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Analysis for Training Factor on Chinese Women's Walker Break the 20km Race Walking World Record

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Abstract:

This research analyzed the technical and tactical characteristics of two elite race walkers from China, Yang Jiayu and Liu Hong, using methods of competition testing and experts interviewing. In this way, we summarized the reasons why they set the world record. Race walking is a "compound type of mobile pendulum movement" which synchronizes "near fixed positive pendulum motion" and "far fixed inverted pendulum motion" with single support and periodic motion. For these two athletes, speed in the first 10km was faster than the second 10km. Both increased the minimum speed and lowered the maximum speed to reduce the fluctuation of the game speed, thereby improving the stability of their competition state. Both increased their stride length, and the left stride length was longer than the right. When walking at low speed, the differences between left and right were larger. The average stride frequency of Yang Jiayu and Liu Hong was lower than that of world record. Yang Jiayu's highest and lowest stride frequency were both lower than the world record and kept relatively stable. Liu Hong's highest stride frequency was equivalent to the world record but the lowest stride frequency was lower. Both Yang Jiayu and Liu Hong's flight time were at the lower limit of the penalty standard range. Both had a certain possibility of improvement in body movement posture. In the arrangement of training load from 2016 to 2021, it showed the variation characteristics of "limiting higher intensity, controlling lower intensity, and increasing effective intensity".

***Keywords**: Race walking, Women, World record performance.*

I. INTRODUCTION

Chinese women's race walking is an event that has an ability to compete for gold medals in the Olympic Games in track and field sports. Two elite athletes of race walking, Yang Jiayu and Liu Hong, broke their own world records in selection competition for Tokyo Olympics with 1hour23min49s and 1hour24min27s respectively, on March 20, 2021. Their outstanding performance demonstrated that Chinese women’s 20km race walking event has a leading position in the world. Therefore, we believe that

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analyzing technological breakthroughs from the perspective of kinematics for Yang Jiayu and Liu Hong will bring important practical value[1].

II. MATERIALS AND METHODS

2.1 Materials

The objects of the research were two outstanding women athletes' race walking technique of from 20km race walking selection competition for Tokyo Olympics in 2021. These two athletes were Liu Hong and Yang Jiayu form China (Table 1).

TABLE I Basic Information of Liu Hong and Yang Jiayu

Name	Nation	Date of birth	Height (cm)	Weight (kg)	Results	Personal best results
Yang Jiayu	China	1996/02/18	162	45	1:23:49	1:23:49
Liu Hong	China	1987/05/12	161	46	1:24:27	1:24:27

2.2 Methods

2.2.1 Measurement method

2.2.1.1 Video shooting method

Using three-dimensional fixed-point positioning video method, the technology of women's 20km competition was obtained in Huang shan City, Anhui Province, 7:30-9:30 am on March 21, 2021. The competition venue was 1 km per lap. Two CASIO-FH25 cameras were used. The scope of the video was about 4x6m, centered on the area where the race walkers passed. Before and after the competition, during the 14th lap, the Peak three-dimensional calibration frame was used to make the space coordinate system. The height of the camera was 1.10m, the shooting frequency was 120 fields/s, and the shutter speed was 1/1000s. The vertical distance between the camera and the route in the forward direction of the athlete's movement was approximately 14.5m. The angle between the main optical axes of the two cameras was about 100°.

2.1.1.2 Film analysis

Using the APAS three-dimensional motion technology analysis system developed by the American ARIAL company, according to the Japanese Matsui Hide ji's human inertia parameter model, 20 joint points were selected to digitally process the athlete's race walking technology video. Low-pass filtering was used to smooth of the data. In the data smoothing process, the smoothing coefficient was selected according to the data change trend of the key technical links, and the smoothing coefficient was 7. Finally,

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the original kinematics data of the parameters needed for the research were obtained[1,2,3].

2.2.2 Expert interview

During preparations for the Tokyo Olympics competition, we monitored Yang Jiayu and Liu Hong's race walking techniques for a long time. At the same time, we also communicated with many coaches from national team, such as Zhang Fuxin, Sun Li'an etc., on the issue of race walking technique. After selection competition for Tokyo Olympics in 2021, a summary meeting was also held. All experts discussed and reached consensus. Through these methods, the objectivity, reliability, and authenticity of the results can be improved. Finally, we revealed the factors for their breakthroughs.

