Changes in maximum linear running speed and sprint kinematics following a 20-week sprint training program

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Speed | **Sprint kinematics** | **Markerless motion capture** | **Youth athletes** | **Sprint training**

Headline

Maximal speed is a critical yet difficult attribute to enhance in team sport athletes due to genetic factors, technical complexity, and competing training demands (1). While speed training for team sports is often acceleration-based (2), field sport athletes frequently reach near-maximal speeds from moving starts (3-5). Proper sprint mechanics such as switching, stiffness, and positive running; are key to performance and injury prevention (6-8). Markerless motion capture now offers a practical way to assess technique (9).

Aim of the paper

This study examines how a 20-week sprint technique program influences key running mechanics using a 2D markerless system.

Methods

A descriptive one group mid- and post-test only design was conducted to examine the changes in sprint kinematics and speed following a twice weekly, 20 week sprint training program. Fifteen youth athletes participated (males: n = 10; females: n = 5; 17.1 ± 0.6 yrs; 66 ± 15 kg). All were attending a high school sports academy and were involved in a range of individual and team sports. All subjects were required to meet the study inclusion criteria; [i] at least 2 speed training sessions per week; and [ii] not suffering from any lower limb injury in the 4 weeks leading up to the start of the project. In addition to the sprint training program, each week participants attended regular sport technical training (2-4 sessions of 1-2) and completed two 50 minute strength and power sessions. The analysis of sprinting performance was a standardised assessment undertaken by the participants as part of their school sporting program. Access to the retrospective data was approved via signed written informed consent/assent. The study was approved by the Victoria University ethics committee (HRE24-138).

Pre-tests, mid and post-tests were performed by each subject under the same conditions on the selected day, 1 week before, at 10 weeks and 20 weeks. Participants completed a 5-minute structured dynamic warm-up protocol completed under the direction of a strength and conditioning coach. Participants then performed two flying 20 metre sprints each, with between 5-7 minutes rest between repetitions. The sprint track was 1.22 m wide and marked with specific reference markers placed at the start (0 m), mid-point (10 m) and finish (20 m). These markers were required for reference points for the VueMotion software. Testing was conducted indoors on a sprung wooden floor.

During the sprint, an iPhone 15 Pro was positioned in the middle of the capture zone, approximately 19 metres back from the sprint track and on a tripod at a height of approximately 1.5 metres high. The iPhone 15 Pro camera was used to record a video of the sprint performance in 4K (3840 x 2160) resolution at 60 frames per second. Video files were uploaded to the VueMotion cloud-based service for analysis. VueMotion uses a proprietary artificial intelligence algorithm to isolate the athlete and detect key action events and body pose points to estimate body kinematics. From this kinematic analysis the metrics of stiffness, switching, and positive running were extracted. “Switching" was quantified by measuring the angle between the swing thigh and the stance thigh at the moment of ground contact (6). “Stiffness" refers to the change in ankle angle during the amortization phase (from touchdown to mid-support) (6). “Positive running" (Figure 1) refers to the angle between the thighs at toe-off (6). If initial contact was made with the ground via the heel with any subject, stiffness was not assessed. Further, instantaneous speed of the hips is established allowing for the assessment of maximal speed. The trial recording the highest instantaneous speed was used for assessment.

Participants were coached through two speed development units each week, performed barefoot on an accommodating surface (sand, mats or grass), with each unit being approximately 30 minutes in duration. The first unit focussed on top speed, acceleration and deceleration mechanics. This included ankle stiffness exposure, hip mechanic drills, switching drills, two sprint exposures and two drills each for acceleration and deceleration. The second unit focussed on reactive/short contact plyometrics (both double leg and single leg), with accessory work on gymnastics and flexibility movements. Each unit progressed every 6-7 weeks, totalling three blocks for this intervention (Table 1).

