Research on the Mechanics Principle of 100-Meter Running

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Abstract. Fascinated by “superpowers” all over time, people are increasingly attracted by speed, a form of superpowers, which can be seen from the “flash” in movies or “locomotive” in American TV series. Given such obsession with the pursuit of speed, this paper selects the 100-meter race that reflects the speed of human beings as the research topic. This research analyzes the most basic movement of humans, that is, running. Firstly, with humans regarded as particles, 100-meter running is divided into stages of start, acceleration, maintenance, and sprint in this paper. By analyzing the speed, acceleration, reaction time, stride length, stride frequency, and other indicators of top athletes represented by Bolt in different stages, MATLAB simulation is conducted for comparison and summary. Secondly, with humans regarded as non-particles for analysis, simulation research is implemented on the landing mode of feet, the force exertion mode of arms, and some leg muscles combined with torque. Finally, this paper carried out experiments to understand the laws of particle motion mechanics in 100-meter running as well as figure out how various stride frequencies and arm swings affect running speed, in addition to analyzing the influence of resistance on running posture. Theoretically and experimentally exploring the principles of running mechanics, this paper initiates a detailed discussion of the influencing factors and their improvement from an innovative perspective, so as to put forward suggestions for teenagers to optimize their running performance.

Keywords: Walking, Running, Stride Frequency, Arm Swing, Torque, Particle, Acceleration, Kinematics.

1. Research Background

Speed has been overwhelmed by people’s infinite reverie since ancient times. For example, Dai Zong, the teacher of the crown prince in Water Margin, can walk 400 kilometers every day; a three-legged golden crow can escape 60,000 kilometers with its rainbow-crossing magic. Such stories are all mythic with people’s reverence for speed. In the real world, some land animals also have unspeakable speeds, such as cheetahs can reach a speed of nearly 120 km/h. As for other animals, their speed far exceeds the limit of humans. With the frequent introduction of various running products by major companies in society, people can easily discover the role and significance of running to creatures. But why is there such a big difference between the top speed that humans and animals can reach? To solve this problem, we need to understand the principles of human running and refer to the fastest 100-meter race in all sports events. As a representative of human speed, Bolt from Jamaica set a world record in 9.58 seconds as shown in Figure 1-1 [1, 2], and Su Bingtian from China broke through the Asian record in 9.83 seconds.

Figure 1-1 Bolt’s 100-Meter Race  Figure 1-2 Su Bingtian’s 100-Meter Race
*Both are sourced from the network
Can the mythic 400-kilometer daily travel be realized in reality? Why is there such a huge difference in speed between people and animals? We hope to find ideas and methods to solve these problems in this study. The experiment first grasps the principle of human walking and figures out the changes in speed and acceleration in the 100-meter race. Then, the stress in the running is analyzed and taken as the experimental object to study how the stride length and stride frequency affect speed. Finally, this paper aims to improve the running performance through research and improvement.

2. In-depth Analysis of Running Mechanics

2.1 Stress Analysis of Walking

Running means that terrestrial animals use their feet to move \[3\]. It is defined as a step in motion and the feet will not touch the ground at the same time. Running can also be an aerobic or anaerobic exercise, during which each person can master the speed, distance, and route of running by himself. To better understand running, the pre-basic action of running, and walking should be analyzed from the perspective of physical stress. Walking can be roughly divided into three stages:

![Figure 2 Walking Disassembly Diagram (sourced from network)](image)

Stage 1: The muscle contraction of the left leg is similar to the spring after gaining momentum, while the muscles contracted in the knee during the stretched state are similar to the spring that begins to relax, which is accompanied by a decreasing acceleration during the relaxation. When the knee is completely straight, it is equivalent to reaching balance, but it is not completely straight during normal walking. When the left leg touches the ground, the speed is reduced to zero in a very short time. It means that there is a large acceleration at this time, which is provided by supporting and friction forces respectively. Hence, there is a forward force. The right foot is pulling up with the hip as the axis, which is equivalent to the spring gaining momentum. However, at this time, a counterclockwise moment is generated, so the upper body will provide the right force to balance this moment.

