Kinematic analysis of Jolanda Ceplak's running technique

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An elite runner's running technique is shaped by a number of physical characteristics, the influence of previous training (volume, methods of training) and racing. Hence, the running style of each individual is very specific. The purpose of this study is to point to some important kinematic variables of the running stride of Jolanda Ceplak, the indoor world record holder over 800 metres. From the 3-D kinematic analysis it is possible to draw the following conclusions: The plant is close to the vertical projection of the body's CM (centre of mass). Vertical displacement of CM is optimal, which can help to improve running economy. Great plantar flexion range, high angular velocity of plantar flexion in the ankle joint and explosive knee extension enable Ceplak to produce a substantial propulsive force and adds to the length of her stride. The amplitude of the thigh swing of the swing leg is greater than this parameter in comparable studies. Several kinematic parameters of Ceplak's running are quite similar to parameters of longer sprint events (200m and 400m) especially during the onset of fatigue.

Introduction

Jolanda Ceplak's competitive performances during the 2002 and 2003 seasons certainly go down in the history of the 800 metres. She is the indoor world record holder (1:55.82) and her outdoor PB 1:55.19 is the seventh best performance of all times.

Running technique contributes to the competitive edge of a long or middle distance runner. Efficient running biomechanics helps to keep injuries at bay and ensure that the runner's neuro-muscular potential is fully
exploited. It also helps to save the energy, which in turn results in better racing.

An elite runner's running technique is shaped by a number of physical characteristics such as flexibility, power, neuro-muscular function, body composition etc., the influence of previous training (volume, methods of training) and racing. Hence the running style of each individual is very specific. However, there are general modelling laws that determine optimal running stride, and these are important starting points in the teaching and improving young runners' running technique.

The running cycle (double stride) consists of the support phase ("braking" phase: foot strike, mid-support and "propulsion" phase or takeoff) and flight phase (follow-through or float, forward swing and foot descent).

Studies show that running stride efficiency
depends to a large extent on how the runner plants his or her foot and how he or she uses the time during the support phase.\textsuperscript{1,5,10,11} This in turn affects the speed, the onset of tiredness and running economy.

The purpose of the study is to show kinematic parameters of Jolanda Ceplak's running cycle during the finishing stages of the 800m. We focused our attention on parameters that describe dynamic of support phase.

Methods

We studied the kinematic parameters of Ceplak's running stride using a video of her competitive effort at European Athletic Association meeting held in Velenje. Her winning time for the race was 1:59.52 (1st 400m – 61.57, 2nd 400m – 57.95). The kinematic analysis covers the distance between 738 and 743m of the race.

3D kinematic parameters were measured with two synchronised Sony DVCAM DSR-300 PK cameras with a frequency of 50Hz. The cameras had an internal synchronisation system. They were placed at an angle of 90° with respect to the object recorded. Spatial calibration was done with eight reference points of two cubes with 1m sides.

For a 3-D kinematic analysis of running technique, we used APAS kinematic systems (Ariel Dynamics Inc., USA) and our own software. CM (centre of mass) of separate body segments and the total body CM were calculated using a 15-segment anthropometric model.\textsuperscript{4} Using this model we studied trajectories, velocities, angles and angular velocities of each point and segment. All numeric data were smoothed with a 7Hz digital filter.

Results and discussion

The basic aim of this study was to define and show the stride cycle kinematic parameters that influence the efficiency of Ceplak's running to the greatest extent.

The results (see Figures 1–4 and Table 1) show basic kinematic variables of Ceplak's running stride as she is coming off the last turn and into the finishing straight. Running velocity at this stage was 7.10m/s. Average stride length was 197cm, but in the section analysed it varied from 190 to 204cm. Relative stride length (stride length / height of body) was 1.17m. Stride frequency was 3.6Hz.
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(0.27m) in a 400m race (velocity 7.77/8.12m/s). The angle of 70° at foot strike was also similar. In comparison to sprinting, the distance between foot strike and vertical projection of body’s CM is much longer while the angle of foot plant is narrower.

Apart from the method of planting the foot, the contact time and the appropriateness of the evaluation angle in the takeoff also depend on the execution of midsupport and the swing of the swing leg.

The braking phase and takeoff, which represent eccentric-concentric muscular contractions at the ankle, knee and hip joints, represent the phase of converting the runner’s potential energy into kinetic energy.