III. RESULT

3.1 Tactical analysis

3.3.1 Time analysis for the first and second half of the competition

Dividing the 20km into two parts, the first 10km and the second 10km, and then analyzing the time spent in the race. As far as the original world record was concerned, the time spent for the first 10km and the second 10km were 42min39s, and 41min59s. The latter was 40s less than the former. Overall, it showed that the speed for the first 10km was slower than the second. The time spent in the first 10km and the second 10km for Yang Jiayu was 41min52s and 41min52s. The latter was 5s more than the former. Also, for Liu Hong the time spent in the first 10km and the second 10km was 42min1s and 42min26s. The latter was 25s more than the former. Overall, both showed that the speed for the first 10km was slower than the second. For long-distance endurance sports, it is a reasonable rhythm strategy that the speed in the second half is faster than the first half. From the point of view of this competition, both had a problem that the speed in the first half was faster than the speed in the second half. This also shows that they still have the possibility of improving their sports performance.

3.3.2 Analysis for the highest and lowest speed of the competition

The highest and lowest speed of the original world record was 4min5s/km and 4min21s/km. Overall, the average speed was 4min14s/km, and the rate of change for the speed was 6.3%. The highest speed for Yang Jiayu was 4min8s/km, which was 3s/km slower than the original world record. The lowest speed was 4min13s/km, which was 8s/km faster than the original world record. She narrowed this numerical gap from the original world record of 16s/km to 7s/km by increasing the minimum speed and lowering the maximum speed. Moreover, her average speed was 4min11s/km, and her speed change rate had shrunk from the original world record of 2% to the current 4.3%. The highest speed for Liu Hong was 4min10s/km, which was 5s/km slower than the original world record. The lowest speed was 4min20s/km, which was 1s/km faster than the original world record. The average speed was 4min13s/km and the change rate of speed was 3.9%. In selection competition for Tokyo Olympics in 2021, Yang Jiayu and Liu Hong had a lower maximum speed and a higher minimum speed compared to the original world record results. In a word, the speed was relatively smooth throughout the competition.

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3.2 Application Research on Biomechanical Theory of Technique"Compound Clock Pendulum" Employed in Race Walking

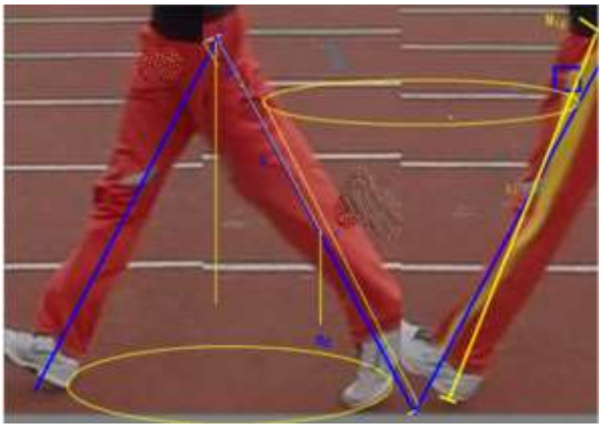

Fig 1: The principle of the "compound pendulum" of the human body in race walking

Note: Mg is the weight of the center of mass of the lower limbs, h is the radius of the center of mass of the lower limbs, M1g is the weight of the center of mass of the body, and h1 is the radius of the center of gravity of the body.

Principle of pendulum movement means that a pendulum completes oscillating motion with a central point fulcrum regularly and repeatedly within a certain range. "Pendulum effect" means that when the initial position of the pendulum is higher, the position it can reached after swinging through the lowest point is higher. On the contrary, the position is lower. Moreover, the larger the swing radius during the swing of the pendulum, the faster the speed formed when swinging. The principles followed are the principles of mechanical energy, that is, kinetic energy and potential energy are transforming each other. Race walking is a "compound type of mobile pendulum movement". Because we can infer from the definition of race walking technique from World Athletics Federation. During race walking, when the supporting foot hits the ground, the hip joint of the supporting leg is the pivot point, and the distance between the center of mass of the swing leg and the pivot point is the radius. These formed a "near-fixed positive-moving pendulum movement". Simultaneously, the supporting foot on the ground is the pivot point, and the distance from the center of gravity to the fulcrum of the body is the radius. These formed a "distant-fixed inverted-moving pendulum movement". As a result, "near-fixed positive-moving pendulum movement" and "distant-fixed inverted-moving pendulum movement" organically combined to form a compound pendulum movement (Figure 1).

