KINETIC, SPATIAL, AND TEMPORAL ASSESENT OF OVERSPEED TOWING WITH ELASTIC TUBING

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Subjects (N = 15) performed sprints over force platforms in a normal condition and in three overspeed conditions of differing elastic tube stretch length. Kinetic and kinematic data were derived. A 3 x 4 RM ANOVA was used to analyze the results. The horizontal and vertical ground reaction force (GRF), and the ratio of horizontal to vertical GRF did not differ among conditions ($p > 0.05$). However, ground contact time was 8.3% to 10.4% shorter, time between steps was 1.4% to 2.7% lower, distance between steps was up to 1.2% greater, and velocity was 3.7% higher in some overspeed towing conditions compared to the normal condition ($p \leq 0.05$). Longer tube conditions were more optimal in most cases. Compared to normal running, overspeed towing results in increased sprinting velocity despite no differences in horizontal or vertical kinetics compared to normal running.

KEYWORDS: running, sprinting, acceleration, assisted methods

INTRODUCTION: Running acceleration and speed are important for success in many sports. As a result, training strategies were devised to improve these variables. Strategies include creating conditions where the athlete runs faster than normal. Overspeed towing with harnesses and elastic tubing is one option. Research on towing with elastic assistance includes training studies examining the effectiveness of select aspects of these methods (Makaruk et al., 2019; Murray et al., 2017; Upton, 2011). Acute biomechanical investigations have also been conducted to further understand this type of training (Bartolini et al., 2011; Clark et al., 2009; Corn & Knudson, 2003; Grabowski & Kram 2008; van den Tillaar & Gamble, 2019).
Training studies used cable and pulley systems (Murray et al., 2017), elastic bands (Makaruk et al., 2019), or tubing (Upton, 2011) to create the overspeed towing condition. These studies compared overspeed training to either resisted or normal sprinting. Overspeed towing demonstrated larger post-training improvements than resisted or normal sprint training (Makaruk et al., 2019; Murray et al., 2017; Upton, 2011). Improvement were found for sprinting velocity (Upton, 2011), reduced flight time (Makaruk et al., 2019), and greater retention of improvements after training (Makaruk et al., 2019). Thus, overspeed towing offers unique advantages, though much is unknown about optimally prescribing this training stimulus.
Acute biomechanical studies were also conducted to assess overspeed towing. Studies used kinematic analyses (Clark et al., 2009; Corn & Knudson 2003; van den Tillaar & Gamble 2019), laser (van den Tillaar & Gamble 2019), or timing systems (Bartolini et al., 2011). Overspeed towing was assessed during sprints under 20 m (Bartolini et al., 2011; Corn & Knudson 2003; van den Tillaar & Gamble 2019) or for 60 m (Clark et al., 2009). Overspeed towing included cable and pulley systems (van den Tillaar & Gamble, 2019) or elastic tubing (Bartolini et al., 2011; Clark et al., 2009; Corn & Knudson 2003). These studies show that overspeed towing had little effect on step frequency (van den Tillaar & Gamble 2019) and small (Clark et al., 2009) or no (Corn & Knudson, 2003) effect on stride rate. However, the overspeed towing condition was better than normal running for other measures. For example, overspeed towing produced higher velocity sprints (Clark et al., 2009; Corn & Knudson, 2003; van den Tillaar & Gamble, 2019), greater step length (Corn & Knudson, 2003; van den Tillaar & Gamble, 2019), reduced ground contact time (Clark et al., 2009), and reduced joint angles during ground contact (Clark et al., 2009). Research also showed that the subject displacement was greater as a function of the magnitude of the towing force (Clark et al., 2009). However, no research assessed subject kinetics during overspeed towing, and no researched examined overspeed towing as a function of elastic tubing length. Therefore, the purpose of this study was to assess select kinetic, spatial, and temporal variables associated with normal sprinting compared to overspeed sprinting with elastic tubing of various lengths.

