DIFFERENCES BETWEEN CONTROL AND SUPPRESSED ARM SPRINT RUNNING DURING THE MAXIMUM VELOCITY PHASE

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The purpose of this study was to clarify sprint characteristic differences between control and suppressed arm sprint running during the maximum velocity phase. Baseball players (n=15) completed a 50 m control and suppressed arm trial, and ground reaction force was measured with force platforms. Sprint characteristics were calculated during the stride that maximum velocity was reached. Cohen's d effect size with 95% confidence intervals and paired T-tests elucidated differences between trials. The maximum velocity decreased by 7.06% during the suppressed arm trial, compared to the control, probably caused by the suppressed arm condition. There were further decreases in propulsive (12.67%), braking (7.40%), vertical (2.81%) and effective vertical (5.95%) mean forces, suggesting significant ground reaction force differences between trials during the maximum velocity phase.

KEYWORDS: ground reaction force, running speed, arm swing, kinematics, kinetics.

INTRODUCTION: Faster 100-m sprint times are achieved through greater average velocity, thus, clarifying relationships between velocity and other sprint characteristics provides an understanding of performance determinants. Among coaches, one popular anecdotal determinant of greater velocity is "optimal" arm swing (Macadam et al., 2018), however, the clarification of optimal arm swing technique and the importance of arm swing during the maximum velocity phase remains ambiguous due to minimal research. Previous research suggested that arm swing serves to maintain balance through countering body rotation, indicating that arm swing is important for supporting the centre of mass (Hinrichs et al., 1987; Macadam et al., 2018). In addition, one study reported vertical range of motion of the centre of mass increased due to vertical arm acceleration relative to the trunk, suggesting a possible relationship between arm swing and greater vertical impulse (Hinrichs et al., 1987). Through dynamic coupling, arm swing may influence lower extremity kinetics or kinematics, demonstrated by ground reaction force (GRF) fluctuations when standing through swinging the arms, compared to standing still on a force platform (Miller et al., 2009). Thus, arm swing has further been suggested to possibly contribute toward increasing propulsive or vertical GRF when sprinting (Macadam et al., 2018). One study supported this speculation, which compared GRFs between control and suppressed arm (SA) trials (SA trials included arms held across the chest and behind the back) during running at the same speed (5km race pace), demonstrating that peak vertical force decreased by 9.7% in SA trials, compared to a control (Miller et al., 2009), though it is unknown whether this result would be translatable to the maximum velocity phase of sprinting. However, theoretically if maximum velocity is different between control and SA sprinting, then a maximum velocity matched comparison may be unachievable, thus, this difference is important to elucidate.

No known research has elucidated sprint characteristic changes due to SA trials during the maximum velocity phase. Therefore, the purpose of the present study was to clarify the velocity and associated GRFs and spatiotemporal variable differences between control sprinting and sprinting while suppressing arm swing, during the maximum velocity phase. Determining differences between trials may assist coaches to better understand the importance of arm swing and help design future research interventions.

METHODS: Fifteen sub-elite male baseball players participated in this study (mean±SD: age 20.2±1.2 years; height 170.3±5.6 cm; body mass 72.6±5.8 kg). This research was approved by the institutes ethics committee. One SA familiarisation session was completed one week prior to measurements. To control for any effect of individualised warm up, the procedure was standardised, involving sprint specific dynamic stretches, drills and sprint repetitions with increasing intensity. Athletic attire and baseball training shoes were worn. During the measurement session, two indoor 50 m maximum effort sprints from a standing start were randomly completed, including one control trial (natural sprint technique) and one SA trial, separated by a six-minute recovery. During SA trials the trunk and pelvis movement was not suppressed or coached in any form, to remain as natural as possible, in accordance with previous SA studies (Brooks et al., 2020; Miller et al., 2009). For the SA trials only the arms were suppressed consciously (voluntarily) by participants (no physical restraints used), who held their arms laterally by their side with the elbows at a 90° angle for the duration of the sprint (Figure 1). Step-to-step GRF was measured with 54 force plates (TF-90100, TF-3055, TF-32120, Tec Gihan, Uji, Japan), with the sampling frequency set at 1000 Hz. Force plates were covered with synthetic material and connected to a single computer and an electronic start gun (used to begin trials and acted as the trigger for data collection).

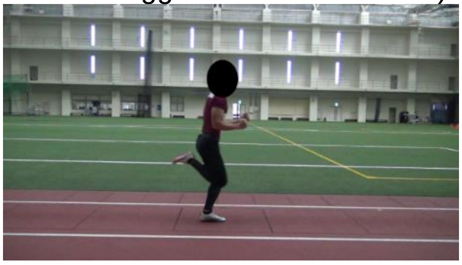

Figure 1. Suppressed arm position example.

