Citation:
Darrall-Jones, J and Roe, G and Cremen, E and Jones, B (2021) Can Team-Sport Athletes Accurately Run at Submaximal Sprinting Speeds? Implications for Rehabilitation and Warm-Up Protocols. Journal of Strength and Conditioning Research. ISSN 1064-8011 DOI: https://doi.org/10.1519/jsc.0000000000003960

Document Version:
Article (Accepted Version)

This is a pre-copyedited, author-produced version of an article accepted for publication in Journal of Strength and Conditioning Research following peer review. The version of record is available online at: http://doi.org/10.1519/jsc.0000000000003960

ABSTRACT

The aim of this study is to examine the ability of team-sport athletes to accurately run at a range of submaximal sprint velocities (60 – 90% maximal velocity; Vmax) under verbal instruction without any objective feedback. Twelve professional male rugby union players (age 19.7 ± 0.9 years, body mass 98.3 ± 13.9 kg, height 184.0 ± 7.5 cm) were verbally instructed to complete three 40 m sprints at each of 60%, 70%, 80% and 90% of Vmax in a randomised order. Percentage Vmax achieved during each sprint was compared to criterion velocities calculated from Vmax testing undertaken a week prior. Players underestimated (ran faster) their sprint velocity when asked to run at 60% (*very large* to *extremely large* mean bias, 23%; range, 57 – 88% Vmax), 70% (*large* to *very large*, 11%; 67 – 93% Vmax) and 80% (*small*, 2%; 71 – 91% Vmax) of their Vmax, while overestimated (ran slower) their sprint velocity when asked to run at 90% Vmax (*moderate*, -4%; 77 – 95% Vmax). Team sport players may require objective feedback when performing submaximal sprinting to ensure that velocities achieved are similar to those prescribed. This may be particularly important where graded exposure to maximum velocities is required, for example during rehabilitation or warm-ups.

Key words; Rehabilitation, speed, warm-up, feedback

INTRODUCTION

Many criterion-based rehabilitation protocols published in the literature refer to the tolerance of maximum velocity (Vmax) running as an important outcome measure for rehabilitating athletes to achieve, prior to returning to participation in sport (15, 21, 29). In order to progress to Vmax running safely, graded exposure to increasing running velocities is required during the latter-stages of lower-limb rehabilitation (2, 29).-Similarly, it is important that athletes gradually increase running velocities during warm-ups to ensure they are adequately prepared for the specific demands of training or match-play (3, 20). In the context of both the warm-up and during hamstring rehabilitation this is of paramount importance, as higher running velocities increase the strain on the muscle-tendon unit (MTU), lengthening muscle fibres and muscle tendon junction (MTJ) (12), induce supramaximal muscle activation in comparison to maximal voluntary contraction (14) and increase joint torques at the hip extensors and knee flexors (23). Increased strain, supramaximal muscle activation and increased joint torques all peak during the late swing phase of sprinting (12, 14, 23), and are greater as sprint velocity increases. Thus it is prudent to ensure that both healthy and injured tissues are exposed to and can tolerate submaximal velocities during warm-ups and rehabilitation respectively, before being exposed to Vmax running.

Anecdotally in practice, therapists and strength and conditioning coaches often prescribe submaximal running speeds during rehabilitation sessions and warm-ups using verbal instructions only; i.e., *"complete this rep at 60% max effort"*, and without objective feedback. Although graded exposure to increasing running velocities has been suggested in many criterion-based guidelines (15, 21, 29), and used in warm-ups prior to Vmax running (6, 22), evidence is lacking as to whether team-sport athletes are able to accurately run at a range of therapist- or coach-prescribed submaximal running velocities without objective feedback. Conversely, it appears that for events in swimming (10, 19) and mid to longdistance running athletes (17) are able to control the pace at which they race. Swimmers competing in the 200 m freestyle swim maintain an even pace with swim velocity decreasing $-0.0035\ \mathrm{m \cdot s^{-1}}$ (10) whilst elite marathon runners have been shown to regulate the pace at which they race (96% ± 2% of critical speed) to be extremely close to their critical speed, thus maximising their performance (17). Whilst the swimmers are unable to pace using feedback, it may be the case that the marathon runners are aware of their critical speed, and thus regulate race pace using feedback via technology such as sports watches.

