WHERE AND WHEN: IDENTIFYING KEY REGIONS OF OVERGROUND SPRINT FOR HORIZONTAL FORCE-VELOCITY PROFILING

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The purpose of this study was to identify regions of an overground sprint trial required to accurately determine independent horizontal force Velocity (FV) measures to minimize the data required for practitioners in practice. Forty-seven university aged athletes completed two overground sprint trials. Baseline FV metrics; theoretical maximum velocity [V_0], peak velocity [V_{max}], maximum power [P_{max}], maximum theoretical force [F_0], decrease ratio of force [DRF], and force-velocity slope [FV_{slope}] were calculated for each trial. Trials were then modified by removing percentages of the total sprint from the beginning and end of the trial independently. FV metrics were compared at each percentage and compared to baseline. Results of this analysis indicate that no changes occur in FV variables until 7% of the sprint is removed from sprint maximum velocity, while significant changes are present after any removal of data from sprint onset.
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INTRODUCTION: Horizontal force-velocity (FV) profiling has emerged as a methodology to evaluate sprint performance and gain insight into athlete's force, power, and velocity abilities (Clavel et al., 2022; Haugen, McGhie, & Ettema, 2019; Perez, Guilhem, & Brocherie, 2021; Samozino et al., 2016). FV profiling uses a velocity model to derive force and power metrics, however, the accuracy of the model is influenced by data collection and processing protocols. Current procedures for FV profiling require that an athlete perform a maximal effort sprint from a standing start and include all continuous data from a zero velocity up to and including the achievement and maintenance of a maximum velocity (Cross, Brughelli, Samozino, & Morin, 2017; Samozino et al., 2016). However, based on different testing constraints or environments, it is not always preferred or possible to complete a full sprint trial. Therefore, this paper aims to explore the minimum amount velocity data necessary to from a sprint trial to accurately determine different FV measures. We hypothesize that distinct segments of the sprint will exhibit varying impacts on specific force-velocity parameters. For instance, the theoretical maximum force [F_0] may be dependent solely on the acceleration phase of the sprint, whereas maximum velocity measures may be contingent upon successfully completing the entire sprint trial.

METHODS: Forty-seven participants (male = 23, female = 24, age = 21.26 ± 2.23 years, height = 1.75 ± 0.10 m, mass = 79.55 ± 12.64 kg) from university ice-hockey and rugby programs participated in this study. Participants varied in their sprint ability, sport history, and previous training. All participants were free of any injury at the time of testing. Ethical approval was obtained from the University of Victoria's Human Research Ethics Board. This study complied with the principles outlined in the Declaration of Helsinki.
The protocol was performed on an outdoor rubberized track surface with participants wearing standard running shoes. Each participant completed a standardized 20-minute warm-up procedure followed by three progressive sprints at increasing intensity (60%, 70%, 90% maximum effort) prior to their first trial. Following the warm-up, participants completed two 40-m sprint trials with a minimum rest period of 5 minutes to ensure the maximal effort across trials. Participants

were instructed to “stand-still” in a staggered 2-point stance for 2 seconds before commencing the sprint to avoid backwards or forwards movement before the sprint and to minimize movement prior to the inflection point of the velocity (i.e., onset of movement). For each trial, a radar gun (Stalker ATS II, Texas, USA) was set at a height of 1 m, 5 m behind the participant, pointed directly at the subject’s lower back. Stalker Stats II software (Version 5.0.3.0, Applied Concepts, Dallas, TX, USA) was used to collect instantaneous velocity data for each sprint (46.875 Hz). Data was filtered before export by the software (fourth order, zero lag, Butterworth filter) in line with previous research (Di Prampero et al., 2005). Barometric pressure (Torr), wind velocity (km/h) relative to the sprint direction, and ambient air temperature was collected (760 Torr, 7°C, 2km/h blowing south to north, respectively) from the University of Victoria weather station (latitude 48.46, longitude -123.6, elevation 60 m; Vantage Pro2, Davis Instruments Corporation, California, USA). For baseline FV measures, all sprint trials were cropped from the onset of movement to the maximum trial velocity. Velocity data was modelled using a mono-exponential model with time delay correction as used in previous research (Morin, Samozino, Murata, Cross, & Nagahara, 2019a) . A total of six common FV outputs; theoretical maximum velocity at zero force [V_0] maximum modelled peak velocity [V_{max}], maximum power [P_{max}], maximum theoretical force at zero velocity (relative to body mass) [F_0], decrease ratio of force [DRF], and force-velocity slope [FV_{slope}] were calculated. For each trial, the velocity model was optimized to minimize root mean square error (RMSE) between the modelled and raw velocity values. Horizontal aerodynamic drag force [F_{Drag}] and all subsequent FV outputs were calculated in accordance with previously validated techniques (Samozino et al., 2016).

To establish the minimum amount of data required for a consistent force-velocity (FV) profile, data was systematically excluded from the end of the sprint trial, working backward from the athlete's peak velocity. Data exclusion proceeded in increments, removing one percentile of the total sprint duration (spanning from the start of movement to peak velocity) during each step. At every percentile reduction, FV metrics were recalculated and compared to the full data set (baseline) for any significant deviations using repeated measures ANOVA with Tukey post-hoc tests for detailed analysis. This iterative process was carried out from a baseline of no data removal (0%) up to a point where 20% of the sprint data was omitted. The same method was then applied to the beginning of the sprint trial. Starting with the initial movement, data was incrementally removed in percentiles, ranging from the sprint's commencement at rest (0%) to a 20% reduction.