Raw GRF signals were filtered using a digital 50 Hz low-pass fourth-order Butterworth filter and step-to-step velocity, step length, step frequency, support time, flight time and respective GRF components were calculated in accordance with previous research (Nagahara et al., 2020). All GRF variables were divided by body mass. To reduce bilateral step-to-step variability, the moving average of step-to-step results were calculated for each variable. The primary focus of this study was the maximum velocity phase, thus, the step-to-step moving average where maximum velocity was reached per trial was defined as the maximum velocity phase. Cohen's d effect size with 95% confidence intervals and a paired T-test (significance set at P < .050) clarified the sprint characteristic differences between control and SA trials during the maximum velocity phase. The effect size results were interpreted using qualitative terms [< 0.2 (trivial), 0.2–0.6 (small), 0.6–1.2 (moderate), 1.2–2.0 (large), 2.0–4.0 (very large) or >4.0 (nearly perfect)] (Hopkins et al., 2009).

RESULTS: Every individual participant had a smaller magnitude of maximum velocity during the SA trial, compared to the control (range 2.57–14.04% decrement) (Figure 2). Table 1 shows the sprint characteristic differences between trials during the maximum velocity phase.

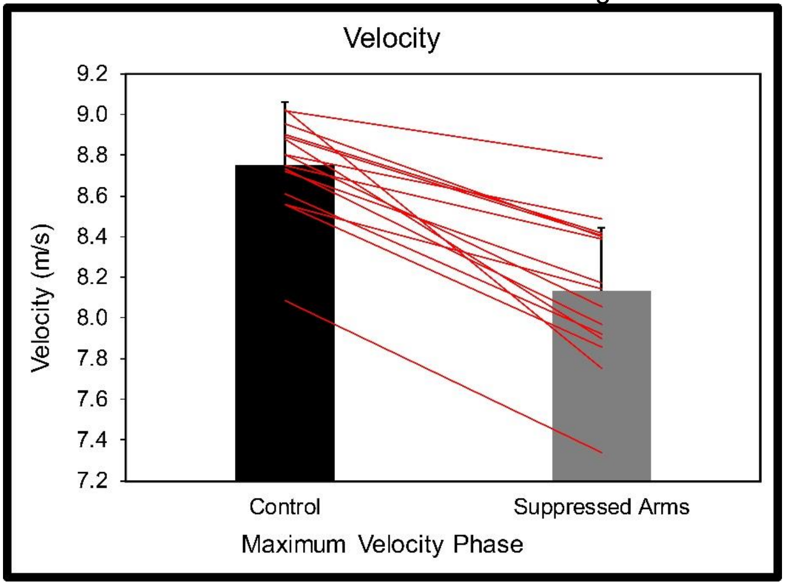

Figure 2. Maximum velocity (bars) plus standard error (error lines) and each individual participant's maximum velocity trend (red lines) between control and suppressed arm trials.

Table 1. Mean values ±standard deviation, Cohen's d effect size (ES) with 95% confidence intervals (CI) and paired T-tests between control and suppressed arm trials during the maximum velocity phase. Significance set at P < .050, indicated with an asterisk.

	Control	Suppressed Arms	ES (CI)	P Value
Maximum Velocity (m/s)	8.75 ±0.23	8.13 ±0.35	−2.09 (−2.41 – −1.78)	< .001*
Step Length (m)	1.89 ±0.08	1.83 ±0.09	−0.74 (−1.28 – −0.19)	.008*
Step Frequency (Hz)	4.63 ±0.23	4.46 ±0.27	−0.70 (−1.05 – −0.35)	.022*
Support Time (s)	0.11 ±0.01	0.12 ±0.01	0.98 (−1.20 – 3.16)	< .001*
Flight Time (s)	0.10 ±0.01	0.10 ±0.01	0.09 (−2.12 – 2.30)	.750
Propulsive Mean Force (N/kg)	3.91 ±0.35	3.41 ±0.43	−1.28 (−1.70 – −0.85)	< .001*
Propulsive Impulse (Ns/kg)	0.25 ±0.02	0.24 ±0.03	−0.57 (−2.07 – 0.93)	.007*
Braking Mean Force (N/kg)	−3.73 ±0.42	−3.46 ±0.56	0.55 (0.16 – 0.95)	.028*
Braking Impulse (Ns/kg)	−0.18 ±0.02	−0.17 ±0.02	0.24 (−1.48 – 1.97)	.301
Anteroposterior Net Mean Force (N/kg)	0.63 ±0.16	0.53 ±0.26	−0.50 (−1.50 – 0.50)	.131
Anteroposterior Net Impulse (Ns/kg)	0.07 ±0.02	0.06 ±0.03	−0.34 (−3.22 – 2.54)	.303
Vertical Mean Force (N/kg)	18.56 ±0.91	18.03 ±0.87	−0.58 (−0.76 – −0.41)	.017*
Vertical Impulse (Ns/kg)	2.08 ±0.10	2.17 ±0.13	0.77 (0.27 – 1.28)	.018*
Effective Vertical Mean Force (N/kg)	8.75 ±0.91	8.22 ±0.87	−0.58 (−0.84 – −0.33)	.017*
Effective Vertical Impulse (Ns/kg)	0.97 ±0.07	0.98 ±0.09	0.13 (−0.60 – 0.85)	.667

