Original Research

Variations in running technique between female sprinters, middle, and long-distance runners

RUTHANN CUNNINGHAM‡, IAIN HUNTER‡, MATT SEELEY‡, and BRENT FELAND‡

Department of Exercise Sciences, Brigham Young University, Provo, UT, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 6(1) : 43-51, 2013. In the sport of track and field, runners excel not only due to physiological characteristics but also aspects in running technique. Optimal technique allows runners the perfect the balance between running speed and economy. The ideal movement pattern may vary between events as the goal goes from economy of movement in the long-distance events to speed and power in the sprints. Understanding how each type of runner moves differently will help coaches more effectively train their athletes for each specific running event. This study was conducted to determine if sprinters, middle-distance, and long-distance runners would exhibit differences in form while running at the same speeds. Thirty female Division I collegiate runners participated in this study. Runners were separated into categories based on the events for which they were currently training in: 10 sprinters, 10 middle-distance, and 10 long-distance runners. Participants were asked to run twenty-two steps at five selected speeds. Knee angles, ground contact time, center of mass separation, and stride length were measured using a Vicon Nexus motion analysis system. Data was processed using analysis of variance and a Tukey post hoc analysis. Significant differences ($p < .05$) occurred between long-distance runners and the other two groups (middle-distance and sprinters) for knee range, ground contact time, center of mass separation, and stride length at all five speeds. While running at the same speeds, there are specific characteristics of technique that distinguish long-distance runners from middle-distance and sprinters.

KEY WORDS: Running, sprinting, mechanics, kinematics, track

INTRODUCTION

To excel in the sport of track and field, not only are physiological characteristics important but runners must possess the kinematics needed for the event. Specific kinematics contribute to the race allowing a runner to excel in power, economy, or a combination of both. By understanding the kinematics needed for the competition distance, performance can be improved.

Runners who compete at different distances typically display differences in kinematics. For example, sprinters spend less time on the ground and have less knee flexion during stance phase compared to distance runners at maximum and competition speeds (2, 11, 17). It has also been observed that the center of mass separation (horizontal displacement between the landing toe and center of mass during ground contact time) is shorter for sprinters than distance runners at competition speeds (2). Lastly, distance runners have a shorter stride length than sprinters while competing in their event (3, 12). These differences in sprinters and distance runners allow each group to compete with the needed technique specific for their race.

While there are physiological differences between all three types of runners, biomechanics differences have not been examined when including a middle-distance group (13, 20). This information would benefit coaches and athletes in training and selection of novice athletes to a specific distance. While novice athlete may not be able to maintain the speeds used in this study, observations of technique at the lower speeds could still be helpful.

The purpose of this study was to determine whether collegiate and elite female runners who compete in sprinting, middle - distance, and long-distance running events exhibit differences in running technique when running at equal speeds. We hypothesized that, independent of speed; long-distance runners would exhibit greater knee flexion, ground contact time, and center of mass separation. We also hypothesized that sprinters would exhibit greater stride length, independent of running speed. Finally, we hypothesized that each group would increase stride length while decreasing knee range of motion and ground contact time with increases in speed.

METHODS

Participants

Thirty female runners from a Division I collegiate track and field team were recruited for this study. These participants were grouped into one of three running categories based on the distances they compete at: sprinters (400 m and less), middle-distance (800 m to 1600 m), and long-distance runners (3000 m and greater). Many athletes compete in middle-distance and long-distance races. We categorized each athlete into the event that they focused on late in the season. This ended up being a single event for most runners. For others that competed in more than one event, both events were in the same category as described above. The top ten participants on the team were selected for each category (Table 1).

Table 1: Subject Characteristics (Mean±SD).

Characteristics	Sprinter	Middle-distance	Long-distance
Height (m)	1.695 ± 0.05^{B}	1.712 ± 0.04^{AC}	1.693 ± 0.06^{B}
Mass (kg)	60.40 ± 5.40^{BC}	58.31 ± 3.64^{AC}	55.44 ± 4.33^{AB}
Age	19.80 ± 2.49	18.80 ± 0.92	19.30 ± 1.16

Note. Differences between groups at $p < 0.05$ in the Tukey post hoc analysis are represented by ^{A}Different from sprinters, ^{B}Different from middle-distance, ^{C}Different from long-distance.