RESULTS: When data was removed from the end of sprint, significant differences were present for V_{max}, F_0, DRF, and FV_{slope} FV measures. After removing 7% of the length of the sprint trial, FV_{slope} and DRF were observed to be significantly different than baseline measures. Similarly, V_{max} and F_0 displayed significant change after removing 15% of the end of the sprint trial. Finally, V_0 became significantly different at the 18% stage, and P_{max} displayed no deviation from the baseline measure anywhere between 1 and 20%. These trends can be clearly viewed in figure 1.

The removal of data from the onset of the trial yielded much more dramatic results, with significant deviation from baseline FV measures occurring after only 1% change in the sprint length for F_0, DRF and FV_{slope} measures. P_{max} displayed significant deviation from baseline at the 2% level, while V_{max} and, V_0 displayed no significant change from baseline within the range of 0-5%.

DISCUSSION: These results indicate that some regions of the sprint may be more crucial for the accurate determination of FV metrics than others. When analysing power and theoretical force measures, the acceleration phase of the sprint is crucial. Even a 1% change in sprint length taken from the onset of the sprint trial causes significant change in FV measures pertaining to these physical principles. Further, based on this analysis, the inclusion of all data surrounding maximum athlete velocity has less of an impact on FV metrics. The most sensitive metric to this change was the FV_{slope}, in which significant change was observed to take place after 7% of the sprint trial was removed back from the achievement of maximum velocity. Furthermore, P_{max} appears to be very robust to removing data backward from maximum velocity, as no significant change occurred even after removing 20% of the sprint trial.

The majority of the work in horizontal FV analysis uses mono-exponential modelling for velocity either with or without a temporal correction (Cross et al., 2019; Morin, Samozino, Murata, Cross, & Nagahara, 2019b; Samozino et al., 2016). A consideration for further work is the exploration of other velocity modelling techniques, and their robustness to changes in sprint length. It is plausible that, depending on the model used for velocity, the regions of the sprint required to accurately determine FV measures may change, allowing practitioners to decern different information from different datasets.

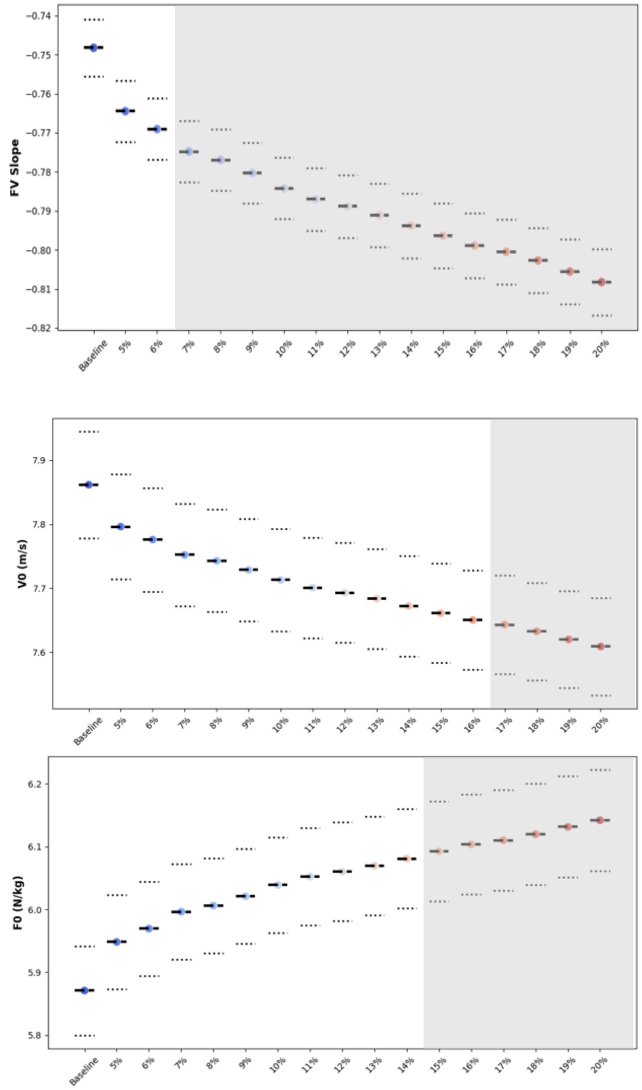

Figure 1. Trends in changes of means and standard error for FV variables when percentages of sprint data are removed from the end of the sprint trial. Percentages range from 0 (baseline, blue) to 20% removed (red). Regions where values were observed to have significant differences from baseline are identified by shaded regions.

The present analysis suggests that a sprint trial in its entirety is not required to accurately determine specific FV measures. Specifically, the end of the sprint trial close to maximum velocity does not appear to have a significant effect on FV measures. While the assumption of a maximum effort is still crucial to the validity of FV profiling, this analysis indicates that it may be possible to determine FV measures using shorter sprint trials without the achievement of maximal velocity.

CONCLUSION: The results of the present study indicate that certain regions of a sprint trial have larger impacts on FV metrics than others. Specifically, the onset and acceleration phase of the sprint appears to be crucial for all metrics other than V_{max} and V_0. On the other hand, the region of the sprint approaching and achieving maximum velocity seems to have less barring overall on FV outputs. This indicates that practitioners may be able to accurately and reliably determine FV measures without the achievement of maximum velocity.

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