Stage 2: The upper body of the human is always providing a forward force, which aims to keep balance. After balancing the moment, it drives the upper body forward. The movement of the lower body can be regarded as the forward movement of the waist, where the center of gravity changes. Originally, the left foot is subjected to a large force, but now after the right foot touched the ground, the center of gravity shifted to the right foot. However, there is a different situation from running. Specifically, the right foot touched the ground by the heel, but this is not the most efficient way to exert force.

Stage 3: When the center of gravity is completely shifted to the right foot, the thigh muscles of the landing foot will produce a backward force, and the friction force at this time will balance the moment. In this process, people’s upper limbs will have an obvious forward movement track. After a certain movement, the non-landing foot will be ready to complete and start to accelerate downward. The process described in Stage 2 will occur and the body will be supported simultaneously. After getting a preliminary understanding of walking, according to what we have learned, we can know that changing the motion state of an object requires force, and force requires work. Thus, in the process of running and walking, what is doing work? Based on the research and speculation, friction does do work when people walk, which is the force on the surface of contact between two bodies, with its direction opposite to that of relative body motion. When people walk, there is friction between their feet and the ground, which enables us to push our bodies forward. When we take a step, a backward thrust is exerted on the ground. Friction is opposite to this thrust, so friction does negative work. Still,
friction is good for us because it provides enough reaction force to make us push forward. The work done by friction can be calculated by the following formula: \( \text{work} = \text{force} \times \text{distance} \times \cos(\theta) \). Force is the magnitude of friction, distance is the distance of the object moving, and \( \theta \) is the angle between the force and moving direction. Because the friction is opposite to the direction of movement, \( \theta \) has an angle of 180 degrees, and \( \cos(180^\circ) = -1 \). Therefore, the work done by friction is negative, that is, negative work. Although friction does negative work, it does play a vital role in enabling us to walk and overcome the resistance of the ground.

2.2 Particle Analysis of 100-Meter Running

After studying the process of walking, a preliminary study will be conducted on running. First of all, we regard people as particles to analyze the running process, which can be divided into four stages [4, 5], including start, acceleration, maintenance, and deceleration (rarely exist among the players in professional competitions). 100-meter running can be divided into the following four stages for speed and acceleration analysis. For better analysis, four groups of results for 100-meter running in the Rio Olympic Games are selected. The fastest two runners are Jamaican Bolt and American Gatling, and the other two are Chinese Su Bingtian and Xie Zhenye.

![Figure 3 Speed-Time Curve of 300-Meter Running Interval (made by MATLAB)](image)

The data comes from the official data of the Olympic Games and Figure 3 is obtained by mapping based on MATLAB. It can be seen from the above figure that in the stage of 0 to 30 meters, the acceleration is large and the speed increases rapidly, which can be regarded as stages of start and acceleration. In the stage of 30 meters to 70 meters, the speed of players is diverted. In the stage of 30 meters to 70 meters, the speed of Bolt and Gatling is slowly increasing. However, the speed of Su Bingtian and Xie Zhenye is increasing on the stage from 30 meters to 50 meters. After 50 meters, the speed has begun to slow down. After the last 80 meters, the speed of all athletes began to slow down. According to the results, the stages of start, acceleration, top speed, and deceleration are analyzed respectively.

Stage 1: Start

In this stage, the athlete starts to accelerate from the static state and increases the speed by pushing backward. At this time, the acceleration of athletes is larger and the speed gradually increases. At the start of the race, the runner will be able to tilt his body, which will reduce the space between his steps. However, it will provide enough power to enable the runner to have a strong burst. Tumbling the upper body forward can also make the legs exert more force, because the legs have to balance the torque. \( \theta \) represents the angle between the leg and the horizontal ground, and \( F \) is the resultant force when kicking. According to the formula: \( \frac{dF_1}{dt} = dF \cos \theta \), there is

\[
F_1 = \int dF \cos \theta \\
\Rightarrow a = \int \frac{dF \cos \theta}{m} dt
\]

Therefore, when the angle is smaller, the acceleration can be obtained at the start, so it can reach the uniform speed stage faster. In this stage, the athlete starts to accelerate from the static state and increases the speed by pushing backward. At this time, the acceleration of athletes is larger and the speed gradually increases.
Table 1 Reaction Time and Total Score of Men’s 100-Meter Running in Rio Olympic Games

