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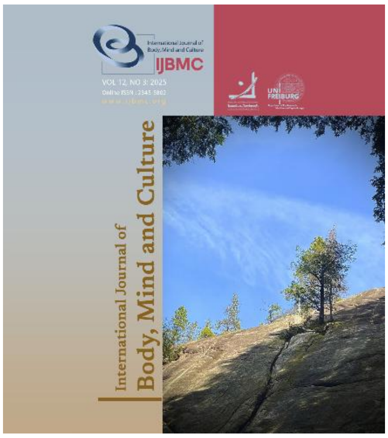

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The Effects of Deceptive Intensities During Wingate Testing on the Anaerobic Performance and Fatigue Index of Male Cross-Country Cyclists

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ABSTRACT

Objective: This study investigated the impact of deceptive intensities during Wingate tests on anaerobic performance and fatigue in elite male cross-country cyclists.

Methods and Materials: Twenty participants were divided into deception and control groups. Both groups completed three Wingate tests, with the deception group experiencing manipulated resistances (-10% and +10% from standard) in the second and third sessions. Peak power (PP), average power (AP), minimum power (MP), and fatigue index (FI) were measured.

Findings: The deception group demonstrated significant PP improvements during both manipulated conditions ($p<0.001$), with increases of 19.3% and 14.9% for -10% and +10% loads, respectively. Average power also increased significantly ($p<0.014$). Minimum power improved significantly only during the -10% load ($p=0.001$). Fatigue index remained unchanged across all sessions ($p>0.05$). The control group showed no significant changes.

Conclusion: Results indicate that deceptive loading can enhance anaerobic performance in elite cyclists without increasing fatigue. This suggests perceived effort significantly influences maximal performance, and deceptive interventions may unlock greater athletic potential.

Keywords: cross-country cyclist, Wingate test, deception, anaerobic performance.

Introduction

The pursuit of athletic excellence in competitive sports has led coaches and sports scientists to continuously explore innovative training methods and performance enhancement strategies. In elite sports, coaches face the ongoing challenge of optimizing their athletes' performance while maintaining a balance between training intensity, recovery, and psychological preparedness. The primary goal of any coaching program is to facilitate peak performance during competition while ensuring sustainable athletic development and minimizing the risk of overtraining or burnout (Granier et al., 2018). Cross-country cycling as a demanding endurance sport that requires athletes to possess a complex array of physiological, neuromuscular, and psychological capabilities. Recent research has shown that successful performance in cross-country cycling competitions depends on the ability to maintain high power outputs across varying terrains while managing technical challenges(Hebisz, 2019). Athletes must navigate difficult terrain while maintaining high power output and decision-making capabilities under extreme fatigue conditions. The multifaceted nature of cross-country cycling necessitates a comprehensive approach to training and performance optimization, incorporating both physical and psychological elements(Hoffmann et al., 2024; Pereira Saborosa et al., 2024). Cross-country cycling competitions rely heavily on anaerobic performance and fatigue resistance. Recent research has further emphasized the importance of these parameters in determining success in the sport. Anaerobic power plays a crucial role in cross-country cycling, particularly during high-intensity efforts required for technical sections, steep climbs, and sprint finishes(Hays et al., 2018; Inoue et al., 2012). A study conducted in 2020 found that the relative peak power output of amateur mountain bikers is inversely correlated with body fat percentage, highlighting the importance of body composition in anaerobic performance (Arriel et al., 2020). The ability to maintain power output throughout a race is equally important. Research has shown that successful mountain bikers demonstrate superior resistance to fatigue compared to their less successful counterparts(Inoue et al., 2012). This is particularly evident in multi-stage races, where the ability to recover and maintain performance over consecutive days becomes crucial (Inoue et al., 2012). Understanding and optimizing these performance factors has become increasingly important for coaches and athletes in the mountain biking community. Hebisz et al. (Hebisz, 2019) have shown that combined high-intensity and sprint interval training can significantly improve exercise capacity and stress response in mountain bike cyclists. The development of effective training methodologies that target both anaerobic capacity and fatigue resistance while considering the sport's specific demands has emerged as a priority in sports science research (de Poli et al., 2021). Recent research has highlighted the importance of diverse training strategies to enhance mountain biking performance, addressing both physical and psychological aspects of the sport. These strategies are tailored to meet the unique demands of different terrains and race conditions (Hoffmann et al., 2024; Saborosa et al., 2024). Additionally, carefully planned training protocols incorporating both high-intensity intervals and technical skill development have shown promise in optimizing competition performance(Hebisz, 2019). The psychological aspect of athletic performance has gained significant attention in recent years, with researchers exploring various factors that influence athletes' mental states and subsequent performance outcomes. One study found that misleading cyclists about their performance could lead to improved outcomes. Participants completed a 4000-m cycling time trial more quickly when they were deceived into believing they were racing against their baseline performance, when in fact, the power output was 2% greater (Stone et al., 2012). However, contrasting evidence indicates that deception may not always have a positive impact on performance. Research has shown that deception has no acute or residual effect on cycling time trial performance, although it negatively affects perceptual responses. This implies that while deception might not directly improve physical performance, it can influence how athletes perceive their efforts and capabilities (Jones et al., 2016).

