UPPER EXTREMITY MOTION AND SPRINT RUNNING: A FAREWELL TO ARMS?

Lance C. Brooks[1], Peter G. Weyand[2], and Kenneth P. Clark[1]

Department of Kinesiology, West Chester University of Pennsylvania, West Chester, Pennsylvania, United States[1]
Department of Applied Physiology and Wellness, Southern Methodist University, Dallas, Texas, United States[2]

Despite a lack of prior research on the topic, the sport coaching community has popularized the use of arm drills for athletes with the intent to enhance sprinting performance. The purpose of this study was to identify the effect of self-restricted arm motion on sprint running velocity. Track & field athletes and team sport athletes (n=15) completed 12 30-meter sprints (six with normal arm motion, six with restricted arm motion) while radar data was collected to quantify running velocity. Using a mono-exponential function, velocity profiles were created for each trial which produced four outcome variables: v_{max}, a_{max}, τ, and 30-meter sprint time. Differences in group means for all four outcome variables were not substantial (<Δ2%) between the two experimental conditions. It was concluded that the use of arm motion during maximal effort sprinting does not play a major role in running velocity enhancement.

KEYWORDS: arm swing, sprinting, running, locomotion, acceleration, velocity profile.

INTRODUCTION: Sprinting is a highly complex skill which is paramount for determining many competitive outcomes across dozens of sports. The ability to accelerate up to maximum velocity quickly is a vital attribute for sprinters and non-sprinters alike. Interest in human running speed and the methods by which to improve it dates back millennia. Aristotle, an ancient Greek philosopher and scientist, believed that an individual is made to run faster by swinging the upper extremities (Farquharson, 2007). This belief has held steady with much of the sporting community implementing drills in practice that specifically teach 'effective' or 'optimal' arm action during maximal-effort sprint running to increase running velocity. However, by observing non-human bipeds (turkeys, ostriches, various lizards, etc.) during locomotion, it can be noted that they run without the presence of large upper extremities oscillating during stride. Although prior research has explored the role of arm motion during jogging tasks (Arellano & Kram, 2011; Arellano & Kram, 2014; Hinrichs et al. 1987; Hinrichs, 1987; Pontzer et al. 2009), none have directly examined the effect of restricting arm motion on maximal effort sprint performance. Therefore, the purpose of this study was to identify the effect of self-restricted arm motion on sprint running velocity. Despite common coaching emphasis on the importance of arm swing for sprinting, since the arms do not directly push the runner forward, we hypothesized that maximal effort sprint running velocity would not be affected by upper extremity motion.

METHODS: *Subjects*: Nine males and six females volunteered to participate in the study. Four males and two females (mass: 72.4 ± 10.8 kg, height: 1.76 ± 0.08 m) were former collegiate track and field athletes with extensive experience performing track block starts. Additionally, five male and four female subjects (mass: 76.6 ± 16.4 kg, height: 1.78 ± 0.10 m) were experienced team-sport athletes. All subjects were less than two years removed from competitive status at the time of the present study (sprints, hurdles, and multi-events for track and field athletes and football, lacrosse, baseball, soccer, and field hockey for team sport athletes). Subjects reported to the lab on three occasions on non-consecutive days for a habituation session and two testing sessions. Each subject reviewed and signed informed consent documents and were fitted for standardized footwear (Waffle Racers, Nike, Inc., Beaverton, OR, USA). For the track and field group, the angle and spacing of the starting blocks was set according to the preference of each individual subject. After a dynamic warm-up, each subject completed six 30-meter maximal effort sprints with full recovery, alternating between two experimental conditions, Normal Arms (NA) and Restricted Arms (RA). The order of the trials during the second session was as follows: NA_1, RA_1, NA_2, RA_2, NA_3, RA_3. This order was inverted for the third session as RA_4, NA_4, RA_5, NA_5, RA_6, NA_6. These two conditions are illustrated in Figure 1. Instantaneous velocity was measured using a radar system (Stalker ATS System, Radar Sales, Plano, TX, USA) at 46.875 Hz. The radar was mounted to a tripod at one meter in height and placed 10 meters behind the subject. During maximal effort sprinting, the velocity-time curve follows the exponential function below. Using least-squares regression, the data was fitted to a curve of best fit (Chelly & Denis, 2001; Samozino et al. 2016):