Verbal and visual objective feedback have been shown to improve acute performance and chronic adaptations during strength training, via increased bar velocity and greater improvements in strength (26-28), thus can be beneficial in a coaching setting. Objective feedback has also been used to regulate the sprint speed of male and female academy level soccer players in a study by Haugen, Tonnessen, Leirstein, Hem and Seiler (13). They used electronic timing gates to regulate sprint speed at 90% of mean velocity achieved across a 20 m sprint. Even with feedback, the first session distribution of sprint intensity ranged from 85% - 94%; this was improved upon in the second session with 90% of all sprint efforts between 89% and 91% (13). These findings may suggest that without objective feedback, self-regulation of sprinting velocity is likely to be poor in team-sport athletes. Another study assessed whether high-school athletes could reliably auto-regulate forward and backward running speeds between 40-55%, 60-75% and 90% maximum effort over 20 m, across three testing sessions (25). The authors report that the reliability of both forward and backward running speeds improved between testing session 2 and 3 (CV% = 2.48 – 12.0%) in comparison to testing session 1 and 2 (CV% = 0.99 – 4.33%), and that CV% decreased at faster running speeds (25). Whereas the study by Haugen, Tonnessen, Leirstein, Hem and Seiler (13) provided feedback within-session, the latter study (25) provided feedback only once, during the initial testing session, therefore athletes may be better able to self-regulate running speeds after familiarization and when repeatedly exposed to such stimuli, such as during standardized team warm-ups.

Given the previous literature (13, 25-28) has shown that providing feedback a minimum of once, or in real-time enables improved training outcomes, the purpose of this study is to investigate the ability of a group of team-sport athletes to achieve accurate submaximal running velocities (60-90% of Vmax) for a set distance under verbal instruction only, with no feedback.

METHODS

Experimental Approach to the Problem

A randomized cross-over design was used to assess the ability of professional team-sport athletes to accurately achieve submaximal sprint velocities (60 – 90% Vmax) over a set distance. Data were collected across two days separated by one week. On day 1, following a standardised warm-up, the Vmax of each player was assessed across three 40 m maximal sprint efforts on a third generation (3-G) synthetic playing surface. The warm-up consisted of light jogging, dynamic stretches that incorporated the musculature of the triceps surae, hamstrings, quadriceps and glutes, sprint specific drills including A-skips, B-skips and scissor runs, and 3 submaximal sprint efforts that increased in intensity (7). On day 2, following the same standardised warm-up excluding any submaximal sprints, participants performed three 40 m submaximal sprints at each of 60%, 70%, 80% and 90% of Vmax. The order in which the sprints were undertaken were randomised for each participant. Prior to each sprint, participants were given verbal instructions to perform each sprint at a specific percentage of their maximum velocity. No feedback on sprint velocity was provided throughout the testing period.

Subjects

Twelve male professional rugby union players (age 19.7 ± 0.9 years, body mass 98.3 ± 13.9 kg, height 184.0 ± 7.5 cm) were recruited from a professional rugby union club in England. The players were a mixture of forwards (n = 6) and backs (n = 6) in their first year as professionally contracted rugby players. Although forwards and backs have been shown to have differing sprinting capabilities (5, 9), for the purpose of this study each player acted as their own control when performing efforts at submaximal speed, therefore differences between positional groups were deemed to be negligible. All players were familiar with the testing procedures and trained 4 days per week including resistance training, aerobic conditioning, speed technique and speed development sessions, alongside rugby training. Players were excluded from the study if they had not sprinted maximally (> 95% Vmax) a minimum of once per week for the three preceding weeks (18). No player in the study had previously received specialist sprint coaching other than that provided by the rugby club. Ethics approval was granted by the university ethics board and written informed consent was acquired from all subjects.