Linear mixed models were used to quantify changes in each variable at each specific time point (i.e., pre, mid and post intervention). Participant identification was included as a random effect, to account for the repeated measurements within the dataset. The least squares mean test was used to obtain comparisons of the entered fixed effect, and the resulting standard deviations and mean differences were used to establish standardised effect sizes (ES) and 90% confidence limits (CL). Standardised ESs were described using the magnitudes; 0.20

trivial; 0.21–0.60 small; 0.61–1.20, moderate; 1.21–2.0 large and 2.01 very large (10). Differences were deemed to be real if they were 75% greater than the smallest worthwhile difference (calculated as 0.2 x the between-athlete SD).

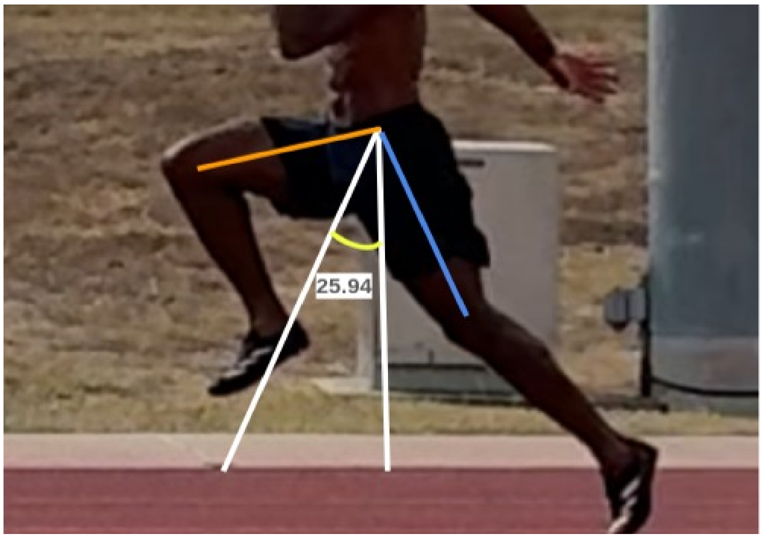

Fig. 1. Positive running refers to the bisecting line of the thighs at toe-off relative to the vertical line from the hip.

Table 1. An overview of the 20-week Sprint Mechanics training program.

Focus	Unit 1	Focus	Unit 2
Ankle stiffness	1 x 5 minutes	Double leg plyometric vertical and lateral	2 x 10-20
Lumbo-pelvic control	2 x 5 each side	Single leg plyometric vertical	2 x 6-10
Switching (4 variations)	2 x 10-15 m	Double leg plyometric horizontal	2 x 4-6
Sprint exposure competition	2 x 30m flying	Single leg plyometric horizontal	2 x 6-10
Deceleration	3 x Stop/Start mechanics	Triple jump	2-3 x 1
		Speed Bound Index competition	1-2 x 20 m
		Gymnastics (2 skills)	1 x 3 mins
		Flexibility	1 x 5 mins

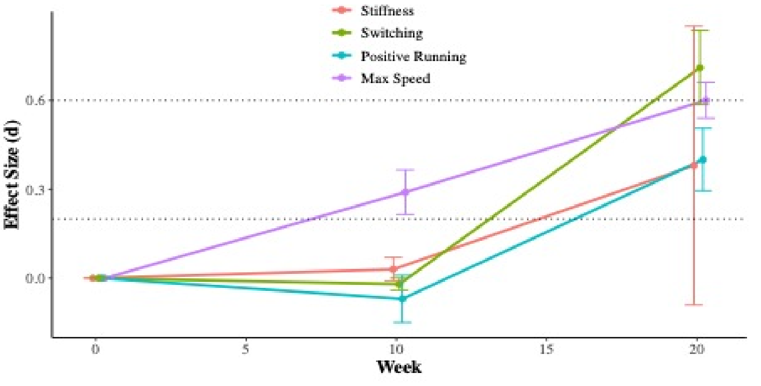

Fig. 2. Effect size changes in stiffness, switching, positive running and maximal velocity over the 20-week training intervention. Note: Stiffness values have been inverted as a higher negative value indicates a positive change.

Table 2. Raw values (Mean ± SD) for each variable at each time point.