Protocol

While in training season, each participant completed one session of running. Measurements for each participant were taken to determine joint centers and form marker placements according to the Vicon Full-body Plugin Gait Model (Vicon Motion Systems Ltd., Oxford, UK). Runners performed all trials on the same treadmill in a biomechanics lab using Vicon Nexus 1.3 (Vicon Motion Systems Ltd, Lake Forest, CA) with six MX 13+ cameras running at 240 Hz. All data and measurements were collected and processed with Vicon Nexus software.

All runners performed the trial wearing racing flats (Nike® Zoom Waffle Racer™). A five-minute warm up was given to allow each runner to adjust to treadmill running. After the warm up, runners ran 22 steps (11 strides) at each speed followed by an immediate increase to the next higher speed ((3.17 m·s^{-1} (8:27 min·mile^{-1}), 3.58 m·s^{-1} (7:30 min·mile^{-1}), 4.11 m·s^{-1} (6.31 min·mile^{-1}), 4.87 m·s^{-1} (5:30 min·mile^{-1}), and 5.95 m·s^{-1} (4:30 min·mile^{-1})). Twenty-two steps were chosen to provide a relatively high number of steps without creating too much difficulty for the athletes to maintain the required top speed of 5.95 m·s^{-1}. The first 16 steps were chosen for analysis as a typical representation of the running gait. Due to starting or stopping the collection in the middle of strides, 22 steps were collected to ensure at least 16 consecutive steps would be available.

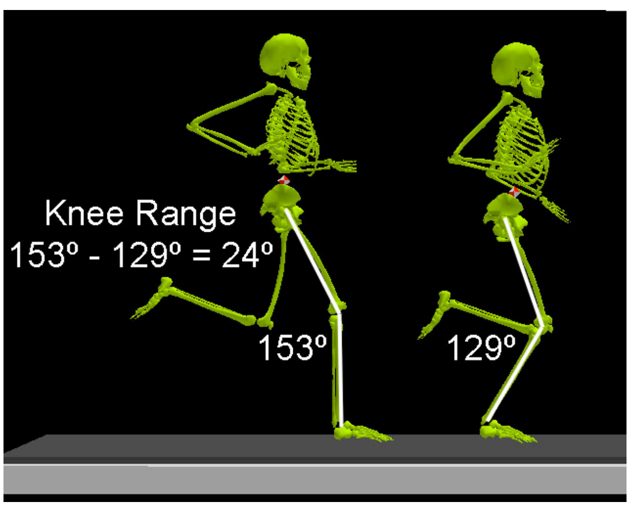

Figure 1. Knee range at touchdown. Knee range is calculated from the point of ground contact to the maximal flexion of the knee during ground contact time.

Knee range (KR) (range of motion of the knee from ground contact to maximum flexion during stance, Figure 1), ground contact time (CT) (amount of time on the ground during stance phase determined visually within Nexus using the "Event Identification Mode" and confirmed with 120 Hz video (Casio Exilim EX-FH100), center of mass separation (CMS) (horizontal distance from the center of mass to the front of the toe at touchdown, Figure 2), and stride length (SL) (the vertical distance divided by time in the air) for each speed was calculated using a customized program (Microsoft Visual Basic.NET). A customized Excel spreadsheet (Microsoft, Redmond, Washington) then calculated averages for eight strides. The left leg was used for analysis throughout all measures.

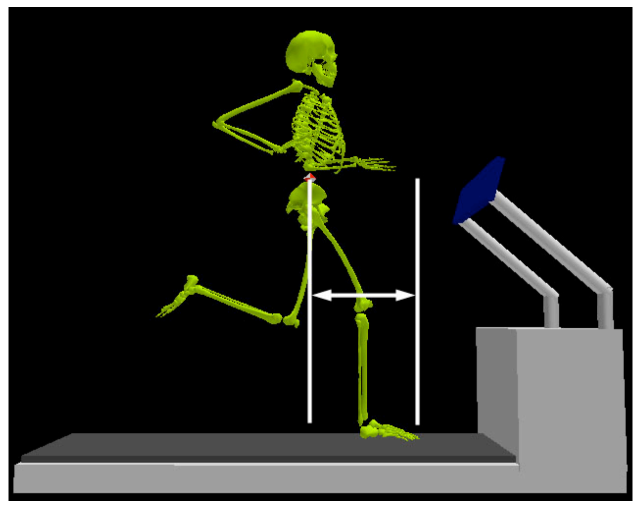

Figure 2. Center of Mass Separation. Center of mass separation is calculated from the initial ground contact phase of the lead foot. Measurement is based on the distance from the toe to the center of mass.