<table>
<thead>
<tr>
<th>Name</th>
<th>Bolt</th>
<th>Gatling</th>
<th>Su Bingtian</th>
<th>Xie Zhenye</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction time (seconds)</td>
<td>0.155</td>
<td>0.152</td>
<td>0.140</td>
<td>0.134</td>
</tr>
<tr>
<td>Total score (seconds)</td>
<td>9.81</td>
<td>9.89</td>
<td>10.08</td>
<td>10.11</td>
</tr>
</tbody>
</table>

According to the above table, compared with the world’s top athletes, Chinese athletes’ 100-meter reaction time is superior, ranking in the top two. Xie Zhenye’s reaction time is 0.021 seconds faster than Bolt’s with a shorter reaction time and faster start. In the top 100-meter competition, the difference of 0.02 seconds can be about 20cm, and the visual effect is obvious. However, the final total score is 0.3 seconds behind, which shows that the final 100-meter score is not only affected by the reaction starting time, but also continues the following analysis.

Stage 2: Acceleration

In the acceleration stage, the athlete continues to increase the speed, but the acceleration gradually decreases. Athletes’ acceleration is higher, but it is no longer the top. At this stage, the athlete’s speed will increase to a top value. After reaching the top value, the resistance will be offset by the forward force provided by himself. This stage is usually concentrated within 0 to 30 meters. As can be seen from Figure 3, within 30 meters, Chinese players Su Bingtian and Xie Zhenye have faster acceleration and speed than Bolt and Gatling, which takes less time. It also reflects from the side that the physique based on Asians has advantages in the first half of the 100 meters. This paper separately takes out the time they spend within 30m and every 10 meters for MATLAB mapping analysis as shown in Figure 4. Within 30 meters, Su Bingtian has obvious advantages. At 30 meters, the total time spent by Bolt, Gatling, Su Bingtian, and Xie Zhenye is 3.841s 3.778s 3.728s 3.758s respectively. Su Bingtian takes 0.083s less time than Bolt, which is a very big time difference in the 100-meter running. In the case of a obvious advantage in the first half, the reason for him lagging behind a lot in the total score will be analyzed in the next section.

Stage 3: Top Speed

From 30 meters to 70 meters, athletes keep accelerating. At the stage of accelerating to the top speed, the speed remains stable, which is the biggest moment of the watershed. It can be seen from Figure 4 that in the 40-50-meter stage, two Chinese players, Su Bingtian and Xie Zhenye, reach the top interval speed. The acceleration is negative and the speed decreases in the 50-70-meter stage. However, Bolt’s acceleration from 30 meters to 60 meters is close to the normal value, which can be regarded as uniform acceleration at this time. The top interval speed appears in the interval from 60 meters to 70 meters, reaching 12.04 meters per second. Compared with other athletes, Bolt has a longer acceleration time, a greater top speed, and more time to maintain the top speed, which explains why there is a big gap between Chinese athletes and the world’s top 100-meter athletes in the middle and late course. With a more intuitive example, in the range of 60 to 70 meters, Bolt, Gatling, Su Bingtian, and Xie Zhenye spent 0.83s, 0.85s, 0.91s, and 0.90s. Bolt is 0.08s faster than Su Bingtian with the huge gap. Considering that the top speed gap is obvious at this time, the time difference after that would be more apparent.

Stage 4: Deceleration
At the position close to the target end point, the athlete begins to slow down, that is, the speed gradually decreases. At this time, the athlete’s acceleration is negative. However, considering the different time and size of the top speed, the gap at this stage will be more obvious. This paper directly analyzes the speed comparison of Bolt, Gatling, Su Bingtian, and Xie Zhenye in the last 20 meters, with MATLAB for further image analysis. As shown in Figure 5, in the second half of 80 to 100 meters, the maximum time gap every 10 meters is between 0.06s and 0.07s. In other words, every 10 meters, Bolt will be 0.6 to 0.8 meters faster than Su Bingtian with a huge gap.

