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Quantification of Velocity Decrement and Kinetic Profile during 10 metre Resisted Sprinting using the Run Rocket™

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ABSTRACT

The Run Rocket™ is used to improve acceleration and maximum velocity sprinting performance. However, no empirical data exist to support its efficacy. Accordingly, this study aimed to examine how incremental Run Rocket™ loads effect sprint velocity (V_{dec}), relative ground impulse and relative peak force. Fourteen recreationally active (13 male, 1 female) participants performed 10 m sprints at three Run Rocket™ arbitrary (AU) resistance levels (10, 20 and 30 AU and unresisted sprints). One-way repeated measures ANOVA, and Cohen's *d* effect sizes identified significant and meaningful differences between conditions. Run Rocket™ induced significant, large (*d*= >4.50) V_{dec} across all conditions. First and second step ground contact times showed large effects (*d*= >2.50) when comparing unresisted sprinting to all Run Rocket™ conditions. Concomitant moderate increases were observed for first and second step relative horizontal propulsive impulses, while first and second step relative horizontal propulsive forces showed no effect, suggesting V_{dec} was attributable to increases in ground contact time during resisted sprinting using the Run Rocket™ in all conditions. The results indicate most Run Rocket™ resistance levels might be too challenging to improve maximum velocity sprinting, yet not challenging enough to improve acceleration. Therefore, lighter Run RocketTM resistances may be preferential.

Keywords: resisted sprinting, acceleration, V_{dec}, ground impulse

INTRODUCTION

Acceleration and maximal sprinting speed are critical performance determinants in many sports and improving these qualities are a key component of the strength and conditioning (S&C) coach's role (Taylor et al., 2017). High-intensity accelerations occur frequently within team sports in particular (Harper et al., 2019) and improving acceleration and sprint performance may yield increased on-pitch success (Hedlund, 2018; Ross et al., 2015; Sierer et al., 2008). In football (soccer), sprinting precedes 45% of all goals scored (Faude et al., 2012). In American football, the quantity of accelerations far exceeds decelerations (Wellmann et al., 2016) and in rugby sevens, the majority of running efforts above 90% maximum velocity influence match outcomes (Misseldine et al., 2021). Resultingly, practitioners must be able to accurately prescribe individualised acceleration and sprint programming to ensure athletes are optimally prepared for the physical demands of competition.

Various training methods have been reported to improve sprint performance, including resistance training (Seitz et al., 2014), plyometrics (Oxfeldt et al., 2019) and unresisted sprinting (Pareja-Blanco et al., 2020b). Resisted sprinting is widely utilised in practice, having been shown to improve maximal sprint speed and acceleration (Alcaraz et al., 2018). However, resisted sprinting has yet to be universally adopted within sports training due to equivocation concerning optimal loads for kinetic and kinematic outcomes and efficacy ahead of other training methods (Alcaraz et al., 2018; Petrakos et al., 2016).

Resisted sprinting is typically conducted utilising sled towing, with training loads prescribed either at a given % of body mass, or from the reduction in sprint velocity experienced (V_{dec}) which accounts for variability in strength, power, and technique (Bentley et al., 2014). However, neither has established a consensus on programming variables. As an alternative to sled towing, the Run Rocket™ is a device that provides adjustable resistance through a flywheel, providing a consistent and smooth resistance profile, unlike a sled tow, and is used by a multitude of professional teams (Run Rocket, 2022). In sled tows, resistance can be calculated by the product of the weight of the sled and the surface friction coefficient. However, no research has examined the resistance that the Run Rocket™ provides across a wide range of resistances, displayed as arbitrary levels (from 0 to 30). To date, only one scientific investigation has reported Run Rocket™ data. Godwin et al. (2020) demonstrated high intra and intersession reliability at low resistance levels (0 and 5 AU from a maximum of 30 AU). Establishing the V_{dec} and ground force profile when using the Run Rocket across a wide range of resistances is necessary to provide data practitioners can apply when utilising the Run Rocket with individuals.

Therefore, the aim of this study was to investigate the velocity decrement and kinetic changes induced by the Run RocketTM across a variety of resistance levels.