$$v(t) = v_{max} \times (1 - e^{-t/\tau}) \quad (1)$$

where v_{max} is the maximum running velocity limit during the trial, while the time constant τ represents the rate of increase in velocity towards the subject's respective v_{max} by determining the time it takes to reach 63% of maximum velocity ($1 - e^{-1} = 0.632$). τ also represents the ratio between v_{max} and a_{max} (Clark et al. 2019), the initial acceleration limit during the trial, and thus is represented in units of seconds (s):

$$\tau = \frac{v_{max}}{a_{max}} \quad (2)$$

Statistical analysis: For the four outcome variables of interest (v_{max}, a_{max}, τ, and 30-meter sprint time), paired two-tailed *t*-tests were performed to test for significant differences between the two conditions (NA and RA). For each variable, percentage change between each condition for all group means was calculated as % change = [(NA – RA) / NA] * 100. The similarity of the velocity curves for the two conditions was assessed on the composite velocity curves for both groups using the R^2 statistic.

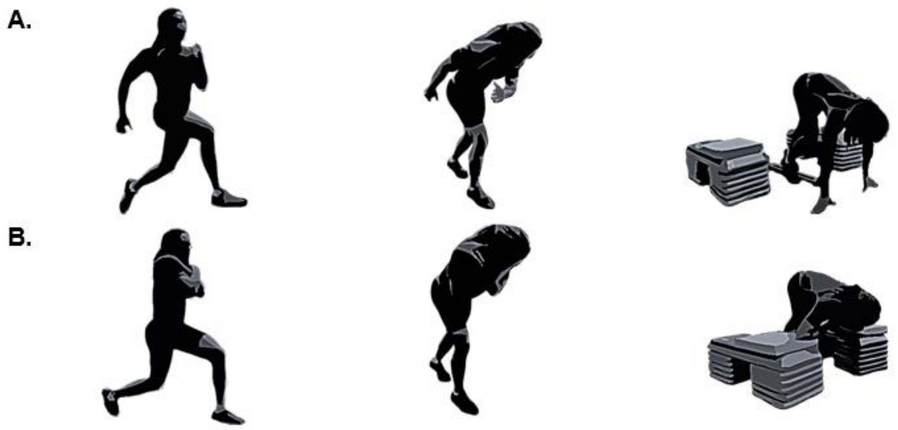

Figure 1. [A] Normal - subjects were given no cueing regarding technique other than to use their natural arm mechanics. [B] Restricted - subjects held their arms across their chest. During the start, subjects supported their elbows on two custom, padded stanchions.

RESULTS: Mean values for v_{max}, a_{max}, τ, and 30-meter sprint time for all subjects irrespective of sport were calculated across the two experimental conditions (NA and RA). v_{max} was 8.22 ± 0.83 m•s^{-1} and 8.17 ± 0.80 m•s^{-1} for NA and RA, respectively (-0.53%; $p < 0.05$). a_{max} was 7.14 ± 1.03 m•s^{-2} and 7.04 ± 0.97 m•s^{-2} for NA and RA, respectively (-1.36%; $p < 0.05$). τ was 1.16 ± 0.12 seconds and 1.17 ± 0.11 seconds for NA and RA, respectively (0.77%; $p > 0.05$). 30-meter sprint time was 4.81 ± 0.41 seconds and 4.83 ± 0.39 seconds for NA and RA, respectively (0.48%; $p > 0.05$).

Mean values for v_{max}, a_{max}, τ, and 30-meter sprint time for all subjects grouped by sport (track & field athletes and team sport athletes) are reported in Table 1. Composite velocity versus time curves for NA and RA groups are presented in Figure 2.

Table 1. Mean values for v_{max}, a_{max}, τ, and 30-meter sprint time for all subjects grouped by sport. Statistically significant p-values are denoted by an asterisk (*).

