International Journal of EXERCISE SCIENCE

Original Research

Effect of Real-Time Feedback on Power Output Using a Novel Smart-Resisted Sled Push

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ABSTRACT

International Journal of Exercise Science 15(6): 1578-1586, 2022. Prior studies have demonstrated the beneficial effects of real-time data feedback (RTF) on athletic performance and motivation. Despite this evidence, the lack of practical means to implement RTF has hindered its widespread adoption. Recently, a smart-resisted sled push was developed to improve athletic power by utilizing electromagnetic motors as a resistance mechanism, coupled with an RTF display. Thirty healthy college-aged male football players were recruited in this randomized, crossover designed study to examine the efficacy of the RTF to improve power output. Participants were randomized into either group 1 (receiving RTF first then no RTF) or group 2 (receiving no RTF first then RTF) during six, 10-meter sled pushes with 3 min rest intervals. The first three pushes were set to an easier level (L1) and the last three were set to a resistance level twice that of the first three runs (L2). A one-month washout period was enforced. For trials 1-3 (L1) (p = 0.026, t = -2.34, ES = -0.428) and 4-6 (L2) (p = 0.035, t = -2.22, ES = -0.405), peak power output (the average peak power output over the course of trials 1-3 and 4-6) was greater in both groups when receiving RTF compared to no-RTF. These findings demonstrate the effectiveness of RTF in augmenting power output during performance training.

KEY WORDS: Conditioning, athletic performance, coaching

INTRODUCTION

Using real-time data feedback (RTF) provides coaches and athletes alike with quantifiable data on their performance during conditioning and exercise. A plausible explanation that uses two popular psychological concepts, game theory and control theory, has been postulated as a mechanistic rationale for the improvements seen with RTF. Game theory applies the concept of gamification, the application of game principles to nongame settings (7). In the context of exercise, RTF can increase gamification through improved goal setting, self-monitoring, and self-reward (2). Control theory, on the other hand, attempts to define the effort an individual places on their perception of what they believe to be attainable (1). Regarding athletic performance, an athlete may push themselves to the limit of what they believe is achievable, irrespective of whether it is their absolute limit. Consequently, a system that defines the athlete's maximum power output may motivate them to push harder during training to achieve or surpass their previous best. Previous studies indicate that the use of feedback improves sprint and jump performance compared to no-feedback (12). Beyond performance benefits, RTF enhances mood and motivation as athletes obtain an increased level of satisfaction upon reaching their predetermined targets (8). RTF can be applied in a variety of different settings to boost athletics performance and motivation. One such setting would be when performing the resisted sled push. Compared to other popular exercises such as the squat, the resisted sled push has demonstrated increased activation within sprint specific muscle groups such as the gastrocnemius that enable faster acceleration and greater top speeds when sprinting (3,11). Additionally, the ability to modulate the sled's resistance allows for increased training specificity. Using heavier relative resistance levels has been associated with improvements in acceleration, while lighter resistances prioritize speed (9).

While the resisted sled push has proven efficacy to increase power and improve sprint performance, it may be underutilized by athletes due to accessibility, its cumbersome nature, lack of ability to quantify effort and provide actionable, real-time feedback (7,8).

To ameliorate some of these issues, a weighted sled that utilizes electromagnetic motors as a resistance mechanism coupled with an RTF display, herein referred to as a smart-resisted sled push (SRS), was developed for commercial use. The SRS allows athletes to see fluctuations in their power output in real time, theoretically motivating them to improve during each successive bout. Moreover, it allows athletes to train more effectively within a given range of power outputs. This may be useful for athletes who compete at submaximal power outputs, helping improve their muscular endurance, lactate clearance, and metabolic conditioning (6).

While the traditional resisted sled push is a viable means to increase sprint speed and power output, there is a dearth of evidence to prove its effectiveness when combined with RTF. We therefore aimed to determine the effect of the RTF utilized by the SRS on power output during a high-intensity interval regimen. Given the beneficial impact of RTF seen in other athletic domains, we posited that the use of the SRS would positively effect power output

METHODS

Participants

Thirty apparently healthy college aged males were recruited from the College of the Canyons football team in southern California. Inclusion criteria included individuals who played organized football for the past two years. Exclusion criteria included the presence of any significant medical diagnoses, including musculoskeletal, cardiovascular, metabolic, pulmonary, or other disorders that would limit the ability to exercise or increase their cardiovascular risk of exercising. All participants provided written and informed consent prior to participation. The study was performed in accordance with the ethical standards of the Helsinki declaration and was approved by the Institutional Review Board. This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (10).