During the braking phase, suitable pre-activation and muscle stiffness enable the runner to keep the range of dorsal flexion of the ankle, as well as knee and hip flexion, as small as possible and the braking phase as short as possible (see Figures 2 and 4).

Despite tiredness in the closing stages of the 800m race, the ranges of dorsal flexion of the ankle at 21° and knee flexion at 7° (the widest angle of knee flexion during the support phase is 30°) are relatively very small and comparable (20° and 9°) to the corresponding ranges of top female runners in the closing stages (onset of fatigue) of a 400m race.

This rather slight "give" in the ankle and knee joints points to the runner maintaining neuro-muscular potential (the ability to maintain muscle stiffness) even with the onset of tiredness. Over the running cycle the hips remain tall, which is reflected in the wide angle (165°) between the trunk and the thigh of the support leg in the braking phase.
From the magnitude of ankle plantar flexion at takeoff (80°), the high angular velocity of the foot (1374°/s⁻¹), a high angular velocity (more than 1000°/s⁻¹) and acceleration in the knee extension, a high forward swing of the recovery leg (63°), the takeoff angle of 62° (the angle between the lower leg and the ground) and the evaluation angle (7°), we can draw the conclusion that this runner’s takeoff action is very efficient and explosive (see Figures 3 and 4). The values are comparable with the parameters of Cathy Freeman’s sprinting and with the results of a group of elite middle distance runners.²,8

The movement of the swing leg significantly contributes to a runner’s efficiency. The swing leg (thigh, lower leg and foot) is the only segment which in the braking phase of the running stride produces the propulsive force acting in the direction of running.²,12 Efficient running stride is determined both by the
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The speed of the swing leg foot during the braking phase is determined by an explosive takeoff and the runner’s relaxation, which contribute to a greater range of knee flexion of the swing leg. This enables the foot to move at high speed as close to the thigh (but-tocks) as possible. A shorter lever enhances the swing leg velocity and transition from follow-through to forward swing.

At footstrike, the horizontal velocity of the swing foot was 11.90m/s⁻¹ and during forward swing it reached its peak with 14.25m/s⁻¹ (see Figure 5). These values are comparable with foot velocities in longer sprint events (200m run)
and 400m) – particularly in conditions of fatigue. In the 200m, Cathy Freeman’s recovery leg foot velocity at footstrike of the opposite leg was 13.80 m/s\(^{-1}\) while in the forward swing phase it was 14.72 m/s\(^{-1}\). The best Slovene sprinters (100m) recorded 13.03 m/s\(^{-1}\) and 16.30 m/s\(^{-1}\) respectively.\(^2\),\(^3\)

The efficiency of Ceplak’s follow-through is reflected in the high position of her foot and a very narrow angle in the flexed knee (148°) of the swing leg in the midsupport (see Figure 1 and Table 1).

An important parameter of running economy is vertical displacement of the body’s CM. The apex of the trajectory of the body’s CM depends mainly on the takeoff angle (the narrower the better) and the relationship between the vertical and horizontal velocities.
of the CM at push-off. Ceplak’s vertical displacement of CM is 0.08m (see Fig. 6); similar to Cathy Freeman (0.08m) and a group of elite female middle distance runners (0.076m).2,12

Conclusion

Strength and power training is reflected in the technique of 800m runners. Several kinematic variables of 800m running appear to be quite similar to the parameters of longer sprint events, particularly in conditions of fatigue.

On the basis of the kinematic analysis of Jolanda Ceplak’s running, we can draw the following conclusions:

◆ Foot strike is close to the vertical of the body’s CM. This minimises horizontal velocity loss during the braking phase of the support phase.

◆ Low degree of amortization in midsupport (dorsal flexion of the foot and knee flexion in the braking phase of the support phase) indicates the runner’s ability to maintain neuro-muscular potential (maintenance of muscle stiffness) even when tired.

◆ A substantial plantar flexion range and high angular speed of ankle plantar flexion and knee extension enable the runner to produce a greater propulsive force and contribute to the increased length of her stride.
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- Amplitude and angular velocity of the swing thigh as well as the overall range of the thigh movement are greater than the ranges recorded in comparable studies. Rear swing (recovery), i.e. transfer of the takeoff leg during the flight, is also very efficient.
- Vertical displacement is optimal, which can help to enhance running economy.

References


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