Procedures

The study was conducted at the end of the playing season, in the month of May. Subjects undertook testing on two days, separated by 1 week. On day 1, the Vmax of each player was assessed across a linear 40 m on a 3-G synthetic playing surface, using a 10 Hz microtechnology unit (Catapult Optimeye S5, Catapult Innovations, Melbourne, Australia). The microtechnology has been validated for evaluating Vmax in rugby union players in comparison to a 50 Hz radar gun (22), with radar previously demonstrating *perfect* correlation (r = 0.99) with timing gates respectively (4, 11, 22). After a standardised warmup, subjects performed 3 maximal 40 m sprints, separated by three minutes of passive recovery (7-9), thus allowing full restoration of creatine phosphate stores, and therefore full recovery, prior to the following sprint (1).

Subjects were instructed to initiate the sprint from a self-selected two-point starting position, consistent with the coaching they received during maximal speed work during a normal training week, in their own time and sprint as fast as possible across the 40 m. The highest Vmax achieved during the three sprints was used to calculate submaximal running velocities. Using the highest Vmax achieved was deemed appropriate as the inter-day reliability of Vmax when using the best trial has been reported to have very good reliability with a CV% = 1.7 (24), suggesting little week-to-week variance between testing sessions.

A week later, on day 2, following the same standardised warm-up and excluding the submaximal sprints, participants performed three 40 m sprints at each of the following subjective intensities; 60%, 70%, 80% and 90% of Vmax. Testing was completed at the same time of day, with the players wearing the same training kit and footwear and on the same 3-G synthetic playing surface. Training in the week prior had been maintained as normal, with players receiving two days of complete rest prior to the day 2 assessment. The order in which the sprints were undertaken were block randomised for each participant; i.e., the participant would complete all three sprints at the assigned intensity before moving to the next randomised sprint intensity. Each sprint was separated by three minutes of passive recovery in line with previous research in rugby union players (7-9). Prior to each sprint, participants were given verbal instructions to run at a specific percentage of their maximum velocity within the 40 m distance. No feedback on sprint velocity was provided throughout the testing period.

Statistical Analyses

Validity. Data are presented as mean ± *SD* or means with 90% confidence intervals (90% CI) where specified. The agreement between the criterion performance,~~ and~~ each sprint, and the average of sprints at 60%, 70%, 80% and 90% Vmax was assessed using a freely available Excel spreadsheet, which calculated mean bias; $([\frac{\bar{x}diff}{\bar{x}\ criterion}] \times 100)$, typical error of the estimate (TEE; prediction error for the regression equation) using the STEYX function (standard error) and Pearson correlation (16). Both mean bias and TEE were standardized using the *SD* of the criterion measure. The standardized mean bias was rated as *trivial* (<0.2), *small* (0.2–0.59), *moderate* (0.6–1.19), *large* (1.2–1.99), *very large* (2.0-3.99) or *extremely large* (>4.0). The standardized TEE was rated as *trivial* (<0.1), *small* (0.1–0.29), *moderate* (0.3–0.59), *large* (0.6-0.99), *very large* (1.0-1.99) or *extremely large* (> 2.0). The magnitude of correlation was rated as *trivial* (<0.1), *small* (0.1–0.29), *moderate* (0.3–0.49), *large* (0.5–0.69), *very large* (0.7–0.89), or *nearly perfect* (0.9–0.99).

To assess whether the speeds achieved by the participants differed at each prescribed intensity, a repeated measures one-way analysis of variance was conducted using SPSS version 25.0, with the alpha level set at 0.05. Prior to analysis the data were assessed for normality using the Shapiro-Wilk test, with all measures deemed normally distributed ($p > 0.05$). Bonferroni adjustments were applied if significant differences were observed. To assess variability in percentage of sprint speed achieved at each intensity, the coefficient of variation was calculated using the following equation; $CV\ \% = ((\frac{\sigma}{\mu})\ x100)$, where σ is the

SD of percentage sprint speed and μ if the mean percentage of sprint speed.