Table 1. Participants' descriptive characteristics (m ± sd).

Height	Weight	Age	BMI
179.5 ± 4.8 cm	91.0 ± 21.3 kg	19.7 ± 1.1 yrs	27.2 ± 4.9

Protocol

A randomized, crossover-designed study was conducted by investigators at the Airway and Exercise Physiology Research Laboratory at UCLA School of Medicine. Using an online random number generator, participants were assigned to either group 1 (receiving RTF first then no RTF) or group 2 (receiving no RTF first then RTF) during the sled push protocol.

The smart resisted sled is on wheels and uses a plate-loaded resistance platform (figure 1). According to the manufacture (RAPTR, Valencia, CA), the 'smart' aspect makes use of a custom controller tied to the electromagnetic motors that provide a variable resistance (using pulse wave modulation technology) with a magnetic encoder on the motor shaft that measures speed, power, and distance. This, coupled to an iPad mounted on the frame that provides RTF to the user. Using the manufacture's proprietary IOS app, power output goals can be programmed to appear on the iPads display. When the programmed power output is achieved, the iPad displays power output readings in green. When programmed power output is not met, the iPad displays power readings in red. The iPad display was disabled during runs without RTF.

Prior to testing, participants were asked to jog with the sled with minimal exertion to warm up and become acquainted with the SRS system. Thereafter, participants power output was monitored as they were encouraged to maximally perform six, 10-meter sled pushes with 3 min passive rest intervals. The first three pushes were set to an easier level (L1) while the last three were set to a resistance level twice that of the first three runs (L2). There was a one-month washout period between trials to minimize the carryover effect between interventions that might otherwise confound the estimates of intervention effects.

Statistical Analysis

Statistical analysis was performed in SPSS v27.0 (IBM, NY, USA). All data is presented as mean (standard deviation (SD)). Power output data was captured via encoder of the motor shaft (Ampflow®, Belmont, CA). Absolute mean power output (MPO) and peak power output (PPO) were averaged for each resistance level. Relative mean (rMPO) and peak power outputs (rPPO) was also computed. Normal distribution of the data was confirmed through Shapiro-Wilk Tests. Paired sample T-test were performed to analyze the effect of RTF across different intensities. Based on a pre-hoc power analysis using previous literature of similar design (14), we calculated a required sample size of 30 (15 for each group) based off high frequency power

– which is an index of power output and correlates with the RMSSD – to detect significant differences assuming $\alpha = 0.05$ and $\beta = 0.8$.

Figure 1. Smart Resisted-Sled, including RTF screen, loaded plate, and electromagnetic assembly.

RESULTS

For trials 1-3 (L1) ($p = 0.026$, $t = -2.34$, ES = -0.428) and 4-6 (L2) ($p = 0.035$, $t = -2.22$, ES = -0.405), PPOs were greater in groups with RTF compared to no RTF. For L1 runs without RTF and with RTF, PPOs were 479.43 W (SD = 129.70) and 501.86 W (SD = 120.80) respectively. For L2 runs without RTF and with RTF, PPOs were 322.49 W (SD = 93.11) and 338.07 W (SD = 88.63) respectively. rPPOs were also greater for L1 ($p = 0.018$, $t = -2.52$, ES = -0.460) and L2 ($p = 0.024$, $t = -2.38$, ES = -0.435) runs. For L1 runs without RTF and with RTF, rPPOs were 5.28 W/kg (SD =

0.97) and 5.53 W/kg (SD = 0.84) respectively. For L2 runs without RTF and with RTF, relative rPPOs were 3.53 W/kg (SD = 0.60) and 3.71 W/kg (SD = 0.55) respectively. For trials 1-3 (L1) (p = 0.286, t = -1.09) and 4-6 (L2) (p = 0.06, t = -1.95), there was no difference in MPO between groups with RTF compared to without RTF.

Table 2. Absolute peak power outputs (W) for runs 1-3 and 4-6 (m ± sd).

