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Original Article

Resist-and-release sprint running using parachute towing causes detrimental changes to performance, kinematics, and kinetics

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Abstract:
Resist-and-release (RAR) using parachute towing (PT) describes running while towing a parachute to apply resistance, before releasing the parachute and continuing to sprint. The release instant is typically performed manually via pulling a Velcro strap, and may influence sprint characteristics. The purpose of this study was to clarify performance, kinematic and kinetic changes due to RAR during sprinting using PT. Ten university club athletes performed 60 m RAR trials using PT over a long force platform system. Paired t-tests, significance set to $P < .010$, and effect sizes ±95% confidence intervals were calculated to compare sprint characteristics between steps before verse after releasing resistance within RAR trials (five pairs). Main findings showed non-significant ($P = .015$, $P = .040$) trivial running speed changes for the 1st–2nd steps before and after releasing resistance, compared to the 3rd–4th steps before release. Step length demonstrated non-significant ($P = .752$) trivial changes for the 1st–2nd steps after releasing resistance, compared to the 3rd–4th steps before release. Step frequency had a significant ($P < .001$) moderate decrease at the 1st–2nd steps before release, compared to the 3rd–4th steps before release. Anteroposterior net impulse demonstrated significantly ($P < .001$) large decreases for all steps after release, compared to the 3rd–4th steps before release. Taken together, results suggested that detrimental changes to sprint characteristics occurred at the 1st–2nd steps before or after manually releasing resistance within RAR trials using PT. Recommendations for sprint coaches included avoiding manual release RAR using PT or being wary of these possible detrimental sprint characteristic changes during the two steps before and/or after the release instant.
KeyWords: Speed chute; running speed; ground reaction force; spatiotemporal; resisted sprint training

Introduction

Resisted sprint training is a broad term including methods of overloaded running,and common examples include parachute towing (PT), sled towing/pushing and wearing weighted garments such as vests (Alcaraz et al., 2008; Cronin& Hansen, 2006). There is one training modality that combines both resisted and unresisted running within a single trial, through releasing applied resistance during the trial. A popular example of this resist-and-release (RAR) method includes a partner assisted pull(Horton, 2016; Nemtsev & Nemtseva, 2017), however, RAR may refer to any type of resisted sprint where release occurs, such as RAR using PT. The RAR modality using PT involves running while towing a parachute to apply resistance, before releasing the parachute and continuing to sprint. Parachute towing has been previously studied in swimming literature with evidence demonstrating increased performance benefits after swim training interventions (L'Uboš et al., 2018), however, there is minimal research focused on the effects of PT training for over-ground sprint running. Resisted sprint running training using PT has been suggested to result in increased neural activation and anteroposterior net force application to overcome the added posteriorly (horizontally) directed aerodynamic drag force due to PT, which may lead to strength specific sprint performance benefits after a PT intervention through increased step length (SL)(Alcaraz et al., 2008;Martínez-Valencia et al., 2015; Tabachnik, 1992).In terms of the influence of PT compared to control trials,running speed (RS) decrementsat approximately the 20 m mark after the start have been reported including a 5% decrement with medium size (121.9 cm diameter)(Alcaraz et al., 2008), and a 4.4% decrement for small (101.6 cm diameter) and medium (121.9 cm diameter) parachute sizes(Paulson & Braun, 2011). In addition, previous PT research showed no significant differences for SL and step frequency (SF) during PT, compared to control sprints (significant difference in RS being due to the trend of decreases in both SL and SF)(Alcaraz et al., 2008; Paulson & Braun, 2011). Furthermore, optimal loads for resisted sprint training have been suggested based on a reduction in maximum RS, compared to control sprints, of < 10%, < 35%, 50% and > 65% for high-speed, speed-strength, power and strength training zones (Cahill et al., 2019).Therefore, PT is typically used to target the high-speed training zone and overload athletes specific to sprint technique in later acceleration or maximal speed phases, without causing RS decrements larger than 10%, which has been linked to adversely changing technique (Cissik, 2005; Lockie et al., 2003; Paulson & Braun, 2011).Although this previous research betters the understanding of PT training prescription strategies,and