RESULTS

The mean bias, TEE and Pearson correlation for each individual sprint effort and the average of efforts at each prescribed sprint intensity are presented in table 1. Running at a subjective 60% of Vmax resulted in *very large* to *extremely large* mean bias and *very large* TEE; the Pearson correlation between criterion velocity and observed velocity was *large*. Subjective running at 70% of Vmax resulted in *large* to *very large* mean bias, TEE and Pearson correlation. Subjective running at 80% of Vmax resulted in *small* mean bias, *large* TEE and *very large* correlations. Running at a subjective 90% of Vmax resulted in *moderate* mean bias, *moderate* to *large* TEE and *very large* to *nearly perfect* Pearson correlations. Averaging the sprint trials did not improve the measures of mean bias, TEE or Pearson correlation at any of the prescribed sprint intensities.

Table 2 shows the percentage of Vmax the participants ran at when instructed to run at 60%, 70%, 80% or 90% Vmax respectively; the range in percentages at each speed and the coefficient of variation. The speeds achieved when instructed to run at 60% (73.0% ± 8.0%) and 90% (86.1% ± 4.3%) of Vmax were significantly different ($p < 0.05$) to all other speeds. The speed achieved when instructed to run at 70% (77.7 ± 7.0%) and 80% (81.8% ± 5.2%) were similar ($p > 0.05$), and both were significantly different ($p < 0.05$) to speeds at 60% and 90% of Vmax. The range of speeds achieved reduced from 30.9% (57.1% - 88.0%) when running at 60% Vmax to 18.0% (76.8% - 94.8%) when running at 90% Vmax. The coefficient of variation reduced from 11% to 5.0% from the slower speed (60%) to the fastest speed (90% Vmax).

DISCUSSION

This study examined the ability of professional rugby union players to accurately run at submaximal sprint velocities under verbal instruction without any objective feedback. The results showed that players underestimated (ran faster than the prescribed percentage of their Vmax) when running at 60%, 70% and 80% Vmax as demonstrated by the positive mean biases. Whereas, when instructed to run at 90% Vmax subjects overestimated (ran slower than prescribed) their running velocity (Table 1). The speed displaying the lowest mean bias (1.3% - 3.0 %; *small*) was at 80% Vmax, with a mean speed achieved of 81.8% ± 5.2% (Table 2). Although this appears to show that the participants were most accurate when running at 80% Vmax, the TEE for all three efforts at 80% Vmax was *large* (2.96% - 3.70%), showing that there was considerable inter-individual variability in the subjects ability to selfregulate sprint speeds at this intensity. This is demonstrated in the range (71.0 % - 91.0 %; 19.8) of percentages at which the subjects ran during the 80% Vmax condition (Table 2).

The inter-individual variability in percentage speed achieved across all conditions may have important implications for how the coaching of submaximal sprint efforts are delivered to team-sport athletes, during warm-up protocols and in a rehabilitation setting. Providing real-time feedback with the use of timing gates (13) or familiarizing athletes with speeds at which you are instructing them to run (25) have both been shown to improve the regulation of sprint speed. This may be due to a greater kinaesthetic awareness as to the prescribed intensity, with improved regulation with a greater number of sessions completed (25).

If the goal of the warm-up or rehabilitation is to gradually expose tissue to greater load and strain (2, 12, 15, 21, 29) as athletes prepare for, or are returned to, sprint activities, it is prudent that the underestimation (faster) of running speeds is minimised, especially when athletes are asked to run at 60%, 70% and 80% of their Vmax. This is important to avoid excessively loading lower-limb tissues during early rehabilitation protocols and prevent injury during warm-up (2). These speeds are especially important as it has been demonstrated that when sprinting at 70% and 85% of Vmax, along-fibre strain at the proximal MTJ of biceps femoris long head (BFlh) is ~ approximately 300% - 350% increased in comparison to active muscle lengthening (12). Furthermore speeds of 75% ± 4% of Vmax have shown EMG amplitudes of 115% ± 13%, and 121% ± 18% in BFlh and semitendinosus in comparison to maximal voluntary contraction respectively (14). Considering speeds in excess of 70% and 85% Vmax were achieved across the 60%, 70% and 80% conditions it can be postulated that the hamstring muscles were placed under high strain in spite of the prescription of submaximal speed. In warm-ups this may be deleterious as it may lead to increased risk of injury, and potentially preventing an athlete from participating in training. Whilst in a rehabilitation setting progression of sprinting may be hindered, if the injured site is loaded beyond tissue tolerance too quickly (2).