Statistical Analysis

Difference between groups at each speed were tested using a two-way analysis of variance (ANOVA) (group by speed) with a Tukey post hoc test for each of the four variables; KR, CT, CMS, and SL. Correlations were observed between height and CMS and in the past height was correlated with SL, thus CMS and SL were normalized for height (3). Alpha was set at 0.05.

RESULTS

Knee Range

Table 2. Knee range (the amount of flexion at the knee from touchdown to maximum knee flexion during stance). Mean ± SD.

Speed ($m \cdot s^{-1}$)	Sprinter (A) Knee Range (deg)	Middle-distance (B) Knee Range (deg)	Long-distance (C) Knee Range (deg)
3.17	25.5 ± 4.4 ^{C}	26.8 ± 2.2 ^{C}	32.5 ± 8.6 ^{AB}
3.58	25.8 ± 5.4 ^{C}	25.5 ± 4.0 ^{C}	30.8 ± 5.9 ^{AB}
4.11	26.2 ± 5.0 ^{C}	25.9 ± 3.4 ^{C}	32.3 ± 4.7 ^{AB}
4.87	23.7 ± 3.5 ^{C}	26.2 ± 2.8 ^{C}	32.8 ± 5.1 ^{AB}
5.95	22.9 ± 3.9 ^{C}	24.7 ± 3.6 ^{C}	30.9 ± 4.5 ^{AB}

Note. Differences between groups at $p < 0.05$ in the Tukey post hoc analysis are represented by ^{A}Different from sprinters, ^{B}Different from middle-distance, ^{C}Different from long-distance.

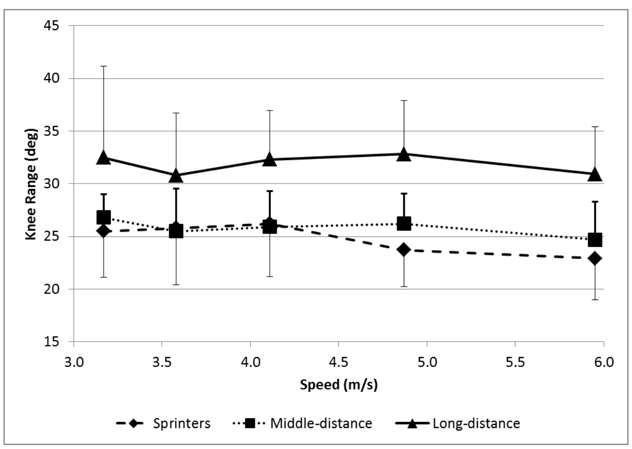

Figure 3. Knee range through the range of speeds tested. Error bars are only shown in one direction to improve readability.

Knee range results showed significant differences in KR between long-distance runners compared to middle-distance and sprinters (Table 2 and Figure 3). Across all speeds, sprinters displayed a smaller KR than that of the middle and long-distance runners.

Higher speeds and runners who compete at higher speeds generally display a smaller knee angle at touchdown, but no group by speed interactions were found (p=0.95).

Ground contact time

Table 3. Ground contact time. Mean ± SD.

Speed ($m \cdot s^{-1}$)	Sprinter (A) Ground contact time (s)	Middle-distance (B) Ground contact time (s)	Long-distance (C) Ground contact time (s)
3.17	0.22 ± 0.018 ^{C}	0.23 ± 0.028 ^{C}	0.25 ± 0.020 ^{AB}
3.58	0.21 ± 0.015 ^{C}	0.21 ± 0.026 ^{C}	0.23 ± 0.017 ^{AB}
4.11	0.18 ± 0.016 ^{C}	0.19 ± 0.020 ^{C}	0.21 ± 0.014 ^{AB}
4.87	0.16 ± 0.016 ^{C}	0.17 ± 0.020 ^{C}	0.19 ± 0.016 ^{AB}
5.95	0.14 ± 0.011 ^{C}	0.14 ± 0.017 ^{C}	0.16 ± 0.013 ^{AB}

Note. Differences between groups at $p < 0.05$ in the Tukey post hoc analysis are represented by ^{A}Different from sprinters, ^{B}Different from middle-distance, ^{C}Different from long-distance.