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performance and kinematic changes due to PT,there is no known research focused on RAR using PT, despite the methods wide adoption for sprint coaching(Tabachnik, 1992). Only one known study has focused on RAR previously, using a partner assisted pull(Nemtsev & Nemtseva, 2017). A partner applied resistance posteriorly from the sprint direction by pulling a rope attached to a waist harness on the athlete, before releasing the resistance 24 m after the start, allowing the athlete to perform the remainder of the trial as a control sprint (no resistance). Comparing variables within RAR trials between distances standardised to before (step nearest 20 m mark) and after (step nearest 30 m mark) the release instant (24 m mark) demonstrated significantly larger RS and SL increases after release compared to before release. During control trials the RS was 8.28±0.61 m/s at the 30 m mark, and during RAR trials the corresponding RSwas 7.06±0.52 m/s (six meters after release)(Nemtsev & Nemtseva, 2017). Before release during RAR trials (20 m mark) the RS was 4.83±0.60 m/s, which is a 32% RS decrement compared to the RS after the release in RAR trials (30 m mark), which is much larger than typical RS decrements due to PT(Alcaraz et al., 2008; Cissik, 2005; Paulson & Braun, 2011). Therefore, results may differ significantly from RAR using PT methods due to applied resistance differences. Implementing RAR using PT anecdotally provides an athlete with an elevated sensation of being light and faster after release (Tabachnik, 1992).The method is a practical and simple to incorporate training modality, typically performed manually by pulling a Velcro strap to release the towed parachute during running by an athlete. Therefore, the manual method of release was incorporated in this study to ensure practicality and translation to training environments were anyone may perform the technique (no partner needed). Any sprint characteristic changes due to RAR with PT are unknown, but may be important for coaches to consider regarding specificity of sprint training, and possible beneficial or harmful technique changes. A successful manual removal of resistance during RAR may be considered as maintaining natural performance, kinematic and kinetic step-to-step changes, or inducing an even greater beneficial change after release. Clarifying any acute beneficial sprint characteristic changes within a single session due to RAR using PT may be important for longitudinal PT intervention and practical training strategy designs. However, the manual release method involves reaching to remove the parachute harness, which may cause further technique changes. Therefore, the purpose of this research was to elucidate the performance, kinematic and kinetic changes within RAR trials using PT during accelerated sprinting. Due to the manual method of release, it was hypothesised that RS would plateau (trivial changes) during one or two steps before or after the release instant while the athlete focused primarily on removing the parachute manually instead of accelerating, before continuing to significantly improve RS thereafter.

Material & methods

Participants Ten university club athletes including six sprinters and four baseball players volunteered to participate after informed consent was obtained (mean±SD: age, 20.4±1.3 years; height, 172.2±6.5 cm; body mass, 69.3±6.5 kg). The current research was approved by the institute'sresearch ethics committee. All participants were taught through instruction and demonstration how to tow and release a parachute during sprinting and complete a three-point start (no blocks used) during one familiarisation session. A self-selected number of sprints (range of three–eight trials) were completed until participants felt comfortable with PT and could competently perform a three-point start using PT. A three-day period separated the familiarisation and testing session. Parachutes used included a small (reportedly 101.6 cm diameter), medium (reportedly 121.9 cm diameter) and large (reportedly 142.2 cm diameter) size, chosen due to being the most common sizes commercially available and the most common sizes used in past research (Alcaraz et al., 2008; Martinopoulou et al., 2011; Tabachnik, 1992).