Underestimation of speed, such as in the present study may be minimised with the implementation of objective feedback. Indeed, it has been shown that using verbal or visual objective feedback when completing a closed task such as barbell back squats, improves performance acutely via increased velocity, and chronically by greater strength adaptations (26-28); similarly the use of electronic timing gates to regulate sprinting speed at 90% of Vmax has been shown to improve soccer players' ability to accurately run 20 m at 90% of their best 20 m time within two sessions (13), whilst providing feedback regarding running speed just once assists in the auto-regulation of running speed on future occasions (25). Alternatively, providing live objective feedback via GPS may also allow athletes to better regulate their running speeds when completing similar sprint progressions.

There are a number of limitations to the study that must also be acknowledged, that if are addressed in future research will strengthen similar studies. The subjects in the present study were a mixture of forwards and backs rugby union players, with each positional group reported to have differing sprinting capabilities in previous research (9). Whilst each subject was assessed against their own maximal capability, i.e., acted as their own control, it may be the case that the backs are better at regulating sprinting speed, as they are exposed to a greater number of sprints within rugby training. This hypothesis was unable to be tested in the present study due to the small sample size. A further limitation was that the inter-day reliability of sub-maximal sprinting speed was not assessed. Whilst the aim of the study was to assess the validity of sub-maximal sprinting without objective feedback, understanding whether athletes are reliable between days would further assist in understanding the variability in sub-maximal sprinting during warm-up and rehabilitation protocols respectively.

In conclusion, the present study demonstrates that when verbally instructed to run at submaximal sprint velocities, team-sport athletes may underestimate (run faster) slower running speeds (60 – 80% Vmax) and overestimate (run slower) faster running speeds (90% Vmax). It is expected that the use of live GPS feedback or timing gates would improve subjective sprinting speed as shown previously in soccer (13) or high-school athletes (25).

PRACTICAL APPLICATIONS

The present data provide evidence that professional rugby union players are unable to regulate their sprint speed when asked to run at 60%, 70%, 80% or 90% of their Vmax, without objective feedback. Thus, in order to ensure the accuracy of therapist- or coach-prescribed submaximal sprint velocities, players should be familiarized with the speeds at which they need to run, via feedback, or alternatively provided with objective feedback within session. This has been done successfully with high-school athletes who were provided with one familiarization session (25), and with academy level soccer players using timing gates within-session (13). Alternatively, and where logistically possible, providing live objective feedback via GPS may also allow athletes to better regulate their running speeds when completing similar sprint progressions.

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Table 1. Agreement between criterion and observed sprinting velocity in twelve professional rugby union players.

