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Article

A study on the effects of different training methods on the biomechanical characteristics of sprinting in young track and field athletes

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Abstract: In order to improve the level of sprinting, we should not only rely on scientific and technological progress, but also have scientific training methods. Based on this, this paper mainly starts from the perspective of sports biomechanics, and studies the influence of two training methods of “weight loss running platform” training and flat running training on sprint biomechanical characteristics of young track and field athletes. The research results show that: The movement curves of the main joints of the lower limbs in the training of “weight loss running platform” have the same basic characteristics as that of flat running. The safety protection of “weight loss running platform” can increase the density of athletes’ high-speed training, but athletes will produce involuntary technical adaptation phenomenon in the training of “weight loss running platform”, and there are some different technical characteristics.

Keywords: athletics; sprinting; biomechanical characteristics; weight-loss running platform training; flat ground running training

1. Introduction

Athletics is the foundation of all sports, and the sprint program is the concentration of speed quality in athletics. Speed quality refers to the human body’s ability to react quickly to various stimuli and to complete the prescribed single action or pass a certain distance in the shortest possible time. Sprint training is a short distance, short time, intensity of the project, sprint training methods, the radiation effect of other competitive sports training should not be ignored. Speed quality is the basic quality of sports, is the basis of athletes’ physical quality, speed quality of the lack of or low quality of sports is the taboo, speed quality training concept, method, means is very important. To improve the speed of athletes, the main method is to improve the step length and step frequency. To improve the step frequency, we must improve the intensity and frequency of high-speed training, so that the athlete’s step frequency or muscle contraction frequency is closer to or even more than the frequency of their own flat ground running. However, regardless of the method of training, the training method of technology is consistent with the competition technology, training effect is in line with the needs of the game, are important standards to judge whether this training method is reasonable.

In the study of biomechanical characteristics of sprinting, Weyand et al. concluded that faster running speeds are determined by greater vertical ground reaction forces [1]. He collected the maximum running speeds that 33 subjects of different athletic levels could accomplish on a running platform and the net vertical ground reaction force normalized by their body weight at maximum running speed.

The results showed that there was a 1.26-fold difference in net vertical ground reaction force between 11.1 m/s and 6.2 m/s. Thelen et al. computed and analyzed hamstring lengths and kinematic data from subjects who sprinted on a running platform, and showed that hamstrings were centrifugally contracted at the end of the pendulum, but that hamstrings did not centrifugally contract during the support phase, and that hamstring strains therefore tended to occur at the end of the pendulum [2]. Morin et al. collected ground reaction forces during full acceleration running on a treadmill and time per 10 m when completing a 100-meter sprint on a real field in 12 subjects and simply defined the first 4 s of field running as the acceleration phase [3]. It was found that the mean ratio of horizontal to vertical forces for all gait cycles during treadmill acceleration running was significantly correlated ($p < 0.01$) with the field 100-meter velocity, the maximum velocity of the phase, and the distance passed in 4 s (representing the acceleration phase), while it was not correlated with the vertical force or the magnitude of the combined force. He concluded that the technique of force application during the acceleration phase (horizontal to vertical force ratio) rather than the magnitude of the combined force is a determinant of 100-meter performance, and further suggested that the direction of the force is more important for athletic performance compared to the magnitude of the ground reaction force during the support phase. The method of inverse dynamics has been widely used in the study of human movement. Relative to a large number of reverse dynamics analyses concerning walking and running movements, sprinting movements have been relatively less studied in this area because of the difficulty of data collection. Bezodis et al. summarized the roles of the three joints of the lower limb during the acceleration phase from the perspective of energy flow: the metatarsal-toe joints and the ankle joints are both plantarflexion moments during the support period, but the ankle joint generates four times as much energy as it absorbs, and the metatarsal-toe joints, on the other hand, mainly absorbed energy [4]. The knee joint was primarily an extension moment during the support period. Comparison of knee power in athletes of different levels revealed that the knee of the sprinter with the best acceleration performance produced two to four times more energy than the other two athletes. Sun et al. investigated the effect of joint moments during the transition phase of oscillatory bracing during sprinting on the risk of hamstring strain [5]. The results showed that large hip extension and knee flexion moments occurred at the beginning of the support; at the end of the swing, a similarly large knee flexion and hip extension moment was generated in the hamstrings in order to prevent the calf from continuing to accelerate forward. Because of the large knee and hip moments at the beginning of the brace and at the end of the swing, hamstrings are more likely to be strained during these two phases in the case of sprinting or high-speed exercise. Xu et al. using a Deep Neural Network (DNN) model and Layer-wise Relevance Propagation (LRP) technology to investigate the differences in running gait patterns between higher-mileage runners and low-mileage runners. It was found that the ankle and knee provide considerable information to recognize gait features, especially in the sagittal and transverse planes [6]. Xu et al. proposes a new method of metaheuristic optimization-based selection of optimal gait features, and then investigates how much contribution the selected gait features can achieve in gait pattern recognition. The new method finalized 10 optimal gait features (6 ankle-related and 4-related knee features) based on the extracted 36 gait features (85 % variable explanation) by feature extraction. The accuracy in gait pattern recognition among the optimal gait features selected by the new method (99.81% ± 0.53%) was significantly higher than that of the feature-based sorting of effect size (94.69% ± 2.68%), the sequential forward selection (95.59% ± 2.38%), and the results of previous study [7].