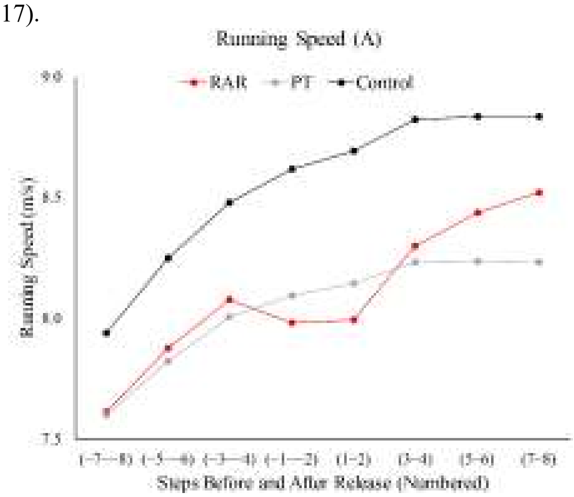
Procedure After a self-selected warm up, seven separate 60 m sprints from a three-point start were completed including one control (no resistance), one separate 60 m PT sprint with each size of parachute (three total), and one separate RAR 60 m sprint with each size of parachute (three total). The order of all PT and RAR trials was randomised. Recovery between repetitions was self-selected (range of six–ten minutes), set according to previous research on short duration repeated sprints (Blonc et al., 1998; Harris et al., 1976; Holmyard et al., 1988). Participants wore their own athletic attire and spiked race shoes (sprinters) or baseball training shoes (baseball players). The control was a 60 m sprint with no resistance and PT trials included towing a parachute over the entire measured length. The control and PT trials were performed as a reference for comparison with RAR trials, however, were not used for further statistical analysis due to being outside the purpose of this study. The RAR trials consisted of PT until the 25 m mark after the start, similar to previous research(Nemtsev & Nemtseva, 2017), where the parachute was released by the participant through pulling a Velcro strap located on the waist belt. In terms of the three-point start phase, parachutes were flat on the track surface positioned directly behind the athlete before each trial and were attached with a Velcro waist belt. All RAR trials (three for each participant) were recorded with a handheld video camera (Galaxy S10, Samsung Electronics Co., Ltd, Suwon, South Korea) positioned at the 25 m mark, to identify the release instant. Wind conditions were controlled for by using an indoor athletic track ensuring a negligible wind effect.

A long force platform system consisting of 54 force platforms (sampling frequency of 1000 Hz) connected to a single computer (TF-90100, TF-3055, TF-32120, Tec Gihan, Uji, Japan) and embedded in an athletic track was used to measure ground reaction forces (GRFs) during sprinting(Nagahara et al., 2018b).A 50 Hz low-pass Butterworth filter was utilised on raw GRF signals(Clark et al., 2017; Nagahara et al., 2017).Foot strike and toe-off were defined as exceeding and falling beneath a 20 N threshold of vertical GRF. In addition, any GRF data due to equipment landing on force plates after release was not detected as a step and was excluded from analysis. Step duration was considered as the time between identified foot strike instants of contralateral feet. The inverse of step duration was calculated and defined as the SF. The centre of pressure for each step was defined as the mean ground contact location of 0.01 s during the middle of the support phase. The anteroposterior distance between contralateral centre of pressure positions for consecutive steps was defined as the SL. Running speed was calculated as the product of SL and SF. Time integration of positive anteroposterior force and negative anteroposterior force were used to calculate the propulsive and braking impulses during the support phase, using the trapezoid formula. Net anteroposterior impulse was calculated as the sum of propulsive (positive value) and braking (negative value) impulses. The three-point start phase was excluded from analysis and the minimum number of steps to complete the measured distance was 24 steps. To reduce bilateral step-to-step variability, the average value of every two steps (1^{st}–2^{nd} step average, 3^{rd}–4^{th} step average and so on) was consecutively calculated for each measured variable, similar to previous studies that grouped steps(Murata et al., 2018; Nagahara et al., 2017). Kinovea open source video editing software was used to visually determine the instant that release occurred for each RAR trial(Puig-Diví et al., 2019). The release instant of the parachute was defined as the first frame that the Velcro strap on the waist belt was completely removed with no Velcro touching (Figure I). If release occurred during flight, the step including the support phase before the identified release flight phase was defined as the 1^{st} step before release and the next step was defined as the 1^{st} step after release. If release occurred during a support phase, the step during the identified release support phase was defined as the 1^{st} step before release and the next step was defined as the 1^{st} step after release. Steps were further grouped into the average of two steps before (reversed consecutive order) and those after release.