Measure	Criterion velocity (m·s^{-1})	Observed velocity (m·s^{-1})	Mean Bias % (standardized bias)	TEE % (standardized TEE)	Pearson Correlation (*r*)
60% Vmax (1)	5.19 ± 0.27	6.25 ± 0.85	21.5 ±7.9 (3.63 ±1.21; *VL*)	4.37 ±1.52 (1.16 ±3.00; *VL*)	0.65 ±0.34; *L*
60% Vmax (2)		6.36 ± 0.89	24.2 ±8.4 (4.04 ±1.25; *EL*)	4.52 ±1.52 (1.25 ±3.38; *VL*)	0.62 ±0.36; *L*
60% Vmax (3)		6.36 ± 0.86	24.1±7.9 (4.02 ±1.18; *EL*)	4.43 ±1.52 (1.19 ±3.14; *VL*)	0.64 ±0.35; *L*
60% Average of trials		6.32 ± 0.85	23.3 ±7.9 (3.90 ±1.19; *VL*)	4.40 ±1.52 (1.17 ±3.07; *VL*)	0.65 ±0.34; *L*
70% Vmax (1)	6.06 ± 0.32	6.75 ± 0.86	11.4 ±6.2 (2.01 ±1.04; *VL*)	3.90 ±1.52 (0.92 ±2.43; *L*)	0.74 ±0.28; *VL*
70% Vmax (2)		6.78 ± 0.80	12.0 ±5.8 (2.11 ±0.97; *VL*)	3.90 ±1.52 (0.92 ±2.43; *L*)	0.74 ±0.28; *VL*
70% Vmax (3)		6.66 ±0. 75	9.9 ±5.4 (1.76 ±0.92; *L*)	4.19 ±1.52 (1.06 ±2.72; *VL*)	0.69 ±0.32; *L*
70% Average of trials		6.73 ±0. 79	11.1 ±5.6 (1.97 ±0.94; *L*)	3.91 ±1.52 (0.92 ±2.44; *L*)	0.74 ±0.28; *VL*
80% Vmax (1)	6.92 ± 0.37	7.16 ± 0.76	3.0 ±4.2 (0.55 ±0.76; *S*)	2.96 ±1.51 (0.60 ±2.04; *L*)	0.86 ±0.17; *VL*
80% Vmax (2)		7.02 ± 0.60	1.3 ±3.3 (0.23 ±0.60; *S*)	3.70 ±1.51 (0.84 ±2.31; *L*)	0.77 ±0.26; *VL*
80% Vmax (3)		7.07 ± 0.69	1.8 ±3.8 (0.33 ±070; *S*)	3.34 ±1.51 (0.71 ±2.15; *L*)	0.81 ±0.22; *VL*
80% Average of trials		7.08 ± 0.67	2.0 ±3.6 (0.33 ±070; *S*)	3.20 ±1.51 (0.67 ±2.10; *L*)	0.83 ±0.20; *VL*
90% Vmax (1)	7.79 ± 0.41	7.47 ± 0.64	-4.1 ±3.0 (-0.78 ±0.58; *M*)	3.33 ±1.51 (0.71 ±2.15; *L*)	0.81 ±0.22; *VL*
90% Vmax (2)		7.45 ± 0.65	-4.5 ±2.9 (-0.85 ±0.56; *M*)	3.05 ±1.51 (0.63 ±2.06; *L*)	0.85 ±0.18; *VL*
90% Vmax (3)		7.44 ± 0.66	-4.5 ±2.5 (-0.86 ±0.50; *M*)	2.06 ±1.51 (0.39 ±1.89; *M*)	0.93 ±0.09; *NP*

90% Average of trials	7.46 ± 0.64	-4.4 ±2.7 (-0.83 ±0.52; *M*)	2.73 ±1.51 (0.54 ±1.99; *M*)	0.88 ±0.15; *VL*

are mean observed sprint velocity in comparison to criterion sprinting velocity (± SD) and include percentage and standardized mean bias, typical error of the estimate, and Pearson correlation coefficient ±90% confidence intervals and descriptor; *S* = small, *M* = moderate, *L* = large, *VL* = very large, *EL* = extremely large, *NP* = nearly perfect.

Table 2. Percentage speed achieved when running at subjective intensity of maximal sprinting

Data

Subjective (%)	**Coefficient of Variation**	**Vmax % Speed**	**Minimum %**	**Maximum %**	**Range (%) (%)**
60	73.0 ± 8.0$_{a}$	57.1	88.0	30.9	11.0
70	77.7 ± 7.0$_{b}$	66.5	92.5	26.0	9.0
80	81.8 ± 5.2$_{b}$	71.2	91.0	19.8	6.4
90	86.1 ± 4.3$_{a}$	76.8	94.8	18.0	5.0

a; significantly different to all other speeds achieved

b; significantly different to speed achieved when running at 60% and 90% Vmax