 70%, 80%,90% and > 95 % of the estimated 1RM to determine their 1RM. A 3-minute rest

interval between attempts was given for each successive attempt. The 1RM half squat is a highly reliable measure of lower body strength, with good-to-excellent test-retest results across various populations (Moreno-Navarro et al., 2020).

Static Hand grip Test (Left and Right)

Maximal isometric handgrip strength was measured using a calibrated handgrip dynamometer for both left and right hands. Participants standing position with the elbow at 90° and performed two trials per hand. The highest value was recorded. A 30 second rest between attempts was given for each attempt. Studies consistently show excellent test-retest reliability for both left and right hands when measured across different sessions (ICC, >0.90) (Sartorio et al., 2025).

Vertical Jump

Vertical jump performance was assessed using the Trident Vertical Jump Test (ICC range of 0.86 to 0.98) (Palmer et al., 2023) . Participants performed maximal vertical jumps with full leg extension while maintaining natural jumping mechanics. Each athlete completed three trials, with 20 second of rest between attempts. Jump height was calculated as the difference between the maximum height reached during the jump and the athlete’s standing reach height.

60 meter Sprint

Sprint speed was assessed using timing gate (Brower Timing System) were positioned at 0, 30, and 60 m along the sprint track. Each athlete performed three maximal sprint trials from a standing start, positioned 0.5 m behind the initial timing gate. A 5-minute rest period was provided between trials, and the best performance was used for analysis.

Statistical Analysis

All data were reported as means ± standard deviations. Descriptive statistics were calculated to summarize pre- and post-intervention performance measures for both the CT and BT groups. A two-way repeated-measures ANOVA was conducted to examine changes in strength, power, and speed across time (pre vs. post) and between training groups. All analyses were performed using SPSS Version 28 (SPSS Inc., USA) with the level of significance set at $P < 0.001$.

RESULTS

1 RM Bench Press

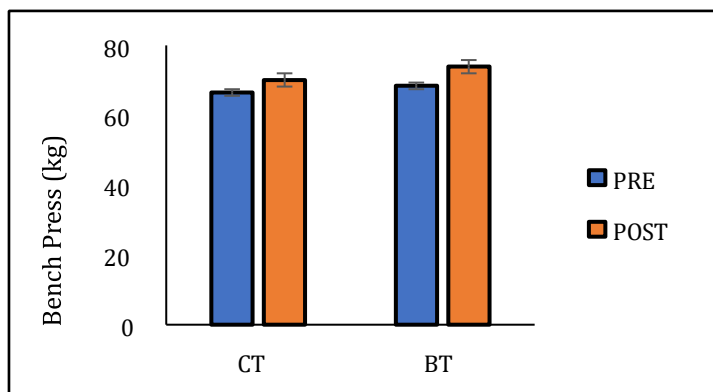


Figure 1: Pre and Post Intervention of Upper Body Strength

Figure 1 illustrate a significant main effect of time was observed for upper-body 1RM strength, $F(1, 18) = 48.76$, $p < .001$, partial $\eta^2 = .73$, with both groups showing improvements from pre- to post-intervention (CT: 66.50 ± 9.66 kg to 70.10 ± 10.12 kg; BT: 68.40 ± 9.65 kg to 73.90 ± 9.75 kg). A significant Group × Time interaction

emerged for upper-body strength ($F(1,18) = 5.63, p = 0.029, \eta^2_p = 0.24$) showed the BT group demonstrating superior gains.

RM Half Squat

Similar trend observed in the lower-body 1RM. The strength increased significantly over time, $F(1, 18) = 28.52, p < .001, \text{partial } \eta^2 = .61$ (CT: 125.00 ± 17.80 kg to 131.00 ± 18.23 kg; BT: 119.50 ± 19.07 kg to 127.00 ± 18.87 kg). The interaction for lower-body strength approached significance ($p = 0.051$) which also favoring BT. Both interventions yielded significant improvements in muscular strength with no statistically significant differential effects between the CT and BT groups.