Figure I. Example of one participant resist-and-release trial with a medium sized parachute.

Statistical analysis

The dependent variables used were RS, SL, SF and anteroposterior net impulse, set according to previous research(Morin et al., 2015; Nagahara et al., 2018a; Nagahara et al., 2014).There was a qualitatively observed RS data spike (sharp decrease) in RAR trials for the 1^{st}–2^{nd} step average before release (Figure II), thus, the average of the 3^{rd}–4^{th} step before release was used as the baseline for within RAR analysis for each dependent variable. The minimum number of steps to complete the measured distance after release was eight steps. Therefore, there were five separate independent variables (1^{st}–2^{nd} step average before release, 1^{st}–2^{nd} step average after release, 3^{rd}–4^{th} step average after release, 5^{th}–6^{th} step average after release and 7^{th}–8^{th} step average after release), for comparisons with the baseline independent variable (3^{rd}–4^{th} step average before release). Cohen's d effect size (ES) ±95% confidence intervals (CI) and paired two-tailed t-tests were used(Cohen, 2013; Harrison et al., 2020; Hedges & Olkin, 2014), with a Bonferroni corrected level of significance set to $P < .010$ (five comparisons per variable), to clarify the change in RS, SL, SF and anteroposterior net impulse within RAR trials(Abdi, 2007). Effect size results were interpreted using qualitative terms [< 0.2 (trivial), 0.2–0.49 (small), 0.5–0.79 (moderate), and > 0.8 (large)](Cohen, 2013). Confidence intervals were interpreted in reference to previously recommended inferences (beneficial, not harmful, trivial, not beneficial, harmful, or equivocal)(Harrison et al., 2020), based on a smallest worthwhile change (SWC) of $1/5^{th}$ of the between athlete standard deviation(Buchheit, 2017).