	Runs 1-3	Runs 4-6
RTF	501.86 ± 120.80	338.07 ± 88.63
No RTF	479.43 ± 129.70	322.49 ± 93.11

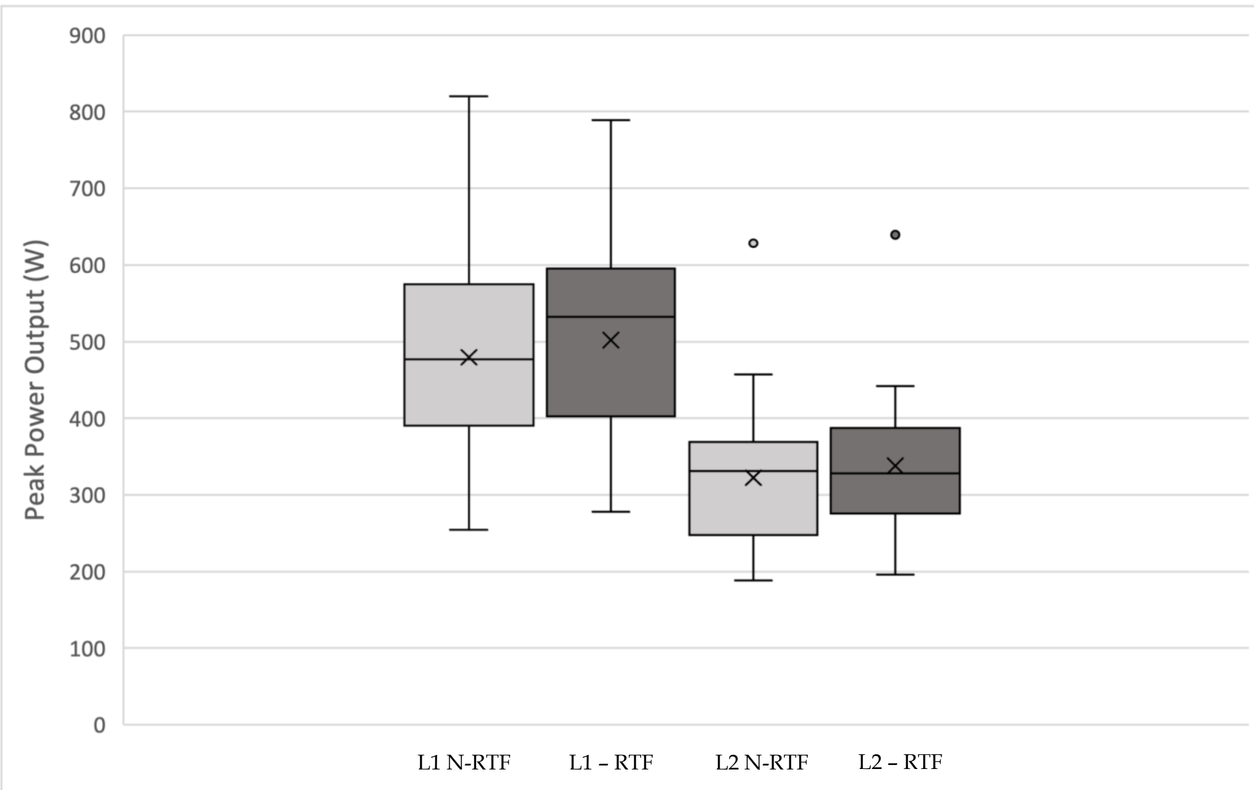

Figure 2. Absolute PPO (W) for level 1 and level 2 runs with RTF and without RTF (N-RTF). N = 30 trained football players. Each data point represents the average of the peak power outputs obtained during each run. The upper and lower fences represent 75th and 25th percentiles respectively, with the median in between. The upper bar represents the top 10th percentile of PPO while the bottom bar represents the bottom 10th percentile. L1 N-RTF: Level 1 without-RTF, L1 RTF: Level 1 with RTF, L2 N-RTF: Level 2 without RTF, L2 RTF: Level 2 with RTF. * Indicates significance

Table 3. Relative peak power outputs (W/kg) for both runs 1-3 and 4-6 (m ± sd).