		Normal	Restricted	% change	p
Track & Field	v_{max} ($m \cdot s^{-1}$)	8.52 ± 0.81	8.45 ± 0.76	-0.8	> 0.05
	a_{max} ($m \cdot s^{-2}$)	7.85 ± 0.83	7.73 ± 0.78	-1.5	> 0.05
	τ (sec)	1.09 ± 0.09	1.10 ± 0.08	0.9	> 0.05
	30-meters (sec)	4.61 ± 0.33	4.64 ± 0.32	0.7	< 0.05*
Team Sports	v_{max} ($m \cdot s^{-1}$)	8.03 ± 0.81	8.01 ± 0.78	-0.2	< 0.05*
	a_{max} ($m \cdot s^{-2}$)	6.70 ± 0.88	6.62 ± 0.79	-1.2	> 0.05
	τ (seconds)	1.21 ± 0.11	1.22 ± 0.09	0.8	> 0.05
	30-meters (sec)	4.93 ± 0.40	4.95 ± 0.38	0.4	< 0.05*

DISCUSSION: The Results generally supported our Hypothesis. Although some variables demonstrated statistically significant differences between NA and RA conditions, all sprint performance variables indicated less than 2% difference between conditions. Furthermore, although statistically significant, total 30-meter sprint times differed by less than 0.03 seconds between conditions, suggesting a minimal difference between conditions from a practical standpoint. Regarding profiling metrics, v_{max} for the Team Sports group was the only one found to be significant, despite the change being small. These findings raise many questions as they are inconsistent with conventional coaching practice. The importance, or lack thereof, surrounding the use of arm motion during sprinting is a controversial issue in the sport coaching realm. It has been ostensibly stated in the sporting community that arm motion is vital in contributing to propulsive forces (Macadam et al. 2018), despite this not being supported in the academic literature. Hinrichs et al. (1987) suggests a slight increase in vertical lift of the center of mass during flight at submaximal speeds but no increases in horizontal propulsion. Although some data suggest a trivial decrease in average sprinting velocity while wielding a field hockey stick (Wdowski & Gittoes, 2018), the effect of arm motion on sprinting has not been directly investigated in the literature. We suggest that arm motion serves merely to counteract extraneous torso rotations, thus conserving forward momentum and making maximal effort locomotion more comfortable.

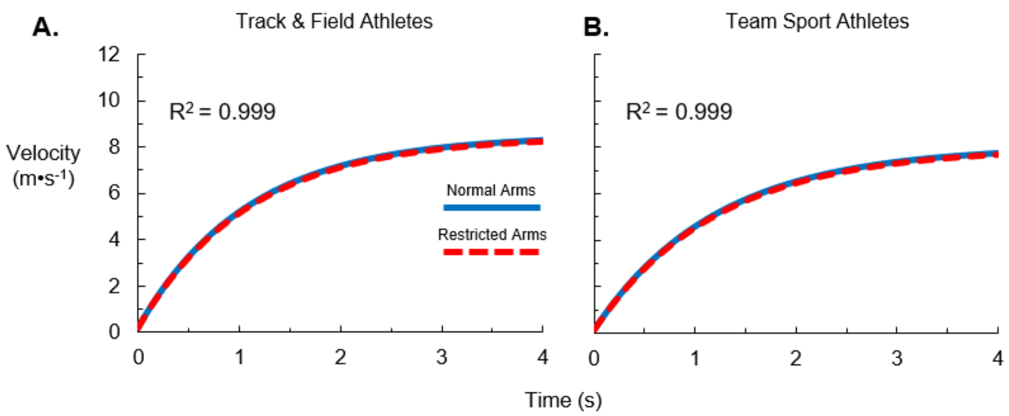

Figure 2. Composite velocity curves for all trials from both groups.

As previously mentioned, humans are the only species currently known to have large upper extremities that produce large movements during gait. Some researchers have postulated that this has less to do with its direct influence on running velocity and more to do with balance (Pontzer et al. 2009) and visual acuity (Grossman et al. 1989). The latter is a paradigm that explains the role of upper extremity motion during running by dealing with the vestibulo-ocular reflex. The absence of arm motion during running is often accompanied by large rotations of the torso (Arellano & Kram, 2014), and with it, the head. This increase in "head yaw" during sprinting can lead to a measurable decline in visual acuity during locomotion, as noted by Grossman et al. (1989), that may be exacerbated by excluding the use of arm motion to offset torsional imbalances. Since humans are susceptible to visual disruptions resulting from head yaw during running, perhaps we employ a mechanism for counteracting these disruptions: upper extremity motion.