The economics and normative of race walking technology depend on the translational effect of these two pendulum movements. First, according to the clock Pendulum Differential Equation (Equation 1) and the relationship between the swing period and the swing radius (Figure 2), the swing period T of an object

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has nothing to do with the mass M of the pendulum body, but is related to the distribution of mass (M), which means that the period T is related to the swing radius(h). The relationship between the swing period (T^2) and the radius of the center of mass of the swing body (h) is that when the radius of the center of mass of the swing body (h) tends to 0, the swing period (T) tends to ∞ and the larger the radius, the shorter the period. However, when the radius is negative, the shorter the radius of the center of mass of the swing body, the shorter the swing period. Second, from the perspective of muscle mechanics, when the hip is relaxed during the swinging leg, it is conducive to forming a reasonable pendulum movement. Third, from the perspective of the law of conservation of momentum, when the supporting leg hits the ground, a huge impact inertia is generated instantly when the supporting leg hits the ground. When the swinging leg is too tight, it will limit the free swing of the swinging leg (Figure 2b) and reduce the swing speed. At this time, the hip will transmit the inertia of motion to the supporting joint through a solid form, which will lead to injuries to the hip, knee, and ankle joints. Fourth, from the perspective of human anatomy, during race walking, a swing with supporting hip as the pivot point and swing leg as the radius is formed (Figure 2a). Only if swinging leg relaxed sufficiently when support leg hitted the ground, the center of mass of the swinging leg will move down, and the swing radius will be enlarged. In turn, the extension of the swing radius (h) will shorten the period of the "positive pendulum" swing and increase the swing speed of the lower limbs (Figure 1, 2). Finally, from the perspective of the movement principle of the "inverted pendulum", during swinging, if the swinging leg is sufficiently relaxed, the center of mass of swinging leg will be dropped, and the center of gravity of the athlete's body will also be dropped, which will cause the radius of the "inverted pendulum" to shorten (h1) and then the swing cycle will be shorten (Figure 3). Therefore, a reasonable completion of the "compound pendulum movement" can increase the stride length and the stride frequency. This can not only improve the standardization of race walking technology, but also improve the effectiveness of the technology. In the end, it will change the traditional technical style of "small stride size and fast frequency".

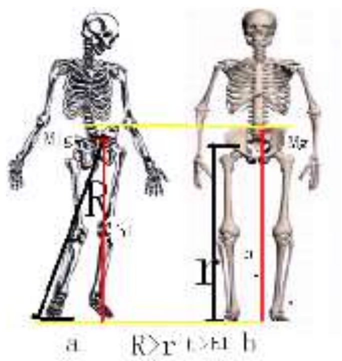

Fig.2 Swing Radius Correlation

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Clock Pendulum Differential Equation (1):

$$\frac{T^2}{4\pi^2} = \frac{Jc}{Mgh} + \frac{h}{g}$$

Note: T swing period, Jc swing inertia, h swing radius M weight

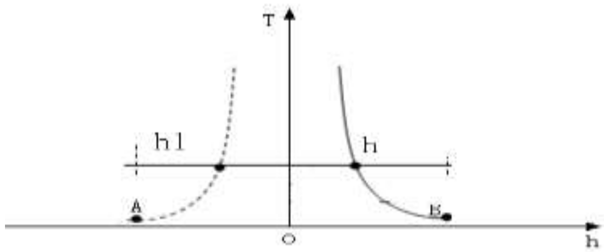

Fig.3 The relationship between the swing period T and the distance h from the center of the pendulum axis

In summary, the level of relaxation of the hip and lower limb muscles is the core reason that affects the application effect of the "compound pendulum" principle. According to the anatomy of the human body, the hip joint is a "pivot" joint surrounded by muscles (Fig.2). In summary, the level of relaxation of the hip and lower limb muscles is the core reason that affects the application effect of the "compound pendulum" principle. According to the anatomy of the human body, the hip joint is a "pivot" joint surrounded by muscles (Figure 2). The relaxation of the muscles around the hip is very important. After the kicking action of the lower limbs is completed, only when the swinging leg muscles are sufficiently relaxed, the hips can perform three-dimensional movements well in the sagittal plane, forehead plane, and horizontal plane. When the hip of the swinging leg is relaxed (Fig.2a), the height of the body's center of gravity will decrease (h>h1). In addition, the increase in the swing radius of the lower limbs (R>r) can not only improve the stability of the center of gravity, reduce the height of the up and down fluctuations of the center of gravity, but also increase the stride length, making race walking more in line with the definition of race walking technology[4,5].