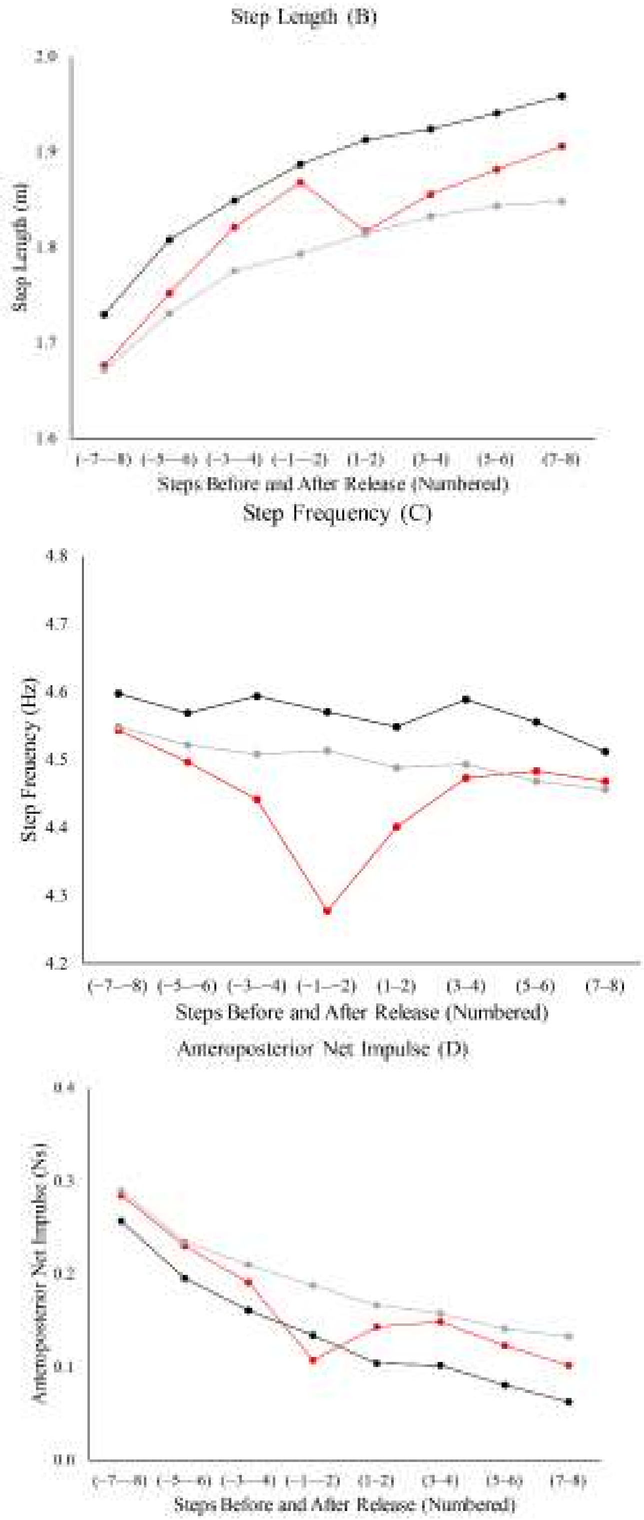


Figure II. Mean values during step averages before and after the release instant (zero on X axis). Two step average of running speed (A), step length (B), step frequency (C) and anteroposterior net impulse (D) for the resist-and-release (RAR), parachute towing (PT) and control group mean. Control and PT standardised to corresponding step number from matching RAR trials.

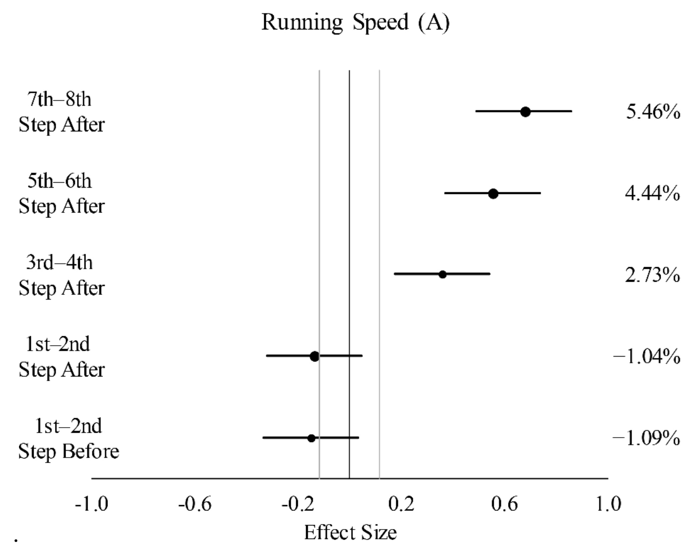
Results

The RS during RAR using PT demonstrated trivial ES changes with not beneficial inferences in terms of CI (Figure III), and statistically non-significant differences (Table I) during the 1st–2nd step before release and the 1st–2nd step after release, compared to the 3rd–4th step before release. The RS recovered from the 3rd–4th step after release and thereafter, demonstrating small–moderate ES increases with beneficial inference in terms of CI, and statistically significant RS increases at the 3rd–4th, 5th–6th and 7th–8th steps after release, compared to the 3rd–4th step before release. The SL had trivial ES change with equivocal CI inference, and a statistically non-significant difference during the 1st–2nd step after release, compared to the 3rd–4th step before release. The SL showed a small ES increase with equivocal CI inference, and a statistically significant increase for the 3rd–4th step after release. The SL fully recovered for the 5th–6th and 7th–8th steps after release, demonstrating moderate ES increases, beneficial CI inferences and statistically significant increases. The SF had a moderate ES decrease with a harmful CI inference and a statistically significant decrease during the 1st–2nd step before release, compared to the 3rd–4th step before release. The SF demonstrated trivial ES changes with equivocal CI inferences and statistically non-significant changes during all steps after release, compared to the 3rd–4th step before release.