In recent years, thanks to advances in mechanical and electronic technology, the Over speed unweighting treadmill has appeared, which accelerates the speed of rotation of the treadmill’s tracks with the addition of a pneumatic protection belt, allowing users to train and test under a safe protection mechanism. In addition, the air pressure reduces the pressure of the athlete’s weight on the treadmill, creating external conditions that are more conducive to faster pacing [6]. It has been proven that athletes can achieve higher cadence more easily and safely with the aid of a “weight-reducing overdrive platform”. However, from the existing research data can be found, for Over speed unweighting treadmill for athletes, especially for young athletes biomechanical characteristics of the impact of the research carried out less, based on this, this paper will be its with the flat running training for this study, for different training methods for young track and field athletes sprinting biomechanical characteristics of the impact of the research carried out. The study was conducted.

2. Research objects and methods

2.1. Objects of study

The subjects of this experiment are 6 provincial athletes from a sports technology school, all of whom have no major injury history. The specific conditions of the subjects are shown in **Table 1** below.

Table 1. Information on the study population.

Participant	Gender	Age	Height/cm	Weight/kg	Training years	Sprint event	Best performance
A	male	18	175	68	3	100 m	10.8 s
B	male	20	177	71	2	100 m	10.52 s
C	male	19	180	72	2.5	100 m	10.34 s
D	male	18	179	70	4	200 m	21.82 s
E	male	20	181	75	3	100 m	10.25 s
F	male	21	176	73	5	200 m	21.53 s

2.2. Research methods

Two training methods, the highest speed flat running training and the weight reduction running platform training, which is as close as possible to the frequency of flat running, were used for technical comparison. The technical videos of the two training methods were obtained by high-speed digital camera, and the kinematic parameters were obtained by using APAS analysis software, and the kinematic parameters were compared and analyzed by classification and comparison methods and statistical methods.

(1) Running track speed setting

In this study, the speed setting of the weight-loss treadmill training, which was used for the technical comparison with the flat running training, was 26 MPH. Since the treadmill speed setting did not coincide with the actual track rotation speed, the setting of 26 MPH did not mean that the track rotation speed reached the speed equivalent to 11.62 m/s, which was measured by the tachometer to be 9.78 m/s, and the expressions of the weight-loss treadmill training in the following sections refer to running training under the actual speed of 26 MPH [7]. All references to weight reduction bench training below refer to bench training at this actual speed, and this setting speed is hereafter referred to as the test speed.