MATERIALS AND METHODS

Study Design

A repeated measures design was used to compare the effects of resisted sprinting using the Run Rocket™ on V_{dec} and relative ground impulse and peak force. All tests were conducted on an indoor rubberised running surface in an environmentally controlled laboratory, to standardise environmental variables and limit influence on the test outcomes. Brower Timing TCi Wireless Timing System gates (Brower Timing Systems, Utah, United States of America) were placed at 0 m and 10 m, set at a height of 1.25 m. This height was necessary to ensure the gates were not triggered by the vertical oscillation of the cable from the waist harness to the Run Rocket™ when participants were sprinting. This gate has been shown to be reliable, although may record slower times than lower, typically recommended heights (Cronin & Templeton, 2008). The start line was positioned so that the initial two steps occurred over Kistler floor-mounted multi-axis force platforms (Kistler Instruments Ltd., Hampshire, United Kingdom), recording at 1000 Hz. From the Kistler force platforms data, vertical and horizontal propulsive impulses were calculated using methods described by Kawamori et al. (2013), and normalised to body mass. The Run Rocket™ (Run Rocket, Texas, United States of America) was placed 3 m behind the start line, with no slack in the tether from the harness to the equipment, to ensure no unresisted sprinting occurred and constant resistance was applied at all times.

Participants

Fourteen healthy adults (13 males, 1 female, 25.8 ± 4.5 years, 177.1 ± 6.8 cm, 77.7 ± 7.2 kg) participated in the study. Inclusion criteria were that all participants were recreationally active on a regular basis, involved in team sports or personal exercise regimes involving running. Exclusion criteria consisted of not being recreationally active, currently suffering from or having sustained a musculoskeletal injury in the last 6 months, or any other complication that would contradict the study procedures and/or risk the participant's health, as well as being under 18 years of age. Participants were informed of the benefits and risks of the study before giving written informed consent and completing a health history questionnaire prior to their participation. Study ethics were evaluated and approved by the Institutional Ethics Sub-Committee. All study procedures adhered to the principles of World Medical Association Declaration of Helsinki were adhered to at all times.

Procedures

Prior to testing, participants were weighed (M-510 Digital Portable Scale, Marsden Weighing Machine Group Limited, Rotherham, UK) and then underwent a standardised RAMP (Jeffreys, 2007) warm-up (jogging, high knees, lunges, straight leg swings, hamstring sweeps, 10 m of A-skips/B-skips, fall forward to accelerate and three 10 m sprints at 80, 90 and 100% perceived maximum velocity) to prepare for acceleration and sprinting, led by the researcher (JK). A five-minute recovery period was provided after the warm-up. Participants first performed three unresisted sprints over 10 m, followed by nine 10 m resisted sprint repetitions. Participants performed three 10 m resisted sprints using the Run Rocket™ and a waist harness at three resistance levels 10, 20 and 30 AU (Figure 1). A minimum of five minutes rest was allocated between each sprint to allow for recovery and to minimise fatigue or potentiation from altering subsequent sprint performance. The order in which each participant completed the resisted sprints was randomised via a customised Excel sheet (Version 16.61, Microsoft Corporation, Washington, USA) to attenuate familiarisation effects, and to mitigate the risk of fatigue on subsequent sprint performance. Participants started 0.5 m behind the start line in a split-stance standing position and were restricted from "rocking" into the sprint start. Cones were placed 2 m beyond the final timing gate to act as a finish line, encouraging participants to sprint through the final timing gate without decelerating. Verbal instructions were provided prior to the trials, no verbal encouragement was provided during the sprints.

Statistical Analysis

Sprint performance data were analysed through Microsoft Excel (Version 16.61, Microsoft Corporation, Washington, USA) and The Statistical Package for the Social Sciences (SPSS for Mac, SPSS Inc, Chicago, USA. v27). An *a priori* sample size analysis was conducted using GPower (Faul et al., Version 3.1.9.3) which determined a sample size of 13 participants was required to achieve a power of 0.8, using an effect size (ES) of .8 (based on Zisi et al., 2022) and an alpha level of .05. One-way repeated measures analysis of variance (ANOVA) and were used to examine differences between conditions for V_{dec}, impulses and peak forces with partial eta square effect sizes reported (η^2). Normality was assessed through a Shapiro-Wilk test and visual inspection of histograms and QQ plots. Sphericity was assessed through Mauchly's test, with violations adjusted using the Greenhouse-Geisser correction. Descriptive statistics are mean ± standard deviation. ANOVA ES calculations were conducted using partial eta square with post hoc comparisons ES calculated using Cohen's d (small ≤.20, moderate .50, large .80), using recommended benchmarks (Cohen. 1988).