Athletes with a higher level of exercise have a fast follow-up speed of the hips in the back swing phase and strong acceleration in the forward swing phase, which causes the swing speed of the hip in the back swing phase to be greater than that in the forward swing phase. During the support of the lower limbs, the efficiency of maintaining the speed of the hip is high, which is beneficial to increase the angle of the thighs when the supporting leg is off the ground, reduce the height of the body's center of gravity, increase the range of motion and the stride length. Ultimately, the standardization of race walking technology was improved. Through the above analysis, we can also summarize some key points of technical training. For supporting leg, it is necessary to support the ground, but also to fully extend and kick out. For swinging leg. Supporting leg: It is necessary to support the ground, but also to fully extend and kick out. The swinging leg needs to be relaxed enough so that the body's center of gravity can follow up effectively. The hips of the swinging legs should be sent forward. And, when the heel is ready to touch the ground, the

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ankle joint should quickly complete the dorsiflexion movement. During walking, the knee joint should be in a straight line. The waist should be upright, the shoulders should be relaxed, and the hips should complete the three-dimensional movement during the forward process. For the arm swing technique of the upper limbs, the muscles should be fully exerted when swinging back, and the muscles should be relaxed when swinging forward. In daily training, the coach should remind the athletes to keep the hips relaxed during the swing phase and speed up the follow-up speed of the center of gravity. In the support phase, it is important to emphasize the rapid follow-up of the hips, to avoid premature exertion of the lower limbs, and to achieve a reasonable sequence of muscle contractions. During the stage when the supporting leg is off the ground, it is necessary to improve the ankle dorsiflexion ability of the swinging leg, especially when the swinging leg is about to hit the ground, in order to increase the back kick distance and increase the stride length.

3.3 Analysis for technology during competition

3.3.1 Stride frequency

The highest and the lowest stride frequency were 228 stride/min and 216 stride/min respectively. Overall, the average stride frequency was 224 stride/min. The rate of change for stride frequency was 5.3%. For the athlete of Yang Jiayu, the highest and the lowest stride frequency were 228 stride/min and 216 stride/min respectively. The average stride frequency was 224 stride/min. Her highest stride frequency was 7 stride/min lower than the original world record, the highest stride frequency was 5 stride/min lower than the original world record, and both the lowest stride frequency and the highest stride frequency were lower than the original world record. For the athlete of Liu Hong, the highest and the lowest stride frequency was 228 stride/min and 211 stride/min. Overall, the average stride frequency was 218 stride/min. The rate of change for stride frequency was 6.8%. Her highest stride frequency was the same as the original world record, and the lowest stride frequency was 5 strides/min lower than the original world record. Compared with her past sports performance, the lowest stride frequency had been reduced, and the average stride frequency had dropped by 6 stride/min.

3.3.2 Stride length

For stride length of original world record, the maximum stride length and shortest stride length were 1.11m and 1.07m. The average stride length was 1.08m and the change rate of stride was 3.7%.

For athlete of Liu Hong, the maximum and the shortest stride length was 1.12m and 1.08m. Her average stride length was 1.10m, and the change rate of stride was 3.6%. Compared to the original world record results, Liu Hong's longest and shortest stride length were both 1cm longer, and the average stride length was also 2cm longer. Therefore, the improvement of stride length was the main factor for her record-breaking. Also, her average stride length of left and right were 1.11m and 1.09m. The distance gap between the two sides was 2cm. Moreover, when the speed of motion was relatively low, the distance gap between the two sides was larger and can reach 4cm[5,6].

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For athlete of Yang Jiayu, the longest and the shortest stride length were 1.14m and 1.10m. Her average stride length was 1.11m, and the change rate of stride was 3.6%. In this election competition, Yang Jiayu 's longest stride length was same as the original world record result, while her shortest stride length was 1cm longer and the average stride length was also 3cm longer. Therefore, the improvement of stride length was also the main factor for her record-breaking. Also, her average stride length of left and right were 1.12m and 1.10m. The distance gap between the two sides was 2 cm. The distance gap between the two sides was 2cm. Moreover, when the speed of motion was relatively low, the distance gap between the two sides was larger and can reached 5 cm.

3.3.3 Flight time

For air flight time, their performance was 63.7ms and the left was 66.7ms. For athlete of Yang Jiayu, her left air flight time was 0.3ms longer than the original world record results and the right was 1.1ms longer. Both were same as before and were maintained at the lower limit of the 60ms-80ms standard range even though the speed were improved. For athlete of Liu Hong, her flight time of left and right were 60ms, and 61.6ms. The left was 3.7ms shorter than the original world record, and the right leg was 5.2ms.