The presence of competitors and external factors has been shown to impact internal attentional focus and overall performance in cycling events (Williams et al., 2015). Various psychological strategies have been employed to enhance athletic performance. Research by Shei et al. (Shei et al., 2016)has demonstrated that deception-based interventions can establish reproducible improvements in cycling performance (Shei et al., 2016). The effectiveness of these strategies often depends on their appropriate application and the individual athlete's receptiveness to the intervention. An emerging area of interest in sports psychology is the use of deception-based interventions to enhance performance. The study by Taylor and Smith (Taylor & Smith, 2014) examined how deceptive running speeds affect performance, physiological responses, and perceptual experiences during sprint-distance triathlons. They found that when athletes were misled into believing they were running faster than their actual pace, their performance improved significantly, leading to faster run times. This deception also influenced physiological measures, such as heart rate and perceived exertion (RPE), with athletes reporting lower levels of effort despite maintaining higher intensities (Taylor & Smith, 2014). The application of deceptive intensity training in cross-country cycling presents a unique opportunity to advance our understanding of performance optimization in this demanding sport. Given the critical role of anaerobic performance and fatigue resistance in cross-country cycling success (Novak & Dascombe, 2014), investigating the effects of perceived versus actual intensity on these parameters could provide valuable insights for coaches and athletes. Furthermore, the complex interaction between physical and psychological factors in cross-country cycling makes it an ideal context for studying the impact of deceptive interventions on overall performance.

Therefore, this study aims to investigate the effects of deceptive intensities during Wingate testing on the anaerobic performance and fatigue index of male cross-country cyclists. By examining how perceived versus actual intensity influences these crucial performance parameters, we seek to contribute to the growing body of knowledge regarding performance optimization in cross-country cycling and provide practical insights for coaches and athletes in this demanding sport.

Methods and Materials

Study Design and Participants

This study employed a double-blind, repeated-measures design conducted over a three-week period. Testing sessions were separated by one-week intervals to ensure adequate recovery between trials (Micklewright et al., 2010). Both groups completed three Wingate anaerobic test sessions, with the control group performing all tests at standard intensity while the deception group experienced manipulated intensities in their second and third sessions. Neither the participants nor the test administrators were aware of group assignments or intensity modifications to maintain the integrity of the deception protocol (Jones et al., 2016).

Twenty male mountain bike cyclists (age 18-25 years) with normal body mass index (BMI) and a minimum of three years of competitive experience at the national championship level participated in this study. Participants were selected through purposive and convenience sampling in collaboration with professional coaches in Qazvin city. All participants provided written informed consent prior to participation in accordance with the Declaration of Helsinki (2013). Inclusion criteria included: (1) active participation in national-level cross-country mountain biking competitions, (2) no history of musculoskeletal injuries in the previous six months, (3) no use of performance-enhancing substances, and (4) no concurrent participation in other research studies. Exclusion criteria included: (1) any cardiovascular or respiratory conditions, (2) recent illness or infection, and (3) inability to complete all testing sessions. Participants were randomly assigned to either the control (n=10) or deception (n=10) group using a computer-generated randomization sequence. Table 1 shows participant demographic characteristics.