METHODS: Subjects included fifteen men (age = 20.40 ± 1.45 years) who were college athletes. They participated in baseball, football, basketball, and track and averaged 2.7± 0.5 years of NCAA Division III collegiate playing experience. All subjects provided written informed consent for this study, which was approved by the governing Institutional Review Board.
Subjects participated in one research session designed to evaluate normal sprinting and sprinting in overspeed towing conditions with three different lengths of elastic tubing. Subjects performed a general, dynamic, and activity specific warm-up. Subjects were provided a demonstration and practiced in the test conditions including sprinting with: 1) no elastic tubing (No Tube); and 2) elastic tubing stretched to 9.2 meters, 3) 10.7 meters, and 4) 12.2 meters. Subjects were tested in all test conditions, starting 2 cm behind and sprinting across two force platforms (Accupower, Advanced Mechanical Technology, Inc., Watertown, MA, USA). All test sprints were 15 meters. All test trials and conditions were randomized to reduce potential order effects associated with fatigue or potentiation.
The force platforms were calibrated, and data were acquired at 1000 Hz. The first three steps of each sprint were analyzed. The peak horizontal ground reaction force (H-GRF), peak vertical ground reaction force (V-GRF), the duration of the V-GRF, and the ratio of H-GRF to V-GRF (H:V) were calculated for each step of each condition. Horizontal displacement, time, and velocity were determined using center of pressure measurements from the force platforms.
Data were analyzed with a statistics program (SPSS 28.0, International Business Machines Corporation, Armonk, New York). Assumptions for linearity of statistics were tested and met. The trial-to-trial reliability of the dependent variables were assessed using average measures Intraclass correlation coefficients (ICC) and coefficients of variation (CV). The ICC were found to be > .60 and CV less than 10.0; thus, the average values were used for further analyses. A 3 x 4 (steps * test condition) ANOVA with repeated measures for test condition was used to assess H-GRF, V-GRF, duration of V-GRF and H:V. A 2 x 4 ANOVA (difference between steps * test condition) was used to assess distance, time, and velocity differences between steps one to two and between steps two to three of each sprint. Bonferroni adjusted pairwise comparisons were used when significant main effects were found. The alpha level was set at $p \leq 0.05$ for all comparisons. Statistical power (d) and effect size (η_p^2) are reported, with effect size with thresholds of: moderate = 0.3, large = 0.5, very large = 0.7 (Hopkins, et al., 2009).

RESULTS: Figures 1-4 show the results of the analysis of H-GRF, V-GRF, V-GRF duration, and H:V. Figures 5-8 show the results of the analysis of time, distance, velocity between steps, and velocity across all steps. The analysis of stride frequency was not significantly different across test conditions (p = 0.43). Average measure intraclass correlation coefficients for the dependent variables for each exercise test and load condition ranged from .72 to .99.

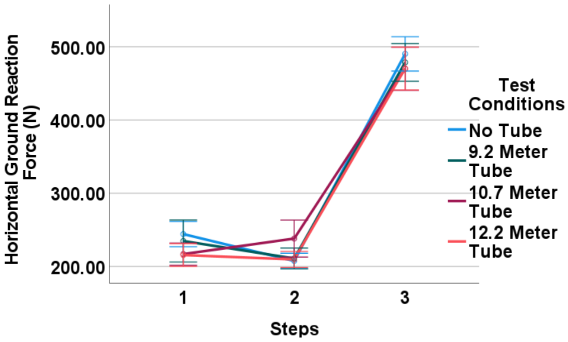

Figure 1. The analysis of H-GRF revealed significant main effects for steps ($p \leq 0.001$, d = 0.99, $\eta_p^2 = 0.92$) but not for the test condition (p = 0.13) or the interaction of steps and test condition (p = 0.26). Post-hoc analysis shows step 1 is different than step 3 ($p < 0.001$).

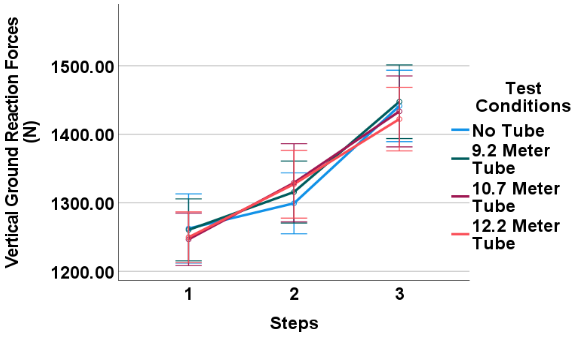

Figure 2. The analysis of V-GRF revealed significant main effects for steps ($p \leq .001$), d = 0.99, $\eta_p^2 = 0.69$), but not for the test condition (p =0.90), or the interaction of steps and test condition (p = 0.46). Post-hoc analysis shows step 1 is different than step 3 ($p < 0.001$).