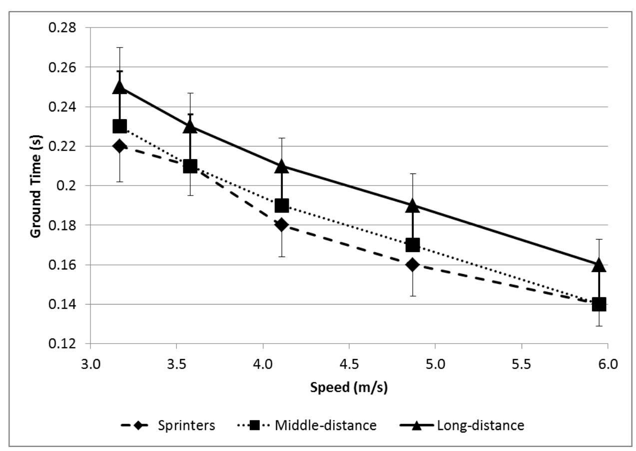

Figure 4. Ground time through the range of speeds tested. Error bars are only shown in one direction to improve readability.

As speed increased, all three groups spent less time on the ground (Table 3 and Figure 4). Results showed significant differences in CT between long-distance runners and the groups of middle-distance and sprinters at each speed (Table 3 and Figure 4). Sprinters spent the least amount of time on the ground followed by middle-distance runners then long-distance runners.

Center of Mass Separation
Increases in speed caused the CMS to increase in all groups (Table 4 and Figure 5). Results indicated CMS was significantly different between long-distance runners to that of middle-distance runners and sprinters at all speeds (Table 4 and Figure 5). At every speed long-distance runners had a greater CMS.

Table 4. Center of mass separation (the horizontal displacement from the center of mass to the touchdown toe at the moment of touchdown). Mean ± SD.

Speed ($m \cdot s^{-1}$)	Sprinter (A) Center of Mass Separation (m)	Middle-distance (B) Center of Mass Separation (m)	Long-distance (C) Center of Mass Separation (m)
3.17	0.179 ± 0.013 ^{C}	0.189 ± 0.020 ^{C}	0.207 ± 0.033 ^{AB}
3.58	0.184 ± 0.015 ^{C}	0.188 ± 0.028 ^{C}	0.211 ± 0.023 ^{AB}
4.11	0.189 ± 0.014 ^{C}	0.196 ± 0.024 ^{C}	0.219 ± 0.015 ^{AB}
4.87	0.191 ± 0.022 ^{C}	0.207 ± 0.020 ^{C}	0.230 ± 0.020 ^{AB}
5.95	0.200 ± 0.015 ^{C}	0.214 ± 0.028 ^{C}	0.243 ± 0.018 ^{AB}

Note. Differences between groups at $p < .05$ in the Tukey post hoc analysis are represented by ^{A}Different from sprinters, ^{B}Different from middle-distance, ^{C}Different from long-distance.

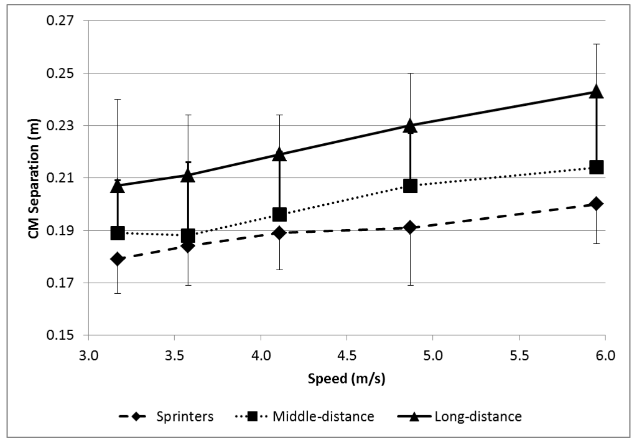

Figure 5. Center of mass separation through the range of speeds tested. Error bars are only shown in one direction to improve readability.