Table I. Paired two-tailed t-test results (P value) with the 3rd–4th step average before the release instant within resist-and-release trials. Significance (*) set at P < .010.

	1st–2nd Step Before	1st–2nd Step After	3rd–4th Step After	5th–6th Step After	7th–8th Step After
Running Speed	.015	.040	< .001*	< .001*	< .001*
Step Length	< .001*	.752	.008*	< .001*	< .001*
Step Frequency	< .001*	.140	.261	.087	.289
Anteroposterior Net Impulse	< .001*	< .001*	< .001*	< .001*	< .001*

The anteroposterior net impulse demonstrated large ES decreases (all step averages) with equivocal (1st–2nd step before, 1st–2nd step after and 3rd–4th step after) and harmful (5th–6th and 7th–8th step after) CI inferences, and statistically significant decreases (all step averages), compared to the 3rd–4th step before release



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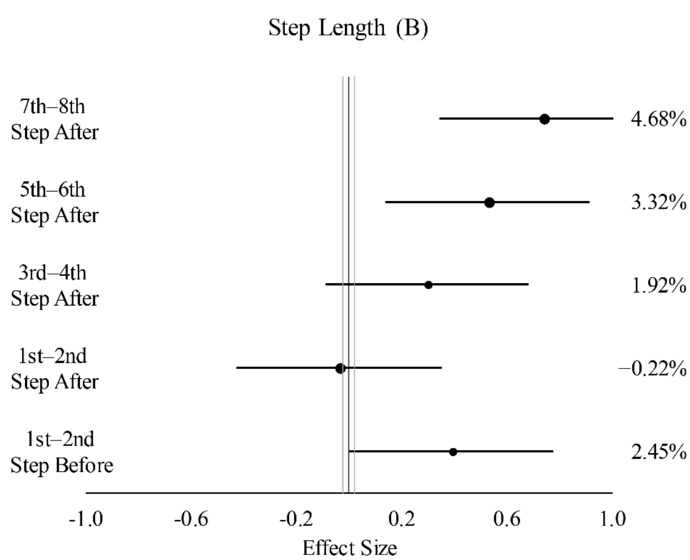