Figure 1. Run Rocket™ sprinting condition

RESULTS

10 m Velocity

ANOVA revealed the different sprinting conditions elicited significant, large reductions to 0-10 m velocity ($F(3,39)= 240.528$, $p< .001$, partial $\eta^2= .949$). When compared to unresisted sprinting Bonferroni post hoc comparisons revealed reductions to sprint velocity for Run Rocket™ 10 (5.04 ± .41 m/s vs 3.31 ± .33 m/s. $p<.001$. ES= 4.65), Run Rocket™ 20 (5.04 ± .41 m/s vs 2.91 ± 0.39 m/s. $p<.001$. ES= 5.32) and Run Rocket™ 30 (5.04 ± .41 m/s vs 2.57 ± .29. ES= 6.96). Compared to Run Rocket™ 10, reductions in sprint velocity were observed for both Run Rocket™ 20 (3.31 ± .33 m/s vs 2.91 ± .39 m/s, $p=.012$, ES= 1.11) and Run Rocket™ 30 (3.31 ± .33 m/s vs 2.57 ± .29, $p<.01$. ES= 2.38). Reductions in sprint velocity were also observed between Run Rocket™ 20 and Run Rocket™ 30 conditions (2.91 ± .39 vs 2.57 ± .29 m/s. $p= .009$. ES= .99). Percentage V_{dec} descriptive data are displayed in Table 1.

Ground reaction forces

For relative peak vertical and horizontal propulsive ground reaction forces, ANOVA revealed non-significant differences for first ($F(1.943, 25.259)= .801$, $p= .457$. partial $\eta^2= .06$) and second ($F(3,39)= .924$, $p=.438$, partial $\eta^2= .066$) step relative peak vertical and first step horizontal propulsive ($F(1.486, 19.312)= 1.568$. $p= .213$. partial $\eta^2= .108$) force between conditions.

ANOVA revealed significant small increases for second step horizontal propulsive relative force production ($F(3,39)= 5.375$. $p= .003$. partial $\eta^2 = .177$). Bonferroni post hoc comparisons revealed no difference between unresisted and Run RocketTM 20 and 30, or between Run Rocket™ 20 and 30 conditions, but a significant large effect between unresisted and Run Rocket™ 10 conditions (8.24 ± .95 vs 9.07 ± .93 N/kg. $p= .027$. ES= 0.88).

ANOVA revealed no significant differences for first ($F(1.472, 19.142)= .405$. $p= .611$, partial $\eta^2 = .030$) or second ($F(3,39)= .179$, $p= .910$, partial $\eta^2 = .014$) step for peak vertical impulse. Significant moderate increases were observed for 1st step horizontal propulsive impulse ($F(1.811, 23.541)= 16.534$, $p<.001$, partial $\eta^2= .560$). Bonferroni post hoc comparisons revealed differences between unresisted sprinting and Run Rocket™ 10 (.92 ± .16 vs 1.22 ± .31 N·s. $p= .002$. ES= 1.22) Run Rocket™ 20 (.92 ± .16 vs 1.41 ± .23 N·s. $p<.01$. ES= 2.47) and Run Rocket™ 30 conditions (.92 ± .16 vs 1.40 ± .27 N·s. $p<.001$. ES= 2.16). No other post hoc comparisons were statistically significant. Significant moderate increases were also observed for 2nd step horizontal propulsive impulse ($F(3,39)= 17.617$, $p<.001$, partial $\eta^2= .575$). Bonferonni post hoc comparisons revealed increases between unresisted sprinting and Run Rocket™ 10 (.79 ± .07 vs 1.17 ± .20 N·s. $p<.001$. ES= 2.54), Run Rocket 20 (.79 ± .07 vs 1.11 ± .35 N·s. $p= .029$. ES= 1.27) and Run Rocket™ 30 (.79 ± .07 vs 1.35 ± .20 N·s. $p<.001$. ES= 3.74). Increases from Run Rocket™ 10 and Run Rocket™ 30 (1.17 ± .20 vs 1.35 ± .20 N·s. $p= .032$. ES= .90) were also observed but there were no significant differences between Run Rocket™ 10 and 20 or Run Rocket™ 20 and 30 conditions.