![Figure 5](image)

**Figure 5** 100-Meter Running Interval-Time Curve (made by MATLAB)

### 2.3 Non-Particle Force Analysis of 100-Meter Running

Since the last section discusses the speed and acceleration analysis of the 100-meter running divided into four stages, analysis in this section regards people as particles, only considering the changes of velocity and acceleration regardless of other influencing factors, such as step frequency, stride length, and body posture [6]. The following is the physical stress analysis with the human body as a non-particle:

The running process of people can be represented in Figure 6:

![Figure 6](image)

**Figure 6** Subdivision Schematic Diagram of Running Movements of People

**Stage 1:** The foot landing stage is equivalent to a gaining stage, which converts gravitational potential energy into elastic potential energy. Its disadvantage is that the athletes in this stage do not provide power during running with the resistance of landing on the front foot only. Therefore, this stage will greatly weaken the runner’s energy and speed. Gravity: the downward action of the human body’s own weight. Impact force: The human body exerts an impact force on the ground, and the ground acts on a reaction force upward. Reverse force: The muscles contract in reverse, driving the toes to lift backward. When the foot touches the ground, it first receives the ground reaction force, which counteracts the gravity force and forms a rebound force, bouncing upward. Meanwhile, the tibia and metatarsal bones are subjected to constant stress. The stress on the tibia is related to stride spacing and supporting time, while the stress on the metatarsal is related to body verticality and force passing through the plantar. At this time, the calf muscles need to exert strong control to keep the body balance.

**Stage 2:** Support stage. Gravity: the downward action of the human body’s own weight. Reverse force: muscle contraction, supporting the body and preventing falling. Rotating force: The soles of the feet push force to the back, moving the body forward. Then, the body will absorb the energy of landing through posture adjustment and muscle contraction. The muscles will convert the energy
generated by a rebound into the energy for the next step. In the energy absorption, the knees will bend. Meanwhile, the muscles of the thighs, patella, ankles, and feet will be affected by stress changes.

Stage 3: Swing arm stage. Inertial force: the upper body swings forward with inertial force. Torsion force: After the upper body is far away, the body twists forward through the hips and steps down to prepare. When the body absorbs enough energy, it begins to move forward. The legs are flushed, and the body is pushed forward with concentrated strength. At this time, it will be affected by the ground reaction force and gravity force. People lean forward to help hip and waist muscles exert strength and push the body forward.

Stage 4: Suspension stage. Gravity: the downward action of the human body’s own weight. Resistance: The upper body inertia moves to the right, and the waist shifts the center of gravity and drives the thighs to lift, forming resistance. Elasticity: After the soles of your feet touch the ground, your body bounces naturally. When the body’s center of gravity moves to the front of the foot, it easily leaves the ground and enters the flight stage. At this stage, the weight of the body and the energy stored during squatting are converted into upward kinetic energy, which is necessary to maintain correct posture and balance. At this time, the force on muscles disappears, and only gravity is affected except air resistance.

In the process of running, torque will also have a great impact on running.

The torque formula used in running is usually to describe the torque at joints to understand the role of muscles and joints in exercise. The moment formula in human body mechanics is used to describe the torque or moment applied to joints in motion, especially in running, which can help us understand the force applied to muscles and joints. The following is a detailed explanation of the moment formula:

\[ \tau = r \times F \times \sin(\theta) \]  

1. Torque (\(\tau\)): Torque is a vector that represents the rotational force around the joint. In running, for example, the knee joint or hip joint may be affected by torque, depending on the athlete’s posture and movements. The unit of Torque is usually Newton·meter (Nꞏm).

2. Lever arm length (r): It is the distance from the joint to the application of force, usually in meters (m). In running, the lever arm length of joints may vary according to the athlete’s posture. For example, when you take a step, the lever arm length of your thigh hip joint will change with the position of your leg.

3. Force (F): This is the force acting on the joint, usually in Newtons (N). In running, this force can be caused by muscle contraction or external force. For example, when you take a step, your thigh muscles may exert force to support your weight.

4. Angle (\(\theta\)): It is the angle between the direction of the moment and that of the lever arm in radians. The included angle determines the direction and magnitude of the torque. In running, the included angle can change according to the joint trajectory and force direction.

Torques can be roughly divided into three types. Gravitational torque: the torque produced by gravity will affect the runner’s body balance. It is equal to the vertical distance from the point of gravity to the center of rotation of the body (such as the point of feet contact) multiplied by the magnitude of gravity. If the gravitational torque is balanced with other torques generated by the support points, the runner can maintain the balance of the body.