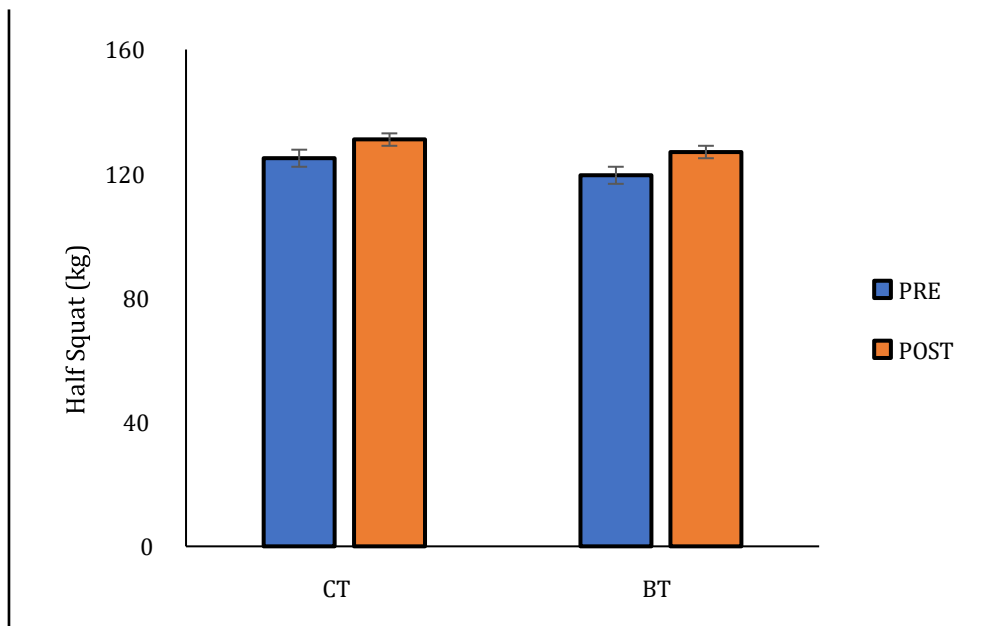


Figure 2: Pre and Post Intervention of 1 RM Half Squat Static Hand Grip Test (Left and Right)

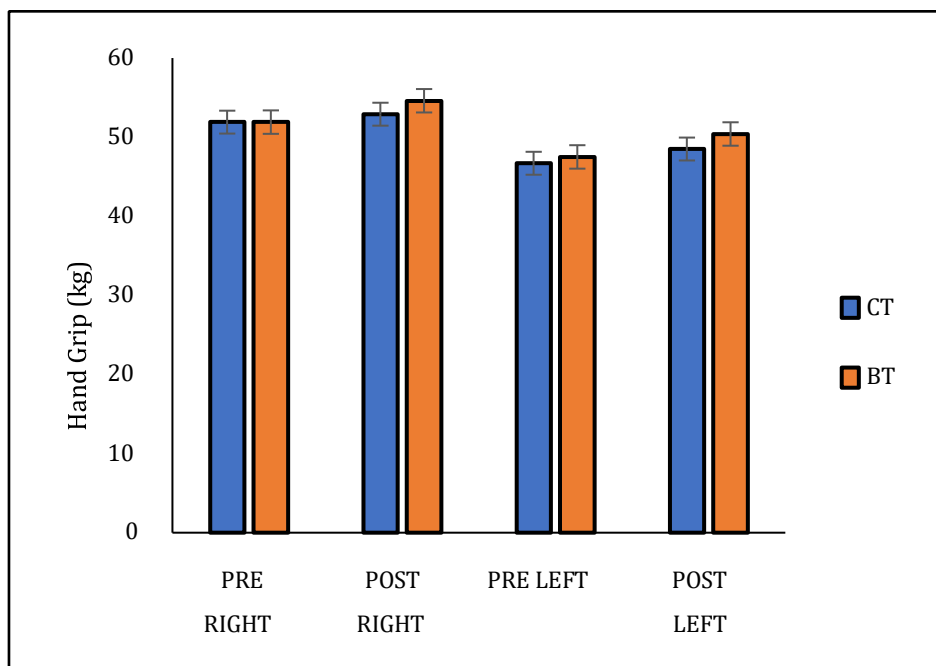


Figure 3: Pre and Post Intervention of Hand Grip Strength Test (Left and Right)

Handgrip strength also demonstrated significant time effects. Left-hand grip increased significantly, $F(1,$

18) = 5.45, $p = .031$, partial $\eta^2 = .23$ (CT: 46.70 ± 6.42 kg to 48.46 ± 6.26 kg; BT: 47.47 ± 8.34 kg to 50.38 ± 9.60 kg), as did right-hand grip, $F(1, 18) = 7.43$, $p = .014$, partial $\eta^2 = .29$ (CT: 51.97 ± 5.75 kg to 52.86 ± 6.63 kg; BT: 51.91 ± 6.83 kg to 54.56 ± 8.93 kg). However no statistically significant differential effects between the CT and BT groups.

Vertical Jump and 60 meter Sprint

Vertical jump height (as an indicator of lower-body power) improved significantly over time, $F(1, 18) = 15.23$, $p = .001$, partial $\eta^2 = .46$ (CT: 39.40 ± 3.72 cm to 40.90 ± 3.14 cm; BT: 35.40 ± 5.90 cm to 37.50 ± 4.32 cm). The CT showed greater improvement on Vertical jump and significant difference compared to BT group. In contrast, no significant change was observed in 60-meter sprint time, $F(1, 18) = 0.01$, $p = .921$, partial $\eta^2 < .01$, with minimal pre- to post-intervention differences in both groups (CT: 8.23 ± 0.53 s to 8.31 ± 0.46 s; BT: 8.47 ± 0.70 s to 8.46 ± 0.66 s).