(2) Test requirements

Maximum speed training for flat running: the athlete is required to run at the maximum speed to the best of his/her ability after warming up in full preparatory activities [8].

Test speed training on the weight-loss running platform: after the tension of the weight-loss pneumatic pump is adjusted to a suitable level for the subject, the athlete is required to enter the running platform at a speed of about 6.7 m/s, accelerate to the test speed and maintain it for 3 s under the premise of a full warm-up and the protection of a weight-loss shoulder harness.

(3) High-speed shooting and analysis

NAC high-speed digital video recorder made in Japan was used to shoot the two training methods of the subjects, and the analysis software was analyzed by APASXP software made by Ariel Company in the United States.

Technical shooting of weight loss running platform training: NAC high-speed digital camera was used for calibration and shooting, the shooting frequency was 250 frames/second, the shooting method was plane fixed point shooting, the shooting distance was 11 m, the camera height was 1.3 m, the main optical axis was located at the waist of the subject during movement, and the fixed length benchmark was used for calibration. Take a technical video after the subject accelerates to the test speed, requiring the subject to hold for 3 to 5 s after reaching the speed. When collecting, only two action cycles in the second half of the 3 to 5 s high-speed video are collected.

For the technical shooting of flat running training, NAC high-speed video recorder was used to calibrate at the position of 50 m on the ordinary 100-meter track and shoot the technical video when the subject ran to the position. The shooting distance was 35 m, the camera height was 1.1 m, the main optical axis height was located at the waist of the subject, and the 3.5-meter fixed length benchmark was used to calibrate. The shooting method is plane fixed point shooting, and the shooting frequency is 250 frames/SEC. During the collection, only one movement cycle of the subject passing through the motion technology within the shooting range of the lens is collected. The American APASXP system was used to analyze the two different training methods. In order to minimize the manual random errors in the digital process of video analysis, the automatic digital function of the APAS system was adopted in the test. Therefore, reflective stickers must be affixed to the test joints of the subjects before the test. Then the software is used to realize the automatic identification of joint position through the method of color difference resolution. The plane coordinate data synthesized after automatic digitization is digitally smoothed by digital filtering, and the truncation frequency is 10.

(4) Parameter Selection

The images of two kinds of sports techniques, flat running training and weight reduction running platform training on the runway, were processed through a series of procedures, such as image acquisition, interception, calibration, automatic digitization, coordinate conversion according to smoothing, etc., to obtain the two-dimensional planar coordinate data of the joint positions at each moment, and the analysis was conducted using five joints to describe the changes in the techniques of the subjects, which were: the left toe point, the left ankle point, the left knee point, the left hip point, and the seventh cervical vertebrae point, and the continuous changes of these five points were used to design the various kinematic parameters needed for this study [9]. These five points are: left toe point, left ankle point, left knee point, left hip point, and seventh cervical vertebrae point, and the successive variations of these five points were used to design the various kinematic parameters needed for this study.

(5) Statistical methods

The present study used the method of categorical comparison to compare and statistically analyze the kinematic indexes under the two training methods [10]. After obtaining the kinematic technical parameters of the two training modes for all subjects, the data of the two groups were analyzed by using SPSS statistical software for paired samples *t*-test to test the significance of the differences between the corresponding parameters of the two training modes, and the *p*-values are listed at the bottom of each table.

$$t = \frac{x - x\_cap}{se} \tag{1}$$

In the formula, *x_cap* is the sample mean, *se* is the standard error of the sample mean, *sd* is the sample standard deviation and *n* is the sample size.

$$se = \frac{sd}{n - 1} \tag{2}$$

$$f(t) = \frac{\Gamma[(v + 1)/2]}{\sqrt{v\pi\Gamma(v/2)}}(1 + t^2/v)^{-(v+1)/2} \tag{3}$$

3. Analysis of results

3.1. Step frequency

Stride frequency is the main concern in the study, and the protection of the weight-loss shoulder harness makes the stride frequency of the weight-loss platform training really close to that of flat running, which is the prerequisite for the comparison of the techniques [11]. The comparison of stride frequency between the two training methods is shown in **Table 2** below.