Muscle torque: During running, the torque generated by muscles plays an important role in the balance and movement of the body. Through the contraction and extension of muscles, the generated torque can promote the movement of the body and maintain the balance of the body. The swing arm can be listed as a kind of muscle torque. The function of the swing arm is as follows: 1. Keep balance: the interaction of forces. When running, the legs are moving forward, the body will twist under the action of force. However, to offset this force to maintain balance, the arms can keep our body balanced. 2. Helping body forward: The arm is to offset the traction force of the legs forward, while the other part is to push the center of gravity of the upper body forward, which plays a boosting role. Arms also stimulate the waist and hips, usually pushing the feet forward when going uphill.

Contact torque: When the runner’s foot comes into contact with the ground, the ground creates a torque by the contact force exerted on the foot. The horizontal distance between this torque and the
supporting point is multiplied by the contact force. Contact torque can affect a runner’s body balance and movement.

There is a close relationship between running and biomechanics. Biomechanics is a scientific field that studies the interaction between biological movement and mechanical principles [7-9]. In running, biomechanics can be used to analyze and optimize all aspects of human movement, including posture, stride length, stride frequency, strength transmission, and so on [10]. Biomechanics can help runners determine the most effective stride length and frequency to improve running efficiency. By analyzing the movement of the musculoskeletal system, we can find the best combination of stride length and stride frequency to reduce energy consumption and improve speed. In running, the body needs to transfer strength to the ground effectively to push the body forward. Biomechanics can study how muscles and joints work together to produce maximum propulsion. To better express the non-particle force analysis intuitively, bodyrun is used to simulate quantitative analysis in the next chapter.

3. Non-Particle Mechanical Simulation of Running

To express the non-particle force analysis intuitively, the quantitative analysis of bodyrun simulation is conducted in this chapter. Introduction of simulation experiment tool, bodyrun: It is a movement simulation software with body mechanics and biomechanics in one.

In the simulation experiment, this paper uses the control variable method, and the study objects include changing the landing mode, stride length, running speed, height, and weight of running. The feedback data includes peak ground reaction force, which shows the peak value of the force that the model must absorb every time it comes into contact with the ground. It is expressed in units of body weight. Because the horizontal component of the force provides the driving force for running forward, this data can reflect the situation of maintaining speed and the size of the body’s consumption force. Metabolism: This parameter shows the energy required to maintain the running mode shown continuously, and the unit is kilocalories required per kilogram of body weight per kilometer. Through these data, this paper can better study how different technical movements influence the energy consumption of the body.

3.1 Simulation of Landing Mode of 100-Meter Running

The 100-meter dash is a very short distance event with specific requirements for landing methods to pursue the fastest speed. The usual running landing methods are heel landing, back sole landing, and front sole landing. Next, a specific simulation will be carried out.

Parameter setting of control variable method:

Invariants: The height is set to be close to the height of high school students by 1.75m, the weight is set to 65kg, the speed is 5.5m/s, and the stride length is set to be the middle proportion of height.

Variables: Control the landing mode for heel landing, back foot landing, and forefoot landing respectively to conduct a simulation experiment.
Heel landing means that the runner’s heel touches the ground first, and then the foot rolls forward to the forefoot. Heel landing causes greater impact to be transmitted to the ankles, knees, and hips, because most body weight is suddenly concentrated on the heel. In this way, thigh muscles, knee joints, and hip joints bear a greater burden, while calf muscles are less involved. Heel landing is usually not recommended for 100-meter short-distance races, because it will cause great impact and slow down.

Hindfoot landing means that the runner’s heel touches the ground first, and then the body rolls forward to the forefoot. Heeling causes a large impact to be transmitted to the ankles, knees, and hips, because a body part is quickly affected by vertical impact. When the hindfoot touches the ground, the thigh muscles, knee joints, and hip joints bear a greater load, while the calf muscles are used less. Hindfoot landing helps long-distance runners keep comfort for a long time, but may increase the risk of ankle and knee injury. This method is suitable for medium and long-distance races, such as 800 meters and 1500 meters.
Through different landings, it can be seen that the ground reaction force produced by forefoot landing is greater. Meanwhile, the consumption of ability is also greater. Forefoot landing means that runners mainly use their toes and forefoot to land, bearing most of their body weight. In this way, the forefoot area will bear more vertical impact force, because gravity acts on the forefoot part, not the whole foot. When the forefoot touches the ground, the calf and ankle muscles will bear a greater burden, and the knee joint flexes less, which can improve the reaction speed and acceleration. However, the ankle and calf muscles have higher requirements, which may increase the risk of injury. This is suitable for short-distance races such as 100-meter races. Therefore, considering the exertion mode, top athletes usually use the forefoot landing mode. As for middle school students, they should decide the running mode according to their physical strength and explosive force.