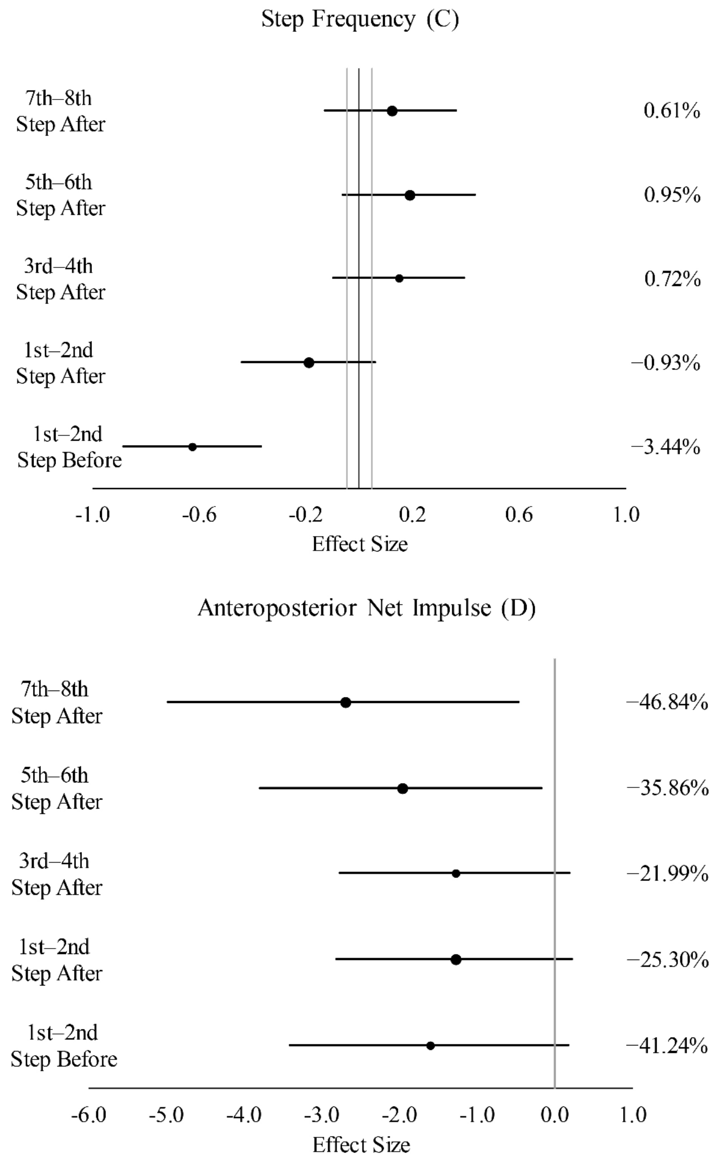

Figure III. Running speed (A), step length (B), step frequency (C) and anteroposterior net impulse (D) effect size (black dots) ±95% confidence intervals (horizontal black lines) between the average of the 3rd–4th step before release (Y axis baseline) and consecutive step averages thereafter (indicated by text labels on left). Grey vertical lines represent the smallest worthwhile change. Labels on the right indicate the mean difference of magnitude change, compared to baseline (%).

Discussion

The purpose of this study was achieved by clarifying the RS, SL, SF and anteroposterior net impulse changes within RAR trials using PT during accelerated sprinting. Main findings showed that RS plateaued during the 1st–2nd step before and after release and recovered thereafter. The RS results supported the hypothesis that RS would plateau during the acceleration phase surrounding the release instant, before continuing to increase step-to-step thereafter. Results further suggested that SL and SF practically changed within RAR trials, during steps before and after the release instant, due to RAR using PT.

A natural RS and SL curve in a control sprint expected during acceleration includes rapidly increasing step-to-step during initial–middle acceleration, and gradually thereafter toward reaching maximal RS and SL(Gleadhill & Nagahara, 2020; Nagahara et al., 2014). Therefore, in theory, releasing resistance during RAR trials using PT in the acceleration phase should cause sudden increases in RS and SL step-to-step after release, due to removing applied resistance before maximum RS was reached. However, results demonstrated that RS plateaued during the 1st–2nd steps before and after release, and the SL trivially changed during the 1st–2nd step after release. In terms of SF, during a typical control sprint the SF increases acutely during initial–middle acceleration before reaching maximum SF and remaining fairly consistent thereafter(Gleadhill & Nagahara, 2020; Nagahara et al., 2014). Therefore, SF was expected to remain stable or possibly increase after release during RAR trials in this study, however, there was a SF decrease at the 1st–2nd step before release. Considering the above findings together, results demonstrated that possibly detrimental changes occurred for RS, SL and SF at either the 1st–2nd steps before or after the release within RAR trials.The two possible causes for these RS, SL and SF detrimental results include the influence of manually releasing the resistance, or the sudden decrease in resistance due to release. Previous research has suggested that arm symmetry may act to counter body rotation and rotary momentum of the legs during sprinting(Macadam et al., 2018), thus, manually releasing the waist belt by moving one arm to pull the Velcro strap may have caused asymmetry and a loss of balance, leading to the detrimental sprint characteristic changes observed. It may further be possible that the abrupt loss of resistance may have resulted in the sprint characteristic changes observed alone, and the manual release may have not influenced these changes. However, the RS and SF changed during the 1st–2nd step average before release, when resistance due to PT was still applied, which supports the notion that the manual process of release was the primary influence of sprint characteristic changes. Therefore, future research may be required to compare manual release and automated release RAR methodologies. Regardless of the cause, results suggest that RAR using PT may detrimentally impact sprint characteristics during for the 1st–2nd steps before or after the release, and coaches and athletes should consider these detrimental changes before prescribing manual release RAR using PT. Taken together, the practical recommendation is to avoid manual release RAR training modalities until further research clarifies the benefits (if any) of RAR interventions.