Table 2. Comparison of stride frequency between the two training methods.

Participant	Flat ground running frequency (step/s)	Weight loss bench frequency (step/s)	Difference in step frequency (step/s)	Spread ratio (%)
A	4.630	4.545	−0.084	−1.82
B	4.425	4.202	−0.223	−5.04
C	4.386	4.167	−0.219	−5.00
D	3.968	4.065	0.097	2.44
E	4.237	4.065	−0.172	−4.07
F	3.846	4.000	0.154	4.00

As can be seen from the data in the table, the stride frequency of the two training methods has been very close to the average value of the weight-loss running platform training stride frequency than the flat running frequency difference of only 0.1075 steps/second, 2.532% slower, the two training methods of stride frequency of individual differences in addition to subject E are distributed within 6%, the comparison of the *P*-value of the inter-group comparison is greater than 0.05, which indicates that the difference in stride frequency between the two groups is not significant [12]. Therefore, it can be assumed that the difference between the two step frequencies is not significant, and the technical comparative analysis of the two training methods studied is less affected by the difference in step frequency.

3.2. Support time

Table 3. Comparison of support time between the two training methods.

Participant	Flat ground running support time (s)	Weight loss bench running support time (s)	Difference in support time (s)
A	0.092	0.082	−0.010
B	0.084	0.072	−0.012
C	0.088	0.082	−0.006
D	0.152	0.092	−0.060
E	0.092	0.104	0.012
F	0.096	0.076	−0.020

The results of the support time comparison between the two types of training are shown in **Table 3**. As can be seen from the data in the table, compared with flat running, the vast majority of subjects in weight reduction running platform training reduced the time of support, the average reduction in support time 0.022 s, in 250 frames/second camera is the difference between 2 to 3 images, the *t*-test *P* value between the groups is less than 0.05, the difference is significant. The reason for this is that the subjects shortened the support time, i.e., the time of cushioning (picking up the ground) and stirrup extension, and lengthened the time of vacating during the weight reduction running table training. The human body produces different adaptations in response to different external environmental stimuli, as do movement techniques [13]. Due to the support of weight reduction, it is favorable for the body to rise, and the high-speed rotation of the running platform is not favorable for support, so the subjects automatically adjusted the movement technique to adapt to this change, which is the unconscious adaptive ability of subjects with a certain level of exercise, and it is for this reason that we must find out which movement techniques are affected by the weight reduction running platform training to produce variation, and this is the purpose of the study.

3.3. Landing moment and knee landing buffer moment

From the training point of view, athletes in the flat sprint training can not deliberately emphasize the landing buffer process, if consciously increase the buffer, it will inevitably cause a change in the direction of the force behind the stirrup extension, increase the upward force and thus the loss of forward speed. However, previous studies have shown that the landing cushioning process does exist, and it is more clearly seen in high-speed camera images. Generally speaking, in order to increase the positive degree of picking up the ground, the front foot landing basically knee joint has not yet begun to bend, that is, the landing cushioning process is generally in the foot touching the ground after the start, only in this way, the whole process of contraction of the flexor muscle groups can be fully utilized. The phenomenon we see in the high-speed shooting and analysis of flat running is also consistent with this. However, what we see in training on the weight-loss running platform is the opposite of this [14]. During the analysis, we used the moment when the left foot touched the ground or the running platform as the zero-moment synchronization point through the analysis software, and described the change of the knee joint angle of the subjects of the two training methods in the form of a curve as shown in **Figure 1**.