### 3.2 Simulation of 100-Meter Running Step Length

In the 100-meter dash, step length and step frequency are often mutually restricted, which makes it difficult to achieve high step frequency under the big step length. In this section, the step length is analyzed. One step is defined as landing from toe to heel, for example, from the right foot leaving the ground to touching the ground again. Short step length and long step length refer to a 10% change in average step length.

Parameter setting of control variable method:

- **Invariants:** The height is set to be close to the height of high school students by 1.75m, the weight is set to 65kg, the speed is 5.5 m/s, and the stride length is set to be the middle proportion of height.
- **Variables:** Running with short step length, average step length, and long step length respectively.

![Figure 10 Schematic Diagram of Simulation Results of Short Step Length, Average Step Length, and Long Step Length](image)

![Figure 11 Schematic Diagram of Simulation Results of Peak Ground Reaction Force with Short Step Length, Average Step Length, and Long Step Length](image)
According to Figures 10 to 11, the larger the step length in sprint, the greater the peak ground reaction force and the resulting speed, and the less energy consumption per unit volume. In the selection of step length and frequency, we can try to increase the step size as much as possible without greatly affecting the frequency, but save energy consumption. Bolt is 1.96m tall and strides an astonishing 2.44m, while Su Bingtian is 1.72m tall and strides 2.04m. If Su Bingtian wants to keep the same speed as Bolt, the frequency must be higher than 20%, which puts forward higher requirements for athletes with short heights and small strides.

3.3 Non-Particle MATLAB Simulation of 100-Meter Running

For further quantitative analysis, MATLAB is used to simulate the non-particle mechanics of middle school students. We assume that the runner’s mass is 70kg, the gravity acceleration is 9.8m/s², the static friction coefficient is 0.7, the dynamic friction coefficient is 0.6, and the contact area between feet and the ground is 0.05 square meters. Through cyclic calculation, contact force, static friction force, and dynamic friction force are calculated in each time step. Meanwhile, this paper visually simulates the gravity moment introduced in the previous section. MATLAB code is in the appendix.
4. Experimental Verification of 100-Meter Running

4.1 Particle Mechanics Analysis of 100-Meter Complete Running

Experimental process: Before running, a 100-meter field is selected with the mark every 10m for 100-meter running. This experiment is recorded by a camera. After running, the video is imported into video editing software to play it frame by frame. The time mark and speed are calculated by marking points to finally analyze the data visualization by MATLAB.

Figure 14 Schematic Diagram of Simulation Results of Running Center of Gravity Torque

Figure 15 Schematic Diagram of 100-Meter Running

Figure 16 Schematic Diagram of Velocity Displacement
It can be seen from the figure that the author reached the top speed in the first 30 meters while running. However, through the analysis of the second chapter of this paper, the range of the top speed of the usual high-level athletes is 60 to 70m, which shows that the author can’t maintain the speed well after passing the acceleration stage early, and the speed drops seriously. Especially at 90m, the top speed has dropped by nearly half of the top speed surprisingly. Thus, to improve the performance, how to stabilize the speed maintenance stage after the acceleration stage is very important. The author’s explosive force problem in the first 30 meters is relatively small, but that is not the case in the middle half of the running and speed maintenance stage from 30m to 60 meters.

At the same time, in the process of running, it is also found that the movements during running will have a great impact on the feeling of running. For example, if the autogenous center of gravity is placed too low, it will lead to insufficient space in the legs, and the legs are not fully extended during each step. Although there is a large force to burst, the force provided by the runner at each step is unstable, and it is easy to stagger and deviate. The reason for this situation is that when the leg is not completely straight, it comes into contact with the ground, resulting in a contact moment. Meanwhile, it makes the lower body have a torque facing the positive direction to push the human body forward. Because the leg is not completely straight, the leg cannot move forward in time. That is, the body is resisting the contact torque generated above and cannot balance it.