	Runs 1-3	Runs 4-6
RTF	5.53 ± 0.84	3.53 ± 0.60
No RTF	5.28 ± 0.97	3.71 ± 0.55

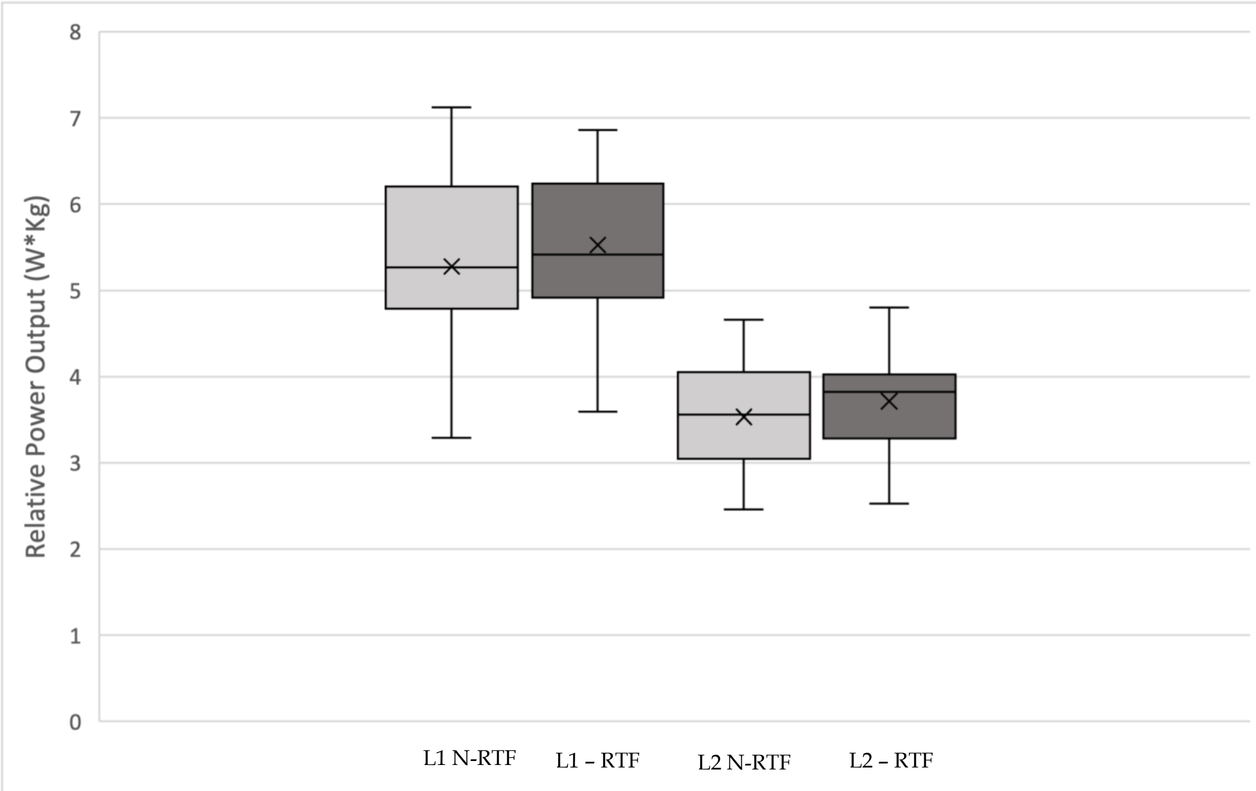

Figure 3. Relative peak power outputs (W/kg) (PPO) for level 1 and level 2 runs with RTF and without RTF(N-RTF). *N* = 30 trained football players. Each data point represents the average of the peak power outputs obtained during each run. The upper and lower fences represent 75th and 25th percentiles respectively, with the median in between. The upper bar represents the top 10th percentile of PPO while the bottom bar represents the bottom 10th percentile. L1 N-RTF: Level 1 without-RTF, L1 RTF: Level 1 with RTF, L2 N-RTF: Level 2 without RTF, L2 RTF: Level 2 with RTF. * Indicates significance