The RS appeared to slowly recover from the 3rd–4th steps after release and thereafter. These increases in RS after release may continue after the measured distance (eight steps after release), returning close to the value achieved during control trials. The SL and SF fully recovered from the 5th–6th step and 1st–2nd step after release, respectively. However, SF remained stable in comparison to SL, which demonstrated greater magnitudes of change (increased) after release. Previous PT research is in accordance with these kinematic results, demonstrating greater changes to SL, compared to SF, due to the inability to apply force to overcome drag due to parachutes during the flight phase (Alcaraz et al., 2008). Furthermore, during RAR trials, after release occurs the remainder of the repetition is similar to a control sprint. However, results demonstrated that anteroposterior net impulse plateaued during the 1st–2nd (0.14±0.03 Ns/kg) and 3rd–4th (0.15±0.02 Ns/kg) step after release. Typical anteroposterior net impulse results during control sprints show rapid decreases during initial acceleration and more gradual decreases thereafter, which is an inverse trend to control RS results (Nagahara et al., 2018a). In addition, posteriorly resisted sprinting typically results in larger anteroposterior net impulse production, compared to control sprinting, to overcome added horizontal resistance (Kawamori et al., 2014). Therefore, after the release instant in this study the anteroposterior net impulse was expected to decrease step-to-step. Anteroposterior net impulse did decrease when step averages were compared to the 3rd–4th step average before release (Figure III), however, these decreases were not step-to-step decreases and anteroposterior net impulse demonstrated absolute magnitude increases consecutively from the 1st–2nd step average before release to the 3rd–4th step average after release (Figure II). The unexpected anteroposterior net impulse plateau/increase from the 1st–2nd to the 3rd–4th step averages after releasesuggests that RAR using PT may delay the onset of step-to-step decreases for four steps after the release instant. These anteroposterior impulse results warrant future research to clarify whether this heightened anteroposterior net impulse application after release may be translatable to control sprint benefits after a RAR using PT intervention. Future research may further explore the influence of modulating the distance where release occurs after the start and compare relationships between increased anteroposterior net impulse after release to performance and other sprint characteristics.

Conclusions

The primary purpose of this research was to clarify performance, kinematic and kinetic changes within RAR trials using PT. The main findings demonstrated possibly detrimental changes to RS, SL and SFsurrounding the manual release instant, however, demonstrated possibly beneficial anteroposterior net impulse changes. Considering a practical context, coaches should be made aware of these possible sprint characteristic changes before prescribing high-speed training with RAR using PT. This sprint training modality may be incorporated into a well thought out periodised training program, however, results suggested that manually releasing resistance may have been the primary cause of performance and kinematic changes.This limitation (manual release) may be solved by incorporating an automated release method. One possibility is to develop a parachute harness that can detach from the athlete with an external button push, however, typical harnesses do not have this feature. Future research and product development should consider developing an automated release feature for RAR adoption.This is the first known research to focus on RAR using PT despite the wide adoption of RAR sprint training, thus, a call for more empirical evidence is needed to better the understanding of this novel field, by further exploring any possible benefits of RAR interventions and elucidating the underlying biomechanical mechanisms of RAR. This study clarified the acute sprint characteristic changes due to RAR using PT within a single session and provided a baseline for a new series of research designs including modulating RAR methods in terms of the distance of release after the start. The practical recommendationsmade may change in the future after further research elucidates the differences between automated and manual RAR methods and the benefits (if any) of longitudinal RAR training interventions.

Conflicts of interest: The authors declare no conflict of interests.

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