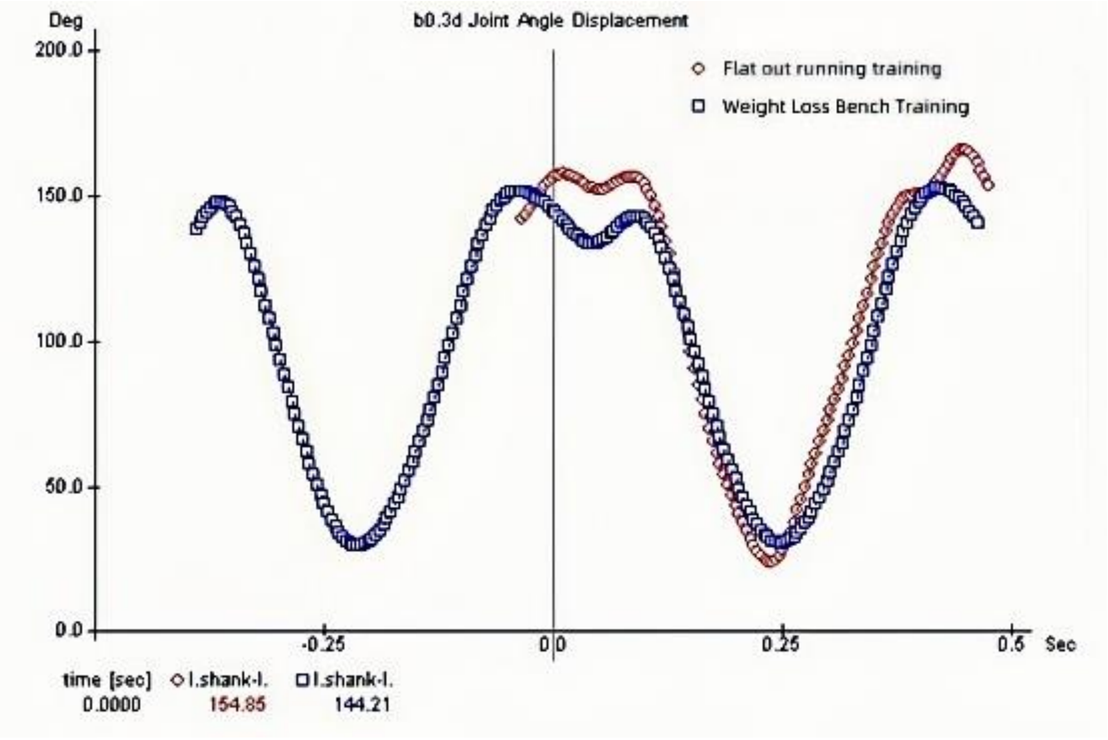

Figure 1. Knee change curves for both training methods.

In flat running training, the touchdown point (zero moment point) is basically located at the maximum position of the knee joint angle, when the knee joint angle has not yet begun to decrease, therefore, in the process of knee flexion afterwards, the knee joint has already been subjected to the ground reaction force, and the flexor muscle group is subjected to the ground reaction force throughout the whole contraction process, therefore, the force is fully utilized. On the contrary, during weight reduction bench training, the foot is not yet on the ground when the knee angle starts to decrease, and there is a period of knee flexion that is not acted upon by the ground force, then the muscle elongation and contraction during this process is not utilized, and this process averages 0.0227 s [15]. After landing due to the high speed rotation of the running platform track backward, its friction on the foot forward will also be reduced, although the movement curve of the knee joint does not change much, in fact, the subject's backward picking up the ground force is not fully utilized.