In addition, according to the online data, it is concluded that the landing place of professional athletes is directly below the body, which can save the time required for the four stages of running above. Similarly, the experiment found that running with the top speed has greater advantages. Assuming that the player wants to finish the race within 10 seconds, if his top speed can reach 12m/s, he only needs to have an acceleration of 2.5 m/s² per second, that is, the acceleration that a normal student has in the first 30m. Therefore, if you want to improve the 100-meter running, you should improve your endurance and top speed, instead of the top acceleration at the beginning of the race.

4.2 Non-Particle Mechanical Analysis of 100-Meter Segmented Running

Experimental process: Before the start of running, a 20-meter field is selected with the mark every 2m. The author runs at a distance of 20m with a small stride, normal stride, and large stride respectively. Then, record it by camera. After running, the video is imported into video editing software to play it frame by frame. The time is marked and the speed is calculated by marking points. Finally, the data is visualized and analyzed by MATLAB.
According to Figures 15 and 16, in the first 4 meters during the running, the short stride has greater acceleration and faster running speed, while in the range of 4 to 20m, the medium stride runs faster instead. The simulation in this experiment is not exactly the same. Here this paper considers that too much running leads to too slow running frequency, which lowers the final speed.

By analyzing the experimental data, in comparison, trot frequency can get a greater acceleration at the beginning of running. However, the top speed can be less than the normal stride, which just supports the above conclusion. As for large strides, the initial acceleration is relatively small, but it is still impossible to reach a larger speed. The reason for this phenomenon is that when running, more force is used to lift the legs, which makes the lower body generate torque. However, the swing arm is not enough to balance this torque at this time, so the runner’s center of gravity will be lowered, resulting in the inability to continue accelerating.

5. Conclusion and Prospect

It is one of the common activities for middle school students to take part in the 100-meter dash in physical education courses, which not only helps students exercise their physical fitness, but also cultivates their competitive spirit. The following is a conclusion and suggestions about the 100-meter running of middle school students:

1. Physical exercise: 100-meter running is a short-distance race, which requires explosive power and speed. In the process of 100-meter running, movement will have a noticeable impact on speed and the most important two stages are the footing and supporting stages. Compared with professional 100-meter runners, ordinary runners will waste a long time in these two stages, and the peak value of force provided by the supporting stage is obviously less than that of professional runners. For professional athletes, whether can burst into greater force in the shorter touchdown event or generate greater impulse in the shorter time has become one of the important factors for getting a good place in the competition. (Reference to pre-landing). Hence, it is an essential training to exercise the explosive force of leg muscles. Participating in this sport helps middle school students exercise
muscle strength, endurance, and explosive power. Middle school students can improve their starting speed through explosive force training, such as squatting, jumping, and pushing backwards.

2. Technical requirements: Although 100 meters is a short distance, technology is still very crucial. Students need to pay attention to the correct starting posture, pace, arm swing, and landing mode to maximize speed. Students should learn the correct starting posture, acceleration skills, and finish line process. Professional guidance can help them improve their skills.

3. The top speed has advantages over the top acceleration. In the first 30 meters of running, a higher step frequency can produce greater acceleration, but it will consume great energy, which leads to the failure to maintain it well in the middle and later stages of running. In contrast, a larger stride in the running can make the runner reach a relatively larger top speed, which can gain a great advantage in the middle and late stages without consuming too much energy. This method is conducive to maintaining the speed.

4. Through investigation and research, it is found that foreign runners run faster. Domestic runners have a great advantage in the first 40 meters. The reason is that domestic runners have a bigger outbreak at the beginning of the competition, and the larger acceleration enables runners to reach their top speed quickly. However, compared with foreign runners, foreign runners accelerate longer and reach their top speed later than domestic runners, and the same top speed is also greater. After that, in the maintenance of the middle and late course speed, the basic track speed does not decrease. However, as for domestic players, the speed in the second half has obvious fluctuations. For foreign players, they have a great advantage in the 70-80m stage.

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