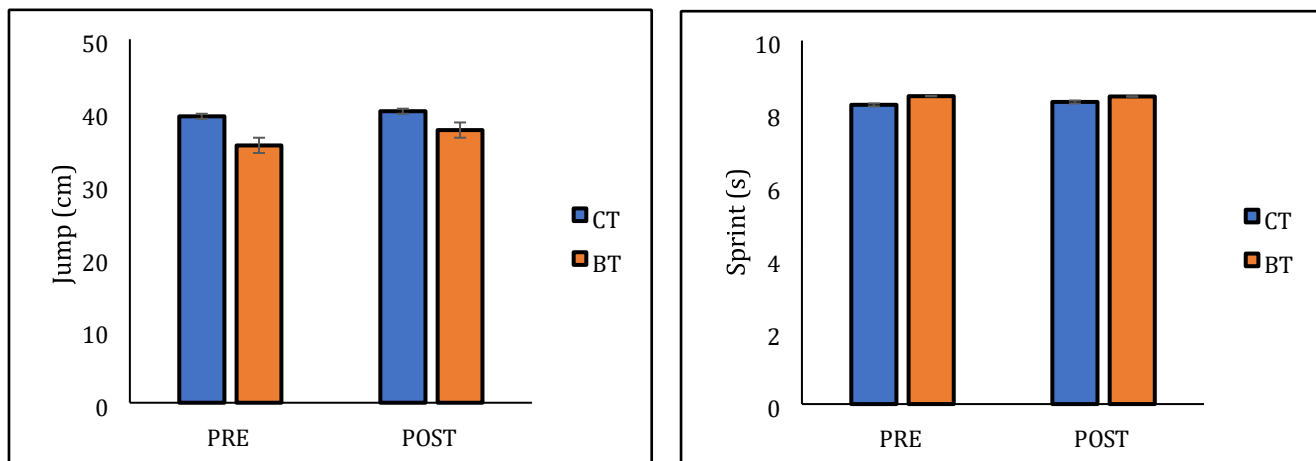


Figure 4: Pre and Post Intervention of Jump and Sprint Performance

DISCUSSION

The present study investigated the effects of BT and CT on upper- and lower-body strength, grip strength, vertical jump power, and linear sprint performance among RMP OCR athletes. Overall, the findings demonstrate that both training interventions were effective in enhancing several strength- and power-related performance variables over time, with modality-specific advantages observed depending on the outcome measured, except for sprint performance. These results align with established evidence indicating that systematic resistance training induces neuromuscular adaptations, including increased motor unit recruitment, firing frequency, and muscle cross-sectional area, which collectively contribute to improvements in maximal strength and power (Kraemer & Ratamess, 2004; Suchomel et al., 2016).

A key finding of this study is that BT demonstrated greater improvements in explosive power compared to CT. This supports that training programs emphasizing high movement velocity and lighter external loads, rather than heavy resistance, can effectively enhance neuromechanical performance without impairing force application at high velocities. The observed improvements are consistent with recent work by Loturco et al. (2025), who reported that light-loaded ballistic exercises (20–30% 1RM), combined with maximal short sprints (10–15 m) performed at high weekly frequencies, significantly improved strength–power qualities. Such adaptations are particularly relevant to OCR athletes, where rapid force production, efficient acceleration, and repeated explosive actions are critical for successful obstacle negotiation.

Greater power adaptations observed following BT may be attributed to its emphasis on high-velocity, explosive movements that enhance the rate of force development (RFD) and neuromuscular efficiency. Ballistic exercises allow continuous acceleration throughout the movement, optimizing the force–velocity relationship and promoting neural adaptations that underpin explosive performance (Suchomel et al., 2020). Previous studies have shown that BT modalities, such as jump squats, bench press throws, and Olympic lift derivatives, elicit greater neuromuscular activation and motor unit recruitment than traditional resistance or complex training

models (Haff & Nimphius, 2019; Petré et al., 2021). Furthermore, BT is closely associated with post-activation potentiation (PAP) mechanisms, which enhance force production through increased motor neuron excitability, reduced presynaptic inhibition, and preferential recruitment of fast-twitch muscle fibers (Moir & Munford, 2018; Hualde & Concejero, 2021).

In contrast, CT, which integrates heavy resistance exercises with plyometric or explosive movements within the same training session, demonstrated broader improvements across multiple performance domains. The effectiveness of CT may be explained by post-activation performance enhancement (PAPE), whereby heavy loading enhances subsequent explosive actions. This dual emphasis on maximal strength and power likely contributed to improved performance in OCR-specific tasks such as obstacle climbing, load carriage, and upper-body pulling actions. Given the multifaceted physical demands of OCR events, CT appears particularly suitable for developing comprehensive physical capacities required for repeated high-intensity efforts under fatigue.