CONCLUSION: The purpose of this study was to identify the effect of self-restricted arm motion on sprint running velocity. Our findings show that maximal effort sprinting performance was minimally affected by restricting upper extremity motion. Based on our findings, it is possible that the innate use of arm motion during maximal effort sprinting is purposed with counterbalancing the legs to mitigate torso rotations which cause balance and visual disturbances. These findings are inconsistent with conventional sport coaching wisdom which suggests that the arms help to provide an increase in running velocity. While the results of the present study are surprising, the authors certainly do not recommend cessation of arm motion while running, but rather call to question the usefulness of coaching emphasis on arm drills to increase sprinting velocity. Since time is often a limiting factor during training, perhaps training resources can be allocated towards other areas of sprinting technique.

REFERENCES

Arellano, C. J., & Kram, R. (2011). The effects of step width and arm swing on energetic cost and lateral balance during running. *Journal of biomechanics*, *44*(7), 1291-1295.
Arellano, C. J., & Kram, R. (2014). The metabolic cost of human running: is swinging the arms worth it?. Journal of Experimental Biology, 217(14), 2456-2461.
Chelly, S. M., & Denis, C. (2001). Leg power and hopping stiffness: relationship with sprint running performance. Medicine & Science in Sports & Exercise, 33(2), 326-333.
Clark, K. P., Rieger, R. H., Bruno, R. F., & Stearne, D. J. (2019). The National Football League Combine 40-yd Dash: How Important is Maximum Velocity?. The Journal of Strength & Conditioning Research, 33(6), 1542-1550.
Di Prampero, P. E., Fusi, S., Sepulcri, L., Morin, J. B., Belli, A., & Antonutto, G. (2005). Sprint running: a new energetic approach. *Journal of experimental Biology*, *208*(14), 2809-2816.
Farquharson, A. S. L. (2007). On the gait of animals by Aristotle.
Grossman, G. E., Leigh, R. J., Bruce, E. N., Huebner, W. P., & Lanska, D. J. (1989). Performance of the human vestibuloocular reflex during locomotion. *Journal of Neurophysiology*, *62*(1), 264-272.
Hinrichs, R. N., Cavanagh, P. R., & Williams, K. R. (1987). Upper extremity function in running. I: center of mass and propulsion considerations. Journal of Applied Biomechanics, 3(3), 222-241.
Hinrichs, R. N. (1987). Upper extremity function in running. II: Angular momentum considerations. Journal of Applied Biomechanics, 3(3), 242-263.
Macadam, P., Cronin, J. B., Uthoff, A. M., Johnston, M., & Knicker, A. J. (2018). Role of Arm Mechanics During Sprint Running: A Review of the Literature and Practical Applications. *Strength & Conditioning Journal*, *40*(5), 14-23.
Morin, J. B., Slawinski, J., Dorel, S., Couturier, A., Samozino, P., Brughelli, M., & Rabita, G. (2015). Acceleration capability in elite sprinters and ground impulse: Push more, brake less?. Journal of biomechanics, 48(12), 3149-3154.
Pontzer, H., Holloway, J. H., Raichlen, D. A., & Lieberman, D. E. (2009). Control and function of arm swing in human walking and running. Journal of Experimental Biology, 212(4), 523-534.
Samozino, P., Rabita, G., Dorel, S., Slawinski, J., Peyrot, N., Saez de Villarreal, E., & Morin, J. B. (2016). A simple method for measuring power, force, velocity properties, and mechanical effectiveness in sprint running. Scandinavian journal of medicine & science in sports, 26(6), 648-658.
Wdowski, M. M., & Gittoes, M. J. (2013). Kinematic adaptations in sprint acceleration performances without and with the constraint of holding a field hockey stick. *Sports biomechanics*, *12*(2), 143-153.

ACKNOWLEDGEMENTS: The authors would like to thank the participants for their time and effort as well as Marshall Lane, Samantha Jenks, Dylan Ferron, and Christopher Meng for assisting with data collection.