DISCUSSION: The purpose was to quantify the effects of suppressing arm swing during the maximum velocity phase. The maximum velocity decreased by 7.06% during the SA trial, compared to the control, through decreased step length and frequency, which were probably caused by the suppressed arms due to no other external factors differing between trials. There were further differences in GRFs between trials (Table 1), demonstrating that vertical mean force and propulsive mean force decreased during SA, compared to control trials, suggesting that arm swing may possibly be important to develop beneficial GRF production. In addition, the increased support time duration and maintained flight time when arm swing was suppressed suggests that participant's may have adjusted kinematics to maintain effective vertical impulse when the effective vertical mean force decreased due to SA trials, which is supported from previous research (Hinrichs et al., 1987; Miller et al., 2009). Taken together, results suggest that arm swing may be important to develop greater velocity during the maximum velocity phase and it may be practically recommended to continue promoting "optimal" arm swing to increase performance. Possible speculations for the higher running speed due to arm swing may be due to the arms counterbalancing the alternating pattern of the legs and conserving horizontal velocity, increasing vertical lift or benefitting unknown contributions to GRFs (Hinrichs et al., 1987; Macadam et al., 2018). These speculations were not possible to clarify by only examining the differences between trials, therefore, the extent to which SA trials or arm swing in general contributes toward GRFs could not be explained by the present results. To better quantitatively clarify the contribution of the arm swing to performance or GRFs, future research should compare SA and control trials with matched velocity and mathematically model (with three-dimensional motion analysis) the magnitudes of arm swing contribution for different sprint characteristics, and elucidate the correlations between arm swing characteristics and velocity or GRFs. In terms of the maximum velocity phase, matching velocity between SA and control trials may not be possible due to the reported differences found, however, treadmills or near maximum velocity may be viable alternatives to match the velocity of control sprints to the maximum velocity of SA sprints.

One previous study comparing SA and control trials during sprinting demonstrated no peak velocity difference (Brooks et al., 2020), suggesting no importance of arm swing in terms of influencing running velocity. These findings were inconsistent with results found in the present study and conventional coaching practice. The inconsistent results may be explained by the methodology differences between studies including participant cohort, running distance and SA method differences (participants held/crossed arms stationary across the chest) (Brooks et al., 2020), which may have resulted in centre of mass location differences during sprinting. In the present study, trunk rotation may have possibly been suppressed due to a larger moment of inertia due to holding the arm position laterally. Trunk rotation was not measured or controlled for in either the present study or the previous study (Brooks et al., 2020). However, other SA research showed no practical GRF or joint angle differences between SA methods (arms behind back or across chest) with voluntary or restricted suppression (Miller et al., 2009), which may be translatable to other SA methods such as the one adopted in this research. Another potential explanation for the velocity decrements found in the present study is that holding the arms laterally may have disrupted coordination or increased rotary momentum of the trunk or pelvis due to participants consciously trying to overcome the greater lateral weight step-to-step without any means to counter this rotation. Regardless of the underlying reason for velocity decrements, the present study and previous SA research comparing differences between trials only serve to speculate at the potential importance of the arms during sprinting, and can’t determine specific magnitudes of performance or GRF contributions due to arm swing characteristics. Therefore, future arm swing research is needed that implements three dimensional motion analysis to quantitatively elucidate the arm swing contributions to sprint characteristics and the arm swing determinants (if any) of sprint performance.

CONCLUSION: The SA trials reduced velocity through step length and frequency decreases, and reduced effective vertical mean force, suggesting that coaches should continue the current practice of promoting “optimal” arm swing to increase performance. Important practical recommendations for future research were detailed which may better elucidate the underlying contributions of arm swing to performance and GRFs during sprinting.

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