Table 1

Participant demographic characteristics

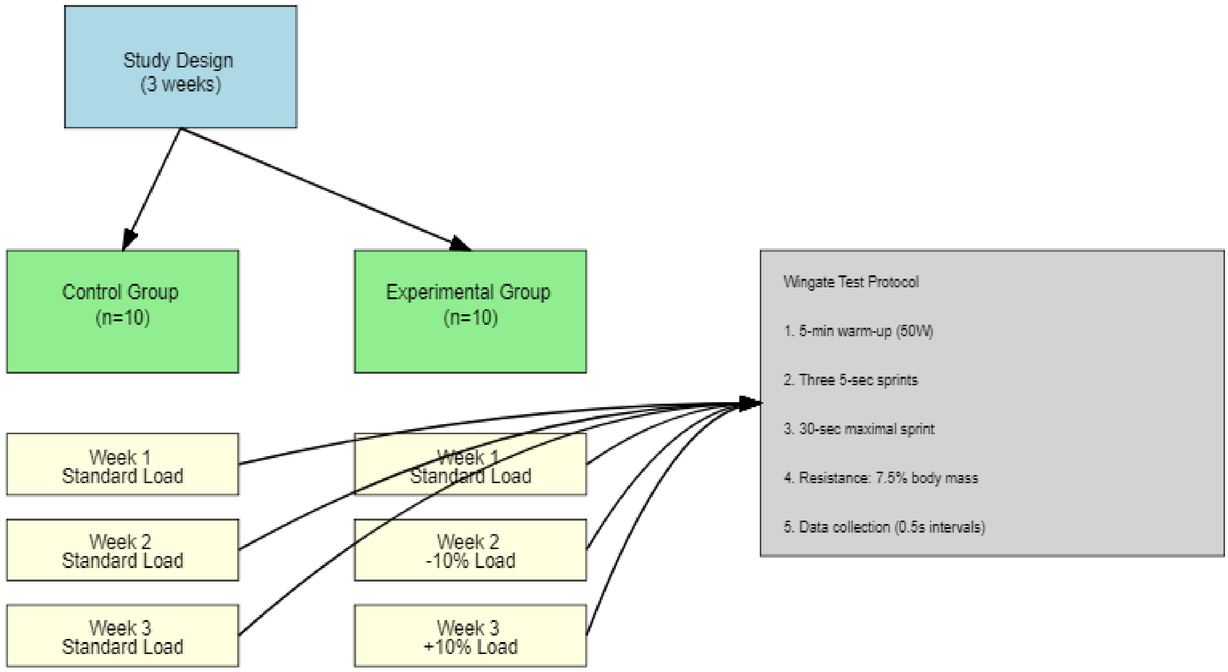
Variable Group	age (years)	height (cm)	weight (kg)	BMI (kg/m^2)
Deceptive	22.20±2.44	176.00±4.57	75.13±2.80	24.25±0.77
Control	22.40±1.89	175.20±6.16	72.88±6.95	23.70±1.51

Wingate Test Procedures

All testing was conducted on a Monark Ergomedic 894E cycle ergometer (Monark Exercise AB, Vansbro, Sweden) equipped with automated data collection software. The ergometer was calibrated before each testing session according to manufacturer specifications. Seat height was adjusted for each participant to achieve optimal knee flexion (25-35 degrees) at the bottom of the pedal stroke (Bar-Or, 1987; Dotan & Bar-Or, 1983). Prior to each test, participants completed a standardized warm-up consisting of 5 minutes of cycling at 50W with three 5-second sprints at minutes 2, 3, and 4. The standard Wingate protocol consisted of a 30-second maximal sprint against a resistance equivalent to 7.5% of the participant's body mass (Bar-Or, 1987; Ezdini et al., 2023). For the deception group, the resistance was modified by ±10% from the calculated standard load in the second and third sessions, while maintaining the appearance of standard loading procedures. Participants were instructed to remain seated throughout the test and received standardized verbal encouragement. Power output was recorded at 0.5-second intervals throughout the 30-second test period. Peak power (PP), minimum power (MP), and mean power (MP) were automatically calculated by the ergometer software. Figure 1 shows the outline of the research process in groups.

Figure 1

Study Design and Wingate Test Protocol (3 Weeks)



Fatigue Index Calculation

The fatigue index (FI) was calculated using the following formula:

FI (%) = [(Peak Power - Minimum Power) / Peak Power] × 100

This index represents the rate of power decline during the test, with higher values indicating greater fatigue rates. Peak power was defined as the highest power output achieved during any 5-second interval, while minimum power was the lowest power output recorded during the final 5 seconds of the test (Castañeda-Babarro, 2021).