When comparing the two training modalities, CT appeared to produce more holistic performance improvements, whereas BT was more effective for enhancing explosive power output. This distinction likely reflects the integrated nature of CT, which closely mirrors the complex strength–power–endurance demands of OCR competition. Nevertheless, BT remains a highly effective and time-efficient strategy for improving explosive capabilities, particularly in contexts where training time, recovery, or equipment availability is limited.

Furthermore, Grip strength outcomes revealed notable differences between training modalities. The BT group demonstrated maintenance or slight improvements in both left and right hand grip strength, whereas the CT group exhibited a small decline in left hand grip strength despite modest gains in the right hand. Grip strength is a critical determinant of OCR performance, as many obstacles require sustained forearm and hand engagement, such as rope climbs, wall ascents, and monkey bars (Rawdon, 2016). Previous research has shown that higher pre- and post-exercise handgrip strength correlates positively with OCR performance (Jorge, 2024). The preservation of grip strength in the BT group may be explained by the inclusion of exercises such as clean pulls and medicine ball slams, which require dynamic grip engagement and may enhance grip endurance. In contrast, the heavy loading and cumulative fatigue associated with CT may have impaired grip recovery between sessions (Loturco et al., 2020).

The significant Group \times Time interaction observed for power output further supports the superiority of BT for developing explosive performance. Consistent with meta-analytic findings by Petré et al. (2021), BT produced larger effect sizes for power and RFD compared to traditional resistance and CT protocols. Moderate-load ballistic training (30–60% 1RM) has been shown to optimize neural efficiency, muscle fiber synchronization, and force production at high velocities (Nishioka & Okada, 2023; Irineu, 2025). These adaptations are particularly advantageous in OCR, where athletes must repeatedly produce maximal or nearmaximal power under conditions of accumulating fatigue (Pritchett et al., 2021; Feito et al., 2022).

Despite improvements in strength and power, both training interventions produced minimal changes in linear sprint performance. This finding suggests that sprint speed may be influenced by additional physiological factors beyond strength and power alone, including cardiovascular fitness, thermoregulatory capacity, anaerobic tolerance, and reactive strength (Del Coso et al., 2020; Naylor et al., 2023). Previous research has highlighted the importance of heart rate responses, blood lactate tolerance, and temperature regulation in OCR performance (Jorge, 2024), which were not directly targeted in the present interventions. Additionally, the relatively short intervention duration and small sample size may have limited the detection of meaningful sprint adaptations, as longer training periods have been shown to produce greater sprint improvements following BT (Chavda et al., 2022).

Practical Implications

From a practical perspective, these findings highlight the importance of prioritizing maximal strength and power development when designing strength and conditioning programs for OCR athletes. Training variables such as exercise selection, load, volume, rest intervals, and progression play a critical role in optimizing performance outcomes and minimizing injury risk (Zachary, 2022). Consistent with long-term athlete development models, novice athletes should initially develop muscular endurance and hypertrophy before progressing to maximal

strength and power training (Stone et al., 2022). Given the upper-body strength demands inherent to OCR, the integration of BT within a periodized training framework may provide functional benefits for OCR-specific performance indicators.

Research contribution

This study provides evidence to the existing literature on training interventions OCR athletes. The findings offer a practical and structured training framework that can be applied to both athletic and general populations, enabling the development of strength and power through periodized BT and CT programs aligned with OCR-specific demands. Importantly, this research supports the RMP by providing evidence-based training protocols that can be used to optimize physical performance, particularly strength, power, and speed, among tactical OCR personnel.

Limitations

Several limitations should be acknowledged. The sample size was relatively small and limited to RMP athletes, which may restrict the generalizability of the findings. Additionally, the intervention duration may not have been sufficient to capture long-term adaptations, sprint-specific improvements, or injury-related outcomes. Future research should incorporate longer training periods, larger and more diverse samples, and additional physiological and biomechanical measures to further explore the mechanisms underpinning OCR performance.

CONCLUSION

In conclusion, both BT and CT are effective methods for enhancing strength and power characteristics in RMP OCR athletes. Complex training appears to offer broader performance benefits due to its combined effects on maximal strength and power, whereas ballistic training is particularly effective for improving explosive power and maintaining grip strength. These findings provide valuable evidence-based insights for the development of optimized, task-specific training programs aimed at improving physical readiness and operational performance in law enforcement personnel.

Authors' Contribution

MSA, JJ and SAA was responsible for the design and conceptualization of the research and the drafting of the manuscript. PSK was responsible for analyzing the data and discussing the findings. All authors read and approved the final manuscript.

Conflict Of Interest

authors declare that there are no conflicts of interest associated with this study.

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