Stride Length
Long-distance runners displayed a shorter stride length than sprinters (Table 5 and Figure 6). Sprinters and middle-distance runners showed no differences between each other in stride length, and neither did middle-distance and long-distance runners. As speeds increased, each group displayed an increase in SL (Table 5 and Figure 6).

Table 5. Stride Length. Mean ± SD.

Speed (m/s)	Sprinter (A) Stride Length (m)	Middle-distance (B) Stride Length (m)	Long-distance (C) Stride Length (m)
3.17	1.305 ± 0.053 ^{C}	1.305 ± 0.041	1.294 ± 0.074 ^{A}
3.58	1.461 ± 0.063 ^{C}	1.439 ± 0.047	1.430 ± 0.083 ^{A}
4.11	1.620 ± 0.072 ^{C}	1.605 ± 0.067	1.589 ± 0.098 ^{A}
4.87	1.819 ± 0.081 ^{C}	1.787 ± 0.084	1.763 ± 0.113 ^{A}
5.95	2.043 ± 0.092 ^{C}	2.004 ± 0.079	1.953 ± 0.126 ^{A}

Note. Differences between groups at $p < .05$ in the Tukey post hoc analysis are represented by ^{A}Different from sprinters, ^{B}Different from middle-distance, ^{C}Different from long-distance.

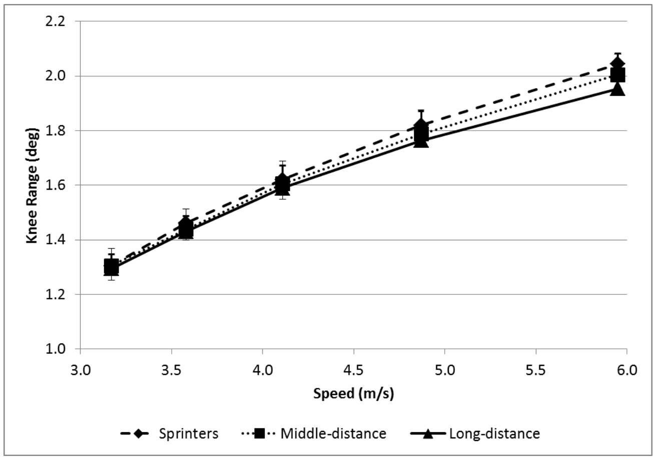

Figure 6. Stride length through the range of speeds tested. Error bars are only shown in one direction to improve readability.

Speeds

No group by speed interactions were observed (knee range, *p*=0.95; contact time, *p*=0.97; center of mass separation, *p*=0.87; stride length, *p*=0.94).

DISCUSSION

The purpose of this study was to determine if college-level sprinters, middle -distance, and long-distance female runners exhibit differences in running technique independent of running speed. Results showed that at all five speeds there was a significant difference in kinematics between long-distance runners and the other two groups (middle-distance and sprinters) with the exception of stride length which was also different between sprinters and middle-distance runners. Specifically, we found: 1) at all five speeds, long-distance runners had the greatest knee range, 2) at all speeds, long-distance runners had the longest ground contact time, 3) at all speeds, long-distance runners had the greatest center of mass separation, 4) at all speeds, long-distance runners had the shortest stride length, and 5) with speed increases, each group displayed a descending slope in knee range and ground contact time and an ascending slope in center of mass separation and stride length.

Prior research found differences in KR occurring between sprinters and long-distance runners at maximal speeds (2, 9, 11). This study observed the same differences occur between sprinters and long-distance runners at matched running speeds. Results also indicated that long-distance runners displayed a different KR between that of sprinters and middle-distance runners.