3.4 Analysis for load of training

TABLE II Statistics on the women's 20km training load of the 2016 and 2021

<table>
<tr><th>Speed range</th><th colspan="2">2016Year</th><th colspan="2">2021 Year</th></tr>
<tr><th>Speed</th><th>Percentage (%)</th><th>Training volume (%)</th><th>Percentage (%)</th><th>Training volume (%)</th></tr>
<tr><td>>5.20</td><td>25.43%</td><td>1220 (25.43%)</td><td>22.20%</td><td>1199 (22.20%)</td></tr>
<tr><td>5.20 - 5.10</td><td>9.68%</td><td rowspan="2">1065 (22.19%)</td><td>8.90%</td><td rowspan="2">1345 (24.9%)</td></tr>
<tr><td>5.10 - 5.00</td><td>12.51%</td><td>16%</td></tr>
<tr><td>5.00 - 4.50</td><td>24.41%</td><td rowspan="3">2104 (43.84%)</td><td>35.70%</td><td rowspan="3">2734 (50.6%)</td></tr>
<tr><td>4.50 – 4.40</td><td>13.33%</td><td>9.80%</td></tr>
<tr><td>4.40 - 4.30</td><td>6.10%</td><td>5.10%</td></tr>
<tr><td>4.30 - 4.20</td><td>4.77%</td><td rowspan="2">410 (8.54%)</td><td>1.20%</td><td rowspan="2">124 (2.3%)</td></tr>
<tr><td><4.20</td><td>3.77%</td><td>1.10%</td></tr>
<tr><td>Total Training Volume (km)</td><td>100%</td><td>4801</td><td>100%</td><td>5403</td></tr>
</table>

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For total training volume, Chinese athlete had increased by 602 kilometers from 2016 to 2021 **TABLE II**. The training volume of low-intensity accomplished below the speed of 5min20s/km was reduced relatively, but the training volume of high-intensity accomplished above the speed of 4min30s/km was improved from 8.54% to 2.3%. The range of change reached 6.24%. Training at the speed of competition can mobilize the comprehensive training of the human nervous system and the peripheral nerve-muscle system. However, this will increase the risk of physical injury. Once the athlete reaches a certain level, the high-intensity training load could be limited. And this is conducive to the rapid recovery of the body after training. In turn, this can improve the systematic of training. Generally speaking, we can see that her coach has an idea of limiting high-intensity training in recent years.

When training at a low intensity (5min20s/km) for a long time, the human body's muscle contraction ability will be relatively reduced, which will cause limbs to loosen and lead to deformation of technical movements. It may even cause certain chronic damage due to the long-term completion of low-efficiency training. But this kind of low-intensity training was reduced for Chinese athletes. Maintaining a low-speed training volume about 1,200 kilometers within a year can basically ensure that athletes can adjust their rest time enough to get the body's enthusiasm recovery.

Comparing the training volume of different intensities, it can be found that the biggest change is the training load of the specific intensity (5min/km-4min 30s/km), especially the speed of 5min/km-4min50s/km, from 24.41% to 35.70%. Training at a speed of 5 min/km-4min50s/km is not only conducive to the athletes' body to withstand a larger load of training, but also can improve their specific aerobic endurance level. Therefore, this intensity of training has a positive effect on enhancing competitive strength, improving aerobic capacity, and optimizing technology. In general, for the training of Chinese athletes, coaches have shown the idea of improving the "intermediate intensity" of training in arranging training.

Ⅳ. CONCLUSION

The technical principle of race walking is a single-supported periodic pendulum project that synchronizes "near fixed positive pendulum movement" and "far fixed inverted pendulum movement".

From a tactical point of view, Yang Jiayu and Liu Hong's speed in the first 10km was faster than the second 10km. It showed that the speed was faster in the front than the rear. However, this tactic was not conducive to make better results. Therefore, both also have a potential to improve their performance.

In this competition, Yang Jiayu and Liu Hong increased their minimum speed and lowered the maximum speed to reduce the fluctuation of the competition speed, thereby improving the stability of the competition state.

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The average stride frequency of Yang Jiayu and Liu Hong was lower than the world record. Yang Jiayu's highest and lowest stride frequency were both lower than the world record and also relatively stable. Liu Hong's highest stride frequency was equivalent to the world record but the lowest stride frequency was lower.

Both Yang Jiayu and Liu Hong's stride length increased, and the left stride length was longer than the right, and when walking at low speed, the differences between left and right were larger.

Both Yang Jiayu and Liu Hong's flight time were at the lower limit of the penalty standard range. Both have a certain possibility of improvement for body movement posture.

In the arrangement of training load from 2016 to 2021, it showed the variation characteristics of "limiting higher intensity, controlling lower intensity, and increasing effective intensity".

It is suggested that in the future competition, they should further limit the starting speed and create good conditions for the creation of a new world record.

In this study, there are still deficiencies in athletes' personalization, and the specific application conditions of payload combination need to be tested in practice. In the future, we will strengthen the research on the comparison relationship of effective training load intensity, improve the systematicness and effectiveness of training, and further improve the competitive ability of women's 20km Race Walking in China.

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