Data Analysis

Data are presented as mean ± standard deviation (SD). The Shapiro-Wilk test was used to verify normal distribution of the data, and Mauchly's test confirmed sphericity assumptions. Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). A two-way repeated-measures ANOVA was conducted to examine the effects of group (control vs. deception) and time (sessions 1-3) on performance measures. The Bonferroni post-hoc test was applied for pairwise comparisons when significant main effects were detected. Effect sizes were calculated as partial eta squared (ηp^2). Statistical significance was set at $p < 0.05$.

Findings and Results

The means and standard deviation of measures of Peak Power (PP), Average Power (AP), Minimum Power(MP), Fatigue Index (FI) are shown in Table 2.

Table 2

Means and standard deviation of variable

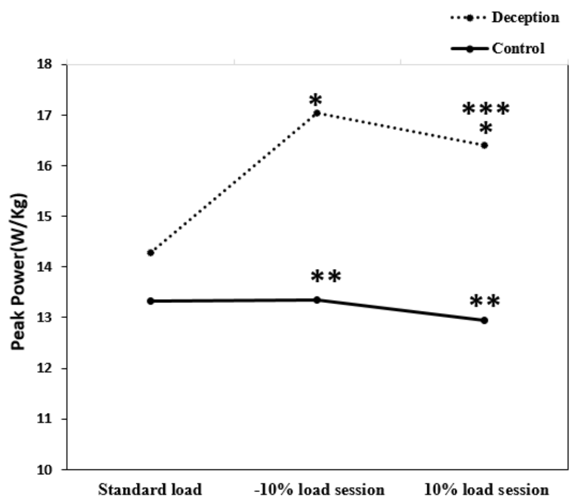
Variable	Deception (mean±Sd)			Control(mean±Sd)		
	Standard load	-10%load	+10%load	Standard load	-10%load	+10%load
PP(W/kg)	14.28±1.22	17.04±1.15	16.41±1.36	13.33±2.16	13.34±1.99	12.94±2.21
AP(W/kg)	8.57±0.90	09.99±1.14	09.47±15	09.30±1.17	09.41±0.87	09.28±0.86
MP(W/kg)	6.18±0.77	07.12±0.73	07.32±1.31	05.44±1.00	05.58±1.14	05.63±1.19
FI(%)	56.47±6.35	57.86±4.59	55.37±4.64	56.19±6.34	55.05±7.20	55.85±9.80

Peak Power

Repeated measures analysis of variance (Tests of within-Subjects Effects) revealed significant differences between Wingate test sessions in the deception group ($F_{2,9}$=74.89, P=0.0001, η^2=0.89). Repeated measures analysis of variance (Tests of within-Subjects Effects) revealed significant differences between Wingate test sessions in the deception group ($F_{2,9}$=74.89, P=0.0001, η^2=0.89). From the baseline of 14.28±1.22 W/kg in the standard load session, PP increased to 17.04±1.15 W/kg during the -10% load session (a 19.3% increase), then decreased to 16.41±1.36 W/kg in the +10% load session (14.9% above baseline). Bonferroni post-hoc analysis confirmed significant differences between all conditions: standard load versus -10% load (P=0.0001), standard load versus +10% load (P=0.0001), and between -10% load and +10% load sessions (P=0.022). For the control group, repeated measures analysis showed no significant differences between sessions ($F_{2,9}$=2.77, P=0.17, η^2=0.23), with values remaining stable between 12.94 and 13.34 W/kg. Tests of between-Subjects Effects demonstrated significant differences between the deception and control groups ($F_{1,18}$=12.67, P=0.002, η^2=0.41), with a significant time*group interaction effect (Figure 2).