DISCUSSION

The primary objective of this study was to investigate the effect of real time feedback on peak power output using the resisted sled push. We saw increases in relative and absolute PPO at L1 and L2 runs in both groups when using RTF. These results support the previous findings that RTF increases performance and boosts power output. Additionally, we noted how the smart resisted sled system allowed for power output readings to be easily monitored and recorded. The lack of correspondence between the increases seen in PPO and MPO is likely due to the fact that for MPO to be greater, athletes would have had to sustain a higher power output for a longer period. Due to the relatively short distances that these sled pushes were conducted, the athletes would have needed to display a dramatic increase in power output throughout the duration of the run for the effect size to be as large as the PPO readings. However, if the sled pushes were conducted over longer distances (20 meters), MPO may have shown a larger difference between the groups with and without RTF. Secondarily, athletes may have fatigued faster during their runs with RTF after reaching higher PPOs, creating a power curve with a more precipitous incline and decline.

A similar study conducted by Stastny et. al looked at the effect of RTF on power-output in 30 elite ice hockey players using a modified Wingate test (14). In parallel with our results, RTF displayed a positive effect on power output. Interestingly, however, Stastny found that the effects of RTF on power output diminished in a fatigued state compared RTF restricted groups. Previous literature has shown that as fatigue increases, there is a corresponding decrement in both motivation and engagement (13). This would imply that RTF is only effective to a receptive athlete who is willing to participate in the game environment that it creates. As the workout progressed, the athletes may have become less interested in the "game" and ignored the RTF all together. These findings support the idea that RTF employs both game and control theory to boost performance, as it is crucial that the athlete engages with the RTF to allow these psychological processes to occur. The present study's results are highly relevant for athletes trying to improve power output (15). While previous studies have examined the effect RTF on other power focused exercises (e.g., jump squat), its effect on the resisted sled push has yet to be elucidated. A review done by Cahill et. al, noted how the resisted sled push is crucially different from other power focused exercises in that it places the athlete in a biomechanically unique position that allows them to train horizontal force production (4,5,9). Another study concluded that the resisted sled push could be particularly beneficial for sprinters, as the first phase of sprint races have a heavy emphasis on horizontal power (9,11).

With well documented efficacy, the lack of scientific inquiry into this exercise modality could possibly be due in part to its underutilization in training. A study conducted by Tano et al, found the resisted sled push to be a reliable means to measure horizontal power output. However, as previously mentioned, the resisted sled push is commonly disregarded due to its accessibility, cumbersome nature, and the lack of ability to quantify effort with actionable, real-time feedback. The smart sled system used in this study remedies some of these issues, however. By providing RTF and using electromagnetic motors to create resistance, users can quantify their effort and set their resistance level without having to load and unload weights.

While our findings for MPO were inconclusive, increases in MPO for L2 runs were substantially larger than L1 runs. This is possibly because the L2 runs required more time to complete, since athletes had to push a heavier load the same allotted distance as they did for the L1 runs (10 meters). As a result, the athletes may have had more time to cognitively register the RTF and apply it during each trial. Importantly, for both groups, L1 runs were seen to have a greater MPO than L2 runs (excluding L2 runs for group 2 with feedback). This is to be expected, however, as MPO was measured as the quotient of the force produced at the wheel and the time required to push the sled. Thus, the increased force production was offset by the increased time required to push the heavier sled. Interestingly, for certain subjects, the use of the RTF had a deleterious effect on MPO. This could be due to a host of different factors ranging from fatigue to increased distractibility (13).

There are several limitations that reduce the generalizability of the present study. We believe that these study results warrant further and larger investigations in the field of athletic/sports conditioning. Additional participants would further substantiate these study findings and add statistical power. Moreover, participants in this study, young competitive football members, were already physically active at the time of recruitment, thus the generalizability of these outcomes may differ for older or less active individuals. Finally, the training status of our population may have also had a notable influence on the effect size. College football players are accustomed to performing repeated bouts of high intensity exertions, and thus may be less likely to see dramatic improvements in performance from any one intervention. Compared to an untrained naïve population with a greater potential for adaptation, the effects of the RTF may have been artificially diminished.

This randomized cross over designed study demonstrated the effectiveness of RTF integrated in a 'smart' resistive sled to improve power output. By eliminating the barriers associated with utilizing the resisted sled and demonstrating increased efficacy, these results make the smart resisted sled push a more appealing training modality for those looking to improve sprint times and increase horizontal power output.

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