The ground contact times for the first and second step across all conditions are presented in Table 2. ANOVA revealed significant, moderate/large effects for ground contact times across conditions for first ($F(3,39)= 39.429$, $p<.001$, partial $\eta^2= .752$) and second steps ($F(3,39)= 42.900$, $p<.001$, partial $\eta^2= .767$). Bonferroni post hoc comparisons revealed significant large effects between unresisted

Table 1. Descriptive Statistics: 0-10 m Velocity (metres/seconds = m/s) in Different Sprinting Conditions

Condition	Mean Velocity ± SD (m/s)	Vdec from unresisted (%)
Unresisted	5.04 ± .41	0 ± 0
Run Rocket™ 10	3.31 ± .33	34 ± 6
Run Rocket™ 20	2.91 ± .39	42 ± 8
Run Rocket™ 30	2.57 ± .29	49 ± 6

Table 2. Mean Ground Contact Time (GCT) in Different Sprinting Conditions

Condition	1st Step GCT ± SD (ms)	2nd Step GCT ± SD (ms)
Unresisted	198 ± 14	181 ± 14
Run Rocket™ 10	256 ± 29	236 ± 22
Run Rocket™ 20	277 ± 32	246 ± 26
Run Rocket™ 30	318 ± 43	255 ± 34

sprinting and Run Rocket™ 10 (.197 ± .014 vs .254 ± .029 s *p*<.001. ES= 2.50) Run Rocket™ 20 (.197 ± .014 vs .280 ± .032 s *p*<.001. ES= 3.36) and Run Rocket™ 30 (.197 ± .014 vs .286 ± .043 s *p*<.001. ES= 2.78). No other post hoc comparisons achieved significance.

DISCUSSION

The aim of this study was to establish the velocity decrement and kinetic factors during sprinting using a Run Rocket™ by examining reduction to velocity over a 10 m sprint, and relative ground impulse and peak force over the first two steps of acceleration. To the authors' knowledge, this is the first study to examine the Run Rocket™ across a range of resistances. The Run Rocket™ caused a large V_{dec} at all resistance levels. Ground contact times were also increased across all Run Rocket™ conditions, which impacted on impulse characteristics, particularly 1st and 2nd step horizontal propulsive impulse.

The major finding from this study is that the Run Rocket™ induced a significant V_{dec} across all conditions. Indeed, there was a consistent pattern of velocity reduction as resistance increased in the Run Rocket™ conditions. Many studies suggest avoiding heavier loads for resisted sprinting, with a 20% V_{dec} commonly accepted as the maximum that should be induced in order to improve sprinting performance without significantly altering kinematics (Bentley et al., 2021; Bentley et al., 2014; Grazioli et al., 2020; Lockie et al., 2003; Osterwald et al., 2021). The V_{dec} caused by Run Rocket™ levels of 10, 20, and 30 were 34%, 42% and 49%, respectively, exceeding this commonly held threshold. However, contemporary literature appears to favour heavier sled loads, causing between 50-75% V_{dec} or ~80% body mass (Cahill et al., 2020; Edwards et al., 2022; Lahti et al., 2020; Morin et al., 2017) to improve sprint times via increased horizontal force output, a key determinant of the acceleration phase of sprint running (Bezodis et al., 2016; Kawamori et al., 2013). This is supported by studies that show no horizontal force benefits with loads inducing 10-30% V_{dec} (Kawamori et al., 2014a) or 10-20% body mass (Martínez-Valencia et al., 2015). Given that the V_{dec} induced by the Run RocketTM fell between 30-50%, it could be theorised that the resistance provided by the majority of Run Rocket™ levels do not provide sufficient resistance to induce meaningful increases in horizontal force application, and therefore fail to drive positive adaptations in acceleration performance.

Ground impulse is known to be a key determinant of acceleration performance (von Lieres Und Wilkau et al., 2020), particularly applying impulse in the horizontal direction (Kawamori et al., 2013). The results of this study indicate that relative first and second step horizontal propulsive impulses were greater across all Run Rocket™ conditions compared to unresisted running. This was attributed to increased ground contact times observed, as first and second step peak horizontal propulsive forces were only shown to have no or small overall effects, respectively. Given that horizontal propulsive impulse contributes heavily to sprint velocity (Hunter et al., 2005), the increased horizontal propulsive impulse in the Run Rocket™ conditions may be explained by the need to overcome greater resistance, as evidenced by the increased V_{dec} in the Run Rocket™ conditions. Cottle et al. (2014) and Kawamori et al. (2014b) also reported that with greater sled mass, horizontal propulsive impulse increased due to longer ground contact times and horizontal direction of force application which agrees with the findings from this study.