Figure 2

Group status in Wingate test sessions for peak power



*: Significant difference with standard load session in deception group

: Significant difference with the control group

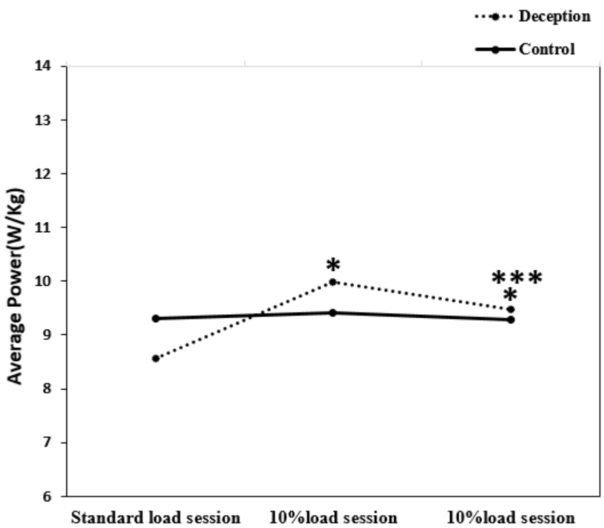
* : Significant difference between deceptive sessions (reducing and increasing load) in deception group

Average Power

Repeated measures analysis of variance (Tests of within-Subjects Effects) identified significant differences across Wingate test sessions in the deception group ($F_{2,9}=21.80$, $P=0.0001$, $\eta^2=0.70$). AP increased from 8.57±0.90 W/kg at baseline to 09.99±1.14 W/kg during the -10% load session (16.6% increase), followed by 09.47±15 W/kg in the +10% load session (10.5% above baseline). Bonferroni post-hoc analysis revealed significant differences between standard load and -10% load (P=0.001), standard load and +10% load (P=0.014), and between -10% load and +10% load sessions (P=0.016). For the control group, repeated measures analysis showed no significant differences ($F_{2,9}=0.27$, $P=0.76$, $\eta^2=0.03$), with values ranging from 9.28 to 9.41 W/kg. Tests of between-Subjects Effects showed no significant group differences ($F_{1,18}=0.1$, $P=0.967$, $\eta^2=0.001$), though there was a significant time*group interaction effect ($F_{2,18}=10.80$, $P=0.0001$, $\eta^2=0.37$) (Figure 3).

Figure 3

Group status in Wingate test sessions for average power



*: Significant difference with standard load session in deception group

: Significant difference with the control group

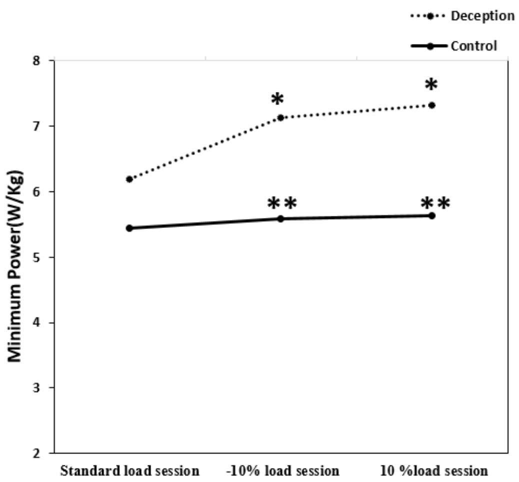
* : Significant difference between deceptive sessions (reducing and increasing load) in deception group

Minimum Power

Repeated measures analysis of variance (Tests of within-Subjects Effects) demonstrated significant differences between Wingate test sessions in the deception group ($F_{2,9}=9.08$, $P=0.010$, $\eta^2=0.50$). MP increased from 6.18±0.77 W/kg at baseline to 7.12±0.73 W/kg during -10% load (15.2% increase), then to 7.32±1.31 W/kg during +10% load (18.4% above baseline). Bonferroni post-hoc analysis showed significant differences between standard load and -10% load sessions (P=0.001), but not between standard load and +10% load (P=0.24) or between load conditions (P=0.99). For the control group, repeated measures analysis revealed no significant differences ($F_{2,9}=1.38$, $P=0.27$, $\eta^2=0.13$), with values remaining stable between 5.44 and 5.63 W/kg. Tests of between-Subjects Effects showed significant group differences ($F_{1,18}=10.72$, $P=0.004$, $\eta^2=0.37$) with a significant time*group interaction effect ($F_{2,18}=5.24$, $P=0.026$, $\eta^2=0.22$) (Figure 4).