Metric	Baseline	Mid	Final
Stiffness (°)	26 ± 8	26 ± 8	23 ± 3
Switching (°)	-39 ± 15	-39 ± 16	-29 ± 12
Positive Running (°)	14 ± 6	14 ± 6	16 ± 5
Max Speed ($m \cdot s^{-1}$)	8.4 ± 0.6	8.6 ± 0.5	8.8 ± 0.6

Results

Raw values for each variable at each time point are provided in Table 2.

When examining changes in each variable between time points (Figure 2) there were unclear changes in stiffness across the study period. There was a moderate decrease in switching between T2 and T3 (ES: -0.7; CI: -0.9 - -0.7) and between T1 and T3 (-0.7; -1.0 - -0.5). For positive running there was a small increase from T2 and T3 (0.5; 0.3 - 0.7) and from T1 to T3 (0.4; 0.2 - 0.6). There was also a small increase in maximal speed between T1 and T2 (0.3; 0.1 - 0.4) and between T2 and T3 (0.4; 0.2 - 0.5). This resulted in a small increase in maximal speed between T1 and T3 (0.6; 0.5 - 0.7). All other changes were non substantial.

Discussion

This study demonstrated the effectiveness of markerless motion capture in evaluating changes in technique during a 20-week training intervention. It is important to recognize this was a descriptive, one-group design featuring pre-, mid-, and post-tests; therefore, results should be interpreted with caution. From pre- to post-test, we noted minor adjustments in kinematic variables, paired with a moderate enhancement in maximal running speed. Considering the 20-week program encompassed both physical and technical development, it is likely various factors contributed to the observed speed changes. Future research involving larger sample sizes could explore performance variations between plyometric training and technique-focused training alone. Additionally, the relatively modest early changes in technique may indicate participants needed more time to master the skill, rather than experiencing immediate physiological adaptations directly from speed training and indirectly from strength training.

Throughout the 20-week training program, participants exhibited moderate improvements in maximal velocity, which appeared to be a consistent progression over time. In contrast, changes in technique were not evident during the first 10 weeks; however, small adjustments were observed in the subsequent 10-week phase. One possible explanation for this pattern is that participants commenced general leg power from the onset of the program. Youth athletes have been shown to have gains in strength between 30% and 50% after 8 to 12 weeks of strength training (11). Further, improvements in leg strength have been shown to enhance sprint performance in professional football players after six weeks of training (12), and improvements in speed and power have been demonstrated after 8 weeks of plyometric training (13). In comparison, changes in technique could be categorized as skill development, suggesting that skill adaptation took longer.

This study demonstrates the use of a markerless motion capture system to monitor changes in running technique over a 20-week period. Although the accuracy of markerless motion capture for assessing kinematics during high-speed movements, such as sprinting, has yet to be thoroughly validated, the technology demonstrates considerable potential for evaluating human movement (14). Importantly, markerless motion capture has shown strong alignment with OptoJump in measuring contact and flight times (15). Additionally, the efficiency and ease of data collection provided by markerless motion capture present significant advantages over marker-based systems, and it is notably quicker than setting up OptoJump for spatiotemporal measurements. Future research should not only investigate the validity of markerless motion capture in comparison to traditional marker-based systems but also evaluate the reliability of sprint kinematics in specific populations to identify meaningful changes in these variables.

Practical applications

- Developing maximal running speed remains a key challenge in sport, but advances in accessible biomechanical tools offer new opportunities to monitor and improve technique.
- This study, using a descriptive pre-, mid-, and post-test design, demonstrated small positive changes in running mechanics over 20 weeks.
- Markerless motion capture systems, once validated, may provide a practical and scalable tool for both performance enhancement and monitoring rehabilitation progress.
- Although less precise than traditional laboratory systems, markerless technologies enable rapid, real-time analysis, significantly reducing processing time from weeks to hours.
- Such accessibility allows coaches at all levels to deliver timely, evidence-informed feedback on technique and training.
- With growing evidence highlighting the importance of maximal speed and running mechanics in performance, the focus can now shift toward optimizing training and coaching strategies to enhance speed while minimizing injury risk.

Acknowledgments

The authors would like to acknowledge the support of staff and students at Maribyrnong Sports College for their support of this research study.

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