Randell et al. (2010) have suggested that gains in sport-specific performance where short, rapid accelerations are required may be achieved through utilising exercises with a horizontal force application component. The Run Rocket™ may offer benefits over traditional sled towing loads in this regard, given the increased horizontal propulsive impulses generated. However, the results of this study suggest that the V_{dec} induced by the Run Rocket™ may be too low to see acceleration specific benefits through increases in horizontal force application, as per recent literature on heavy to very heavy sled towing (Cahill et al., 2019; Cross et al., 2017; Edwards et al., 2022). Nonetheless, the ability of the Run Rocket™ to induce horizontal propulsive impulse and ground contact time adaptations over a training block is unknown. This study has extrapolated conclusions from cross-sectional data, and so future studies may wish to analyse the impact of the Run RocketTM on acceleration, maximum velocity and kinetic variables over a prolonged training intervention.

There are some limitations to acknowledge in this study. Firstly, the height of the timing gates, set at 1.25 m, were approximately shoulder height in a split stance start position. This was necessary as in pilot testing with timing gate heights below 1 m, the vertical oscillation of the Run Rocket™

tether when the participants were sprinting would trigger the Brower timing gates' beam, disrupting the recording and invalidating the trial. While it has been shown that higher timing gate heights are reliable, lower heights are recommended (Cronin & Templeton, 2008). It is possible this increased timing gate height may have recorded slower sprint times than if placed at a lower height, as has been shown previously (Cronin & Templeton, 2008). We do, however, consider this limitation to be minimal given the level of homogeneity of participant height within the sample and that the gate height was consistent across all trials. Secondly, although this study established differences in the V_{dec} and kinetic outputs induced by Run Rocket™, it did not directly calculate the resistance provided by the Run Rocket™. Therefore, it is recommended to determine the exact force required to pull the Run Rocket™ at different resistances and speeds which can then be modified to suit the training goals of an athlete. Finally, the sample population in this study were recreationally trained individuals and as such our findings might not be generalisable across other populations.

PRACTICAL APPLICATIONS

In the only study to date on the Run Rocket™, Godwin et al. (2020) demonstrated high intra and intersession reliability, and suggested that future studies may wish to quantify the effect of the resistance on velocity, with the goal of training prescription based on the V_{dec} caused by the Run Rocket™. This study has fulfilled those needs, and found that the majority of Run Rocket™ resistance levels (≥10) induce a V_{dec} that is likely to be too challenging to improve maximum velocity sprinting performance, and simultaneously not challenging enough to stimulate horizontal force application gains to improve acceleration. The V_{dec} observed is largely attributable to increased ground contact times and therefore, practitioners who are looking to utilise the Run Rocket™ as a tool to improve their athletes' performance should consider this aspect. Those targeting improvements in the maximum velocity phase of sprinting may wish to only program at resistance levels <10, to target increased horizontal propulsive force application for the acceleration phase.

CONCLUSION

In conclusion, the results of the current study indicate that the Run Rocket™ induces large effects to V_{dec} at resistance levels 10, 20, and 30. The Run Rocket™ increases relative horizontal propulsive ground impulse over the first two steps of acceleration compared to unresisted sprinting but does not change relative vertical ground impulse. The Run Rocket™ did not increase relative peak vertical and horizontal propulsive force over the first two steps of acceleration but induce large increases for ground contact time in all conditions compared to unresisted running. Based on this evidence, the Run Rocket™ may have applicability as a training tool for resisted acceleration or maximum velocity sprinting, however, at the resistance levels tested in this study, it does not appear to be optimal for either. Future research observing longitudinal changes to sprint performance and kinetic profiles are required to determine adaptations from training outside of a single session.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

FUNDING

No funding was received for this research.

ETHICAL APPROVAL

Study ethics were evaluated and approved by the Institutional Ethics Sub-Committee. All study procedures adhered to the principles of World Medical Association Declaration of Helsinki were adhered to at all times.

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