Figure 4

Group status in Wingate test sessions for minimum power



*: Significant difference with standard load session in deception group

: Significant difference with the control group

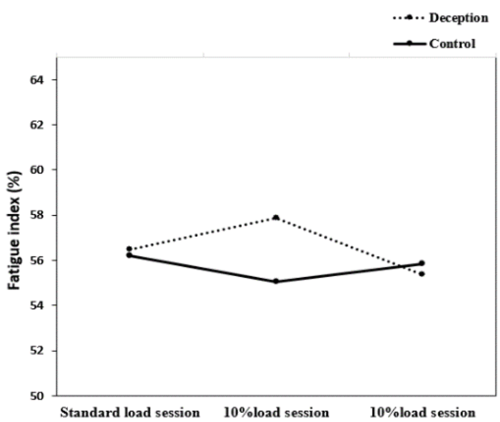
* : Significant difference between deceptive sessions (reducing and increasing load) in deception group

Fatigue Index

Repeated measures analysis of variance (Tests of within-Subjects Effects) showed no significant differences between Wingate test sessions in the deception group ($F_{2,9}$=0.47, P=0.62, η^2=0.05), with values ranging from 56.47±6.35% to 57.86±4.59%. Similarly, repeated measures analysis for the control group revealed no significant differences ($F_{2,9}$=2.60, P=0.10, η^2=0.22), with values between 55.85% and 56.19%. The time*group interaction effect was not significant ($F_{2,18}$=0.63, P=0.52, η^2=0.03) (Figure 5).

Figure 5

Group status in Wingate test sessions for fatigue index



Comprehensive statistical analysis results are shown in Table 3. Deception significantly impacted peak power (PP) with large within-group and moderate between-group effects, plus a moderate time group interaction. Control showed only a small within-group effect. For average power (AP), deception had a large within-group effect, control was trivial, the between-group effect was trivial, but the time group interaction was moderate. Mean power (MP) showed moderate within-group and between-group effects for deception, with a trivial within-group effect for control and a small time group interaction. Fatigue index (FI) changes were minimal across conditions, with trivial to small effects and a trivial time group interaction.

Table 3

Comprehensive statistical analysis results

Variable	Within-Group Effect Size (ηp^2)	Classification	Between-Group Effect Size (ηp^2)	Classification	Time*Group Interaction (ηp^2)	Classification
PP (Deception)	0.89	Large	0.41	Moderate	0.41	Moderate
PP (Control)	0.23	Small	-	-	-	-
AP (Deception)	0.7	Large	0.001	Trivial	0.37	Moderate
AP (Control)	0.03	Trivial	-	-	-	-
MP (Deception)	0.5	Moderate	0.37	Moderate	0.22	Small
MP (Control)	0.13	Trivial	-	-	-	-
FI (Deception)	0.05	Trivial	N/A	N/A	0.03	Trivial
FI (Control)	0.22	Small	-	-	-	-