The smaller knee range displayed by sprinters and middle-distance runners compared with long-distance runners may be a result of the greater power required in these events compared to a long-distance race. Greater leg stiffness for sprinters allows them to spend less time on the ground and generate greater power during toe off (2). A training emphasis for long-distance runners on producing greater power may be beneficial during the final stage of a race when the emphasis of economy changes to that of velocity. As the speed increased, all three groups of runners displayed a smaller KR. Smaller KR was observed when jogging and running speeds were compared to sprinting speeds (9, 11). A smaller KR at maximal speeds is likely to match with training and abilities consistent with runners of events requiring greater power.

Significant differences in ground contact time between sprinters and distance runners are consistent with past literature which analyzed these groups at two speeds (2). Using high-speed video or other technology or other technology currently available, it is relatively easy for coaches and athletes to measure ground contact time to help determine appropriate training methods.

Decreases in ground contact time were also seen as velocity increased. Previous research noted this occurrence, observing that decreases in CT due to increasing speed aids runners in achieving higher velocities by spending less time on the ground to obtain maximal speeds (6, 8). Middle-distance and long-distance runners benefit by implementing the sprint like technique to reduce CT when the velocity of a race increases (14, 16). Long-distance runners may also see some benefits during certain stages of their races where greater running speeds are required. Training that allows them to decrease CT may benefit these runners.

When statistically looking at the differences in CT between the three groups, results show minimal differences to the 100th of a second (Table 3). With little variation, the question posed is if statistically significant differences are practical in the event itself. In high velocity running events these slight differences in CT are important. Often at the end of a race the finish between athletes comes down to the 100th of a second. Finding ways to decrease even a 100th of a second from the overall time can make the difference between second palace and first place in a high velocity finish.

Differences seen in center of mass separation may be due to the different groups focus on power and economy. Previous studies showed differences occurring between sprinters and distance runners at maximal speeds (2). Sprinters bring their legs through the swing phase quickly, placing the landing leg as close to their center of mass as possible. This puts them in a more powerful position at ground contact. Distance runners are more concerned with running economy, displaying a longer CMS and CT. The significant difference in CMS separation at all speeds between long-distance runners and the groups of middle-distance and sprinters supports previous literature.

Greater stride lengths were found in the past for sprinters compared with distance runners at maximum speeds (1, 2). This study added the knowledge of how middle-distance runners compare to sprinters and long-distance runners in stride length. We have also shown how stride length changes through a range of speeds for each group.

Additionally, previous research states that as speed increases, SL increases to benefit sprinters and long-distance runners (4, 8). This increase in SL at increasing speeds is a result of a decrease in CT time and flight time (4, 6, 7, 12, 18, 19).

With an increase in SL at higher velocities the question is how much of an increase will actually benefit the runner. Statistically significant differences between long-distance runners and middle-distance and sprinters were less than 10 cm (Table 5). However, over the course of a race this small difference in one SL becomes meaningful to overall race velocity. Slight variations in SL can have a large impact on overall performance.

Since the sprinters were not running at their race speed in this study, some connections between them and other runners cannot be made effectively. This issue could be addressed in the future with studies using treadmill capable of higher speeds. However, in this study we focused on comparing technique when running at matched speeds to take out the potential issue of determining if observed differences were due to differences in maximum speed.

This study was performed on a treadmill which may lead to slight differences in kinematics (5, 10, 15). This may lead to different results for each individual, but we have no reason to believe the differences between groups would disappear as a result of this.

We used the same shoe for every subject. This could be thought of as a limitation if the subjects were used to other types of shoes for most of their training. However, these shoes are similar in style to what the subjects typically use during their fast running session.

Coaches and athletes make needed adjustments to improve performance. Significant differences in knee range (KR), ground contact time (CT), center of mass separation (CMS), and stride length (SL) are seen between long-distance runners and the groups of middle-distance runners and sprinters through the entire ranges of speeds tested. Combining this with previous studies that investigated maximum running speeds shows that non-maximum running speeds can be used to characterize people into events and help people adjust technique to become optimized for events they may not have done in the past. Sprinters can identify areas of training that will increase velocity by further reducing knee range, decreasing ground contact time and center of mass separation, and increasing stride length. Middle and long-distance runners may include more sprint-like training in these four variables to aid in the final stage of their events. In addition, with further research coaches of novice runners may take these findings and use them to identify characteristics of a runner. These characteristics may aid the coach in suggesting and training the athlete for events that may best fit characteristics displayed in their running form.

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