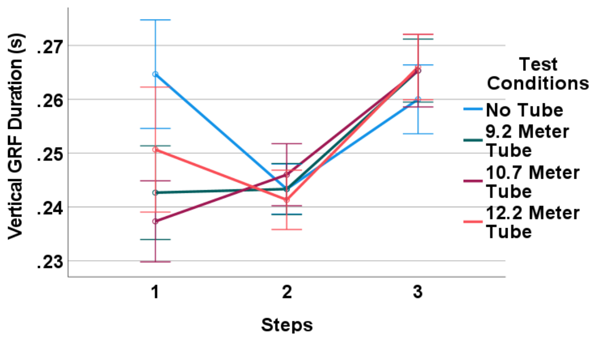

Figure 3. The analysis of V-GRF duration revealed significant main effects for steps ($p \leq 0.03$, d = 0.76, $\eta_p^2 = 0.26$), and the interaction of steps and test condition ($p \leq .001$, d = 0.99, $\eta_p^2 = 0.30$), but not for the test condition ($p > 0.31$). Post-hoc analysis shows differences between all steps ($p \leq 0.012$).

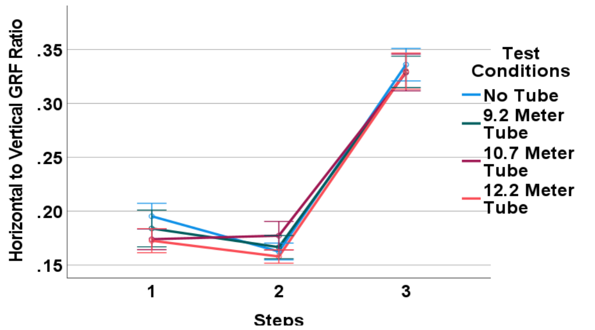

Figure 4. The analysis of H:V revealed significant main effects for steps ($p \leq 0.001$, d = 0.99, $\eta_p^2 = 0.91$), but not for the test condition ($p = 0.14$), or the interaction of steps and test condition ($p = 0.42$). Post-hoc analysis shows step 1 differs from step 2 ($p = 0.049$), step 1 differs from step 3 ($p \leq 0.001$), and step 2 differs from step 3 ($p \leq 0.001$).

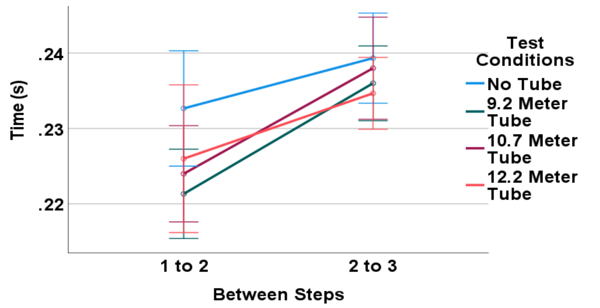

Figure 5. The analysis of time between steps revealed significant main effects for steps ($p = 0.047$, d = 0.51, $\eta_p^2 = 0.24$) and test condition ($p = 0.047$ d = 0.65, $\eta_p^2 = 0.17$), but and the interaction of steps and test condition ($p = 0.02$). Post-hoc analysis shows time between steps 1 and 2 is different than the time between steps 2 and 3 ($p = 0.04$) and that the no tube condition is different than the 9.2 meter tube condition ($p = 0.02$)

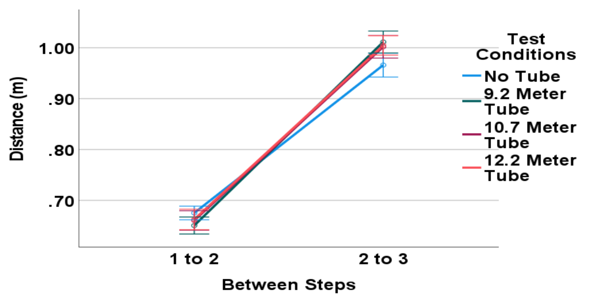

Figure 6. The analysis of distance between steps revealed significant main effects for steps ($p = 0.001$, d = 0.99, $\eta_p^2 = 0.93$) and the interaction of steps and test condition ($p = 0.007$, d = 0.86, $\eta_p^2 = 0.25$), but not test condition ($p = 0.49$). Post-hoc analysis shows that the distance between step 1 and 2 is different than the distance between step 2 and 3 ($p < 0.04$).