Discussion and Conclusion

The primary purpose of this study was to investigate the effects of deceptive intensities during Wingate testing on anaerobic performance parameters and fatigue indices in male cross-country cyclists. Our findings revealed significant improvements in peak power and average power output under deceptive loading conditions, while fatigue index remained relatively unchanged. The most notable finding was the substantial improvement in peak power output during the deceptive loading conditions. When participants were unknowingly subjected to a 10% reduction in resistance, they demonstrated a 19.3% increase in peak power output compared to their baseline performance. This enhancement persisted, albeit to a lesser degree (14.9% above baseline), even when the resistance was increased by 10%. These findings align with several previous studies in the field of deceptive interventions in sports performance. Our results show strong consistency with the work of Stone et al. (Stone et al., 2012), who employed a similar deceptive methodology in cycling time trials. In their study, participants unknowingly competed against avatars displaying performance levels 2% greater than their previous best, resulting in significant performance improvements. The magnitude of improvement in our study (19.3%) was notably larger, which may be attributed to the different nature of the test (Wingate vs. time trial) and the larger manipulation of resistance (10% vs. 2%). Similarly, Shei et al. (Shei et al., 2016) demonstrated reproducible improvements in 4-km cycling performance through deceptive interventions, though their protocol focused on longer-duration efforts compared to our 30-second test. The improvements in average power output (16.6% increase with -10% load, 10.5% increase with +10% load) align with findings from Taylor and Smith (Taylor & Smith, 2014), who reported enhanced performance during sprint-distance triathlons under deceptive conditions. Their study utilized a different methodology, manipulating perceived running speeds rather than cycling resistance, but the underlying principle of performance enhancement through perception manipulation remains consistent. However, some of our findings contrast with existing literature. The lack of significant changes in fatigue index across conditions differs from the results reported by Jones et al. (Jones et al., 2016), who found negative effects on perceptual responses during cycling time trials. Their study, which employed a different deception protocol focused on performance feedback rather than physical resistance, showed that deception could adversely affect psychological responses without improving performance. This difference might be explained by the fundamental differences in test duration and intensity, as our 30-second Wingate test emphasizes different energy systems and psychological mechanisms compared to longer duration time trials. The mechanisms underlying the observed performance improvements appear to involve a complex interaction of psychological, neurological, and physiological factors. From a psychological perspective, the deceptive intervention likely modified the central governor response, as proposed by recent research in performance regulation (Granier et al., 2018). When participants were unaware of the true resistance, their unconscious protective mechanisms may have been less restrictive, allowing for higher power output even under increased loading conditions. This aligns with Williams et al. (Williams et al., 2015)'s findings on attentional focus and performance enhancement. The neurological mechanisms potentially involve enhanced motor unit recruitment and firing frequency when perceived resistance is lower than actual. Recent research has shown that perception of effort plays a crucial role in neural drive to working muscles (Jones et al., 2013). The deceptive intervention may have reduced the perceived effort required, leading to greater neural activation and subsequent power output. This mechanism could explain why performance improvements persisted even during the +10% loading condition, as the central nervous system had already established a pattern of enhanced motor unit recruitment. Physiologically, the improved performance might be attributed to better utilization of anaerobic energy systems. Jones et al. (Stone et al., 2012) demonstrated that when athletes perceive lower effort requirements, they exhibit enhanced phosphocreatine utilization and glycolytic enzyme activity. Our results suggest that removing psychological barriers through deception allows athletes to access greater physiological reserves, supporting the concept of a performance reserve as described by Stone et al. (Stone et al., 2017). The differential responses to reduced and increased loading conditions deserve particular attention. The greater improvement observed during the -10% loading condition suggests that psychological barriers may typically prevent athletes from achieving their true physiological potential. This interpretation is supported by Ansdell et al. (Ansdell et al., 2018), who found that deception could improve performance without augmenting fatigue. The sustained improvement during +10% loading demonstrates that athletes possess greater physiological capabilities than they typically access, a finding that has significant implications for training program design. The practical implications of these findings extend beyond laboratory testing. For coaches and athletes in mountain biking, the results suggest that traditional training approaches may be unnecessarily limited by perceived capabilities rather than true physiological limits. The implementation of carefully designed deceptive interventions in training could help athletes access their full performance potential. However, this must be balanced against ethical considerations and the potential long-term psychological impact of such interventions. Several limitations should be considered when interpreting these results. First, the study included only male athletes aged 18-25 years, limiting generalizability across genders and age groups. Second, the short-term nature of the intervention does not address potential long-term adaptations or the sustainability of performance improvements. Third, the laboratory-based testing protocol may not fully replicate the complex demands of actual mountain biking competition (Hays et al., 2018). Fourth, we did not measure psychological variables or perceived exertion, which could have provided additional insights into the mechanisms of performance enhancement. Finally, the sample size, while adequate for detecting main effects, may have limited our ability to identify subtler interactions between variables.

This study demonstrates that deceptive loading during Wingate testing can significantly improve anaerobic performance parameters in elite male mountain bikers without increasing fatigue rates. The mechanisms appear to involve a complex interaction of psychological, neurological, and physiological factors that allow athletes to exceed their perceived performance limitations. These findings contribute substantially to our understanding of performance regulation in high-intensity cycling and suggest new approaches to training program design. While the results are promising, careful consideration must be given to ethical implications and individual athlete responses when implementing deceptive interventions in practice. Future research should focus on developing practical applications while addressing the identified limitations and exploring longer-term adaptations to this novel training approach.

This study demonstrates that deceptive loading during Wingate testing can significantly enhance anaerobic performance parameters in elite male mountain bikers without increasing fatigue rates. The substantial improvements observed in peak power (up to 19.3%) and average power (up to 16.6%) during deceptive conditions suggest that perceived effort plays a crucial role in limiting maximal performance capabilities.

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The authors extend their gratitude to all participants in the study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Ethical considerations in this study were that participation was entirely optional. Ethical approval for this study was obtained from the local ethics committee at Imam Khomeini International University.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contribute to this study.

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