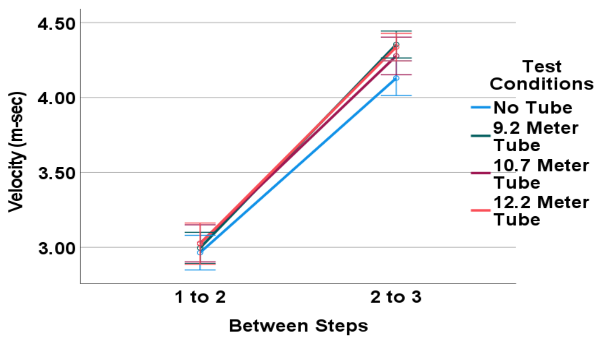

Figure 7. The analysis of velocity between steps revealed significant main effects for steps ($p = 0.001$, d = 0.99, $\eta_p^2 = 0.90$) and test condition ($p = 0.04$, d = 0.67, $\eta_p^2 = 0.19$), but not the interaction of steps and test condition ($p = 0.51$). Post-hoc analysis shows that the velocity between step 1 to 2 is different than the velocity between steps 2 to 3 ($p < 0.001$) and that the no tube condition is different than the 9.2 meter tube condition and the 12.2 meter tube condition ($p \leq 0.05$).

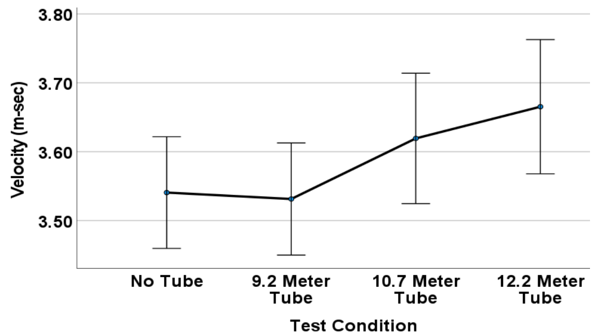

Figure 8. The analysis of the velocity from step one to three revealed significant main effects ($p = 0.024$, d = 0.20, $\eta_p^2 = 0.74$). Post-hoc analysis shows the no tube condition and the 9.2 meter tube condition are different than the 12.2 meter condition ($p \leq 0.05$).

DISCUSSION: This is the first study to assess both the kinetic and kinematic features of overspeed running with different degrees of stretch of elastic tubing. Results show that the

stretch of elastic tubing did not affect H-GRF, V-GRF, or the H:V, nor did these kinetic values differ from the normal condition. The H-GRF and V-GRF have been shown to be uncorrelated with speed in normal running conditions (Thone et al., 2020). There was an interaction between step and test condition for the duration of the V-GRF. Compared to the normal condition, elastic tube conditions had an 8.3% to 10.4% shorter period of ground contact time, with the medium length tube producing the biggest advantage. Less ground contact time during overspeed towing has been shown (Clark et al., 2009; van denTillaar & Gamble 2019).
In the present study, the test conditions yielded different time between steps, with the elastic tube conditions resulting in 1.4% to 2.7% less time. Additionally, the elastic tube conditions resulted in up to 1.2% more distance between steps, which was greatest in the longest tube condition. Others also found that overspeed towing resulted in longer step length (Corn & Knudson, 2003, van den Tillaar & Gamble, 2019) or displacement (Corn & Knudson, 2003), but only in conditions of greater tubing stretch (Clark et al., 2009). The present study also showed a difference in velocity between test conditions. The velocity in the long tube condition was 3.7% higher than the no tube condition. Similar results were shown in acute overspeed towing (Clark et al., 2009, Corn & Knudson, 2003; van den Tillaar & Gamble, 2019) and chronically where overspeed towing was part of training (Murray et al., 2017; Upton, 2011), up to a point that too much tubing stretch led to no differences in velocity (Bartolini et al., 2011). In the present study, there was no significant difference in step frequency, consistent with previous research (Corn & Knudson, 2003; van den Tillaar & Gamble 2019).
In the present study, all of the kinetic and kinematic outcome variables differed between steps. The H-GRF, and V-GRF, V-GRF duration and H:V ratio were all highest in the third step. The time between steps increased from step one and two, to steps two to three, presumably due to the increased distance. Predictably, the velocity increased from steps one to two, to steps two to three.

CONCLUSION: Compared to normal running, overspeed towing results in increased velocity which is accrued due to greater distance and faster between step times, and lower duration of ground contact. These findings are manifested more in the medium and long tube conditions. Velocity is higher in the longer tube conditions despite no differences in horizontal or vertical kinetics. Thus, similar forces are developed in less time which would make overspeed towing, with relatively long tubing stretch, the optimal training stimulus.

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