3.4. Trunk pitch

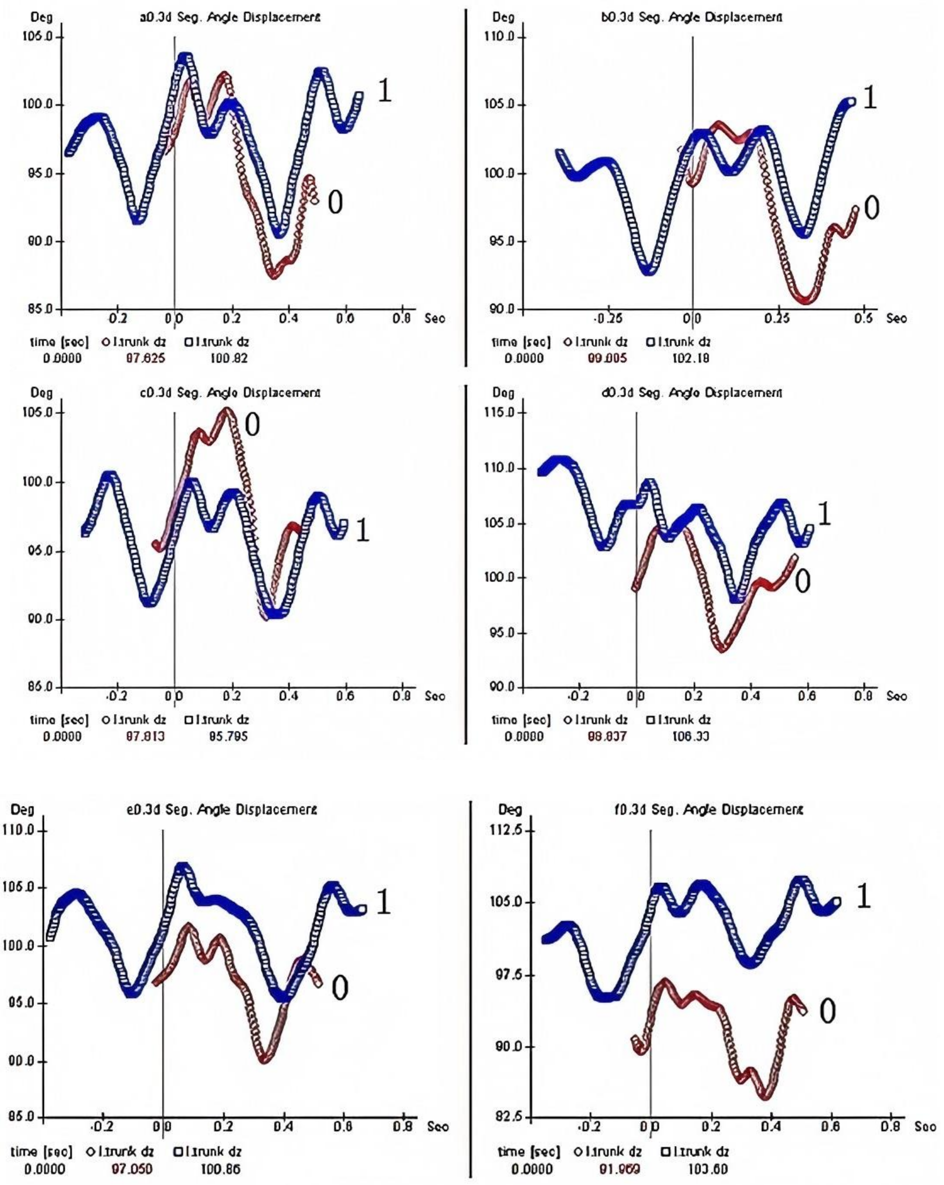

Figure 2. Comparison curves of changes in trunk pitch angle in subjects.

The analysis of trunk pitch angle for the six subjects is shown in **Figure 2**, where curve 0 (red) is the curve of change in body pitch angle for flat running training and curve 1 (blue) is the curve of change in body pitch angle for reduced weight running table training.

The subject's torso pitch angle is shown schematically in **Figure 3** below. Since the high-speed camera was located on the subject's left side during image capture, and the +X direction was the opposite of the direction of motion, the torso angle was expressed as a vector angle pointing from the hip joint to the seventh cervical vertebrae, i.e., the angle turned counterclockwise from the positive direction of the X-axis toward the torso indicated the pitch angle of the torso, so that greater than 90° was considered to be pitch, and less than 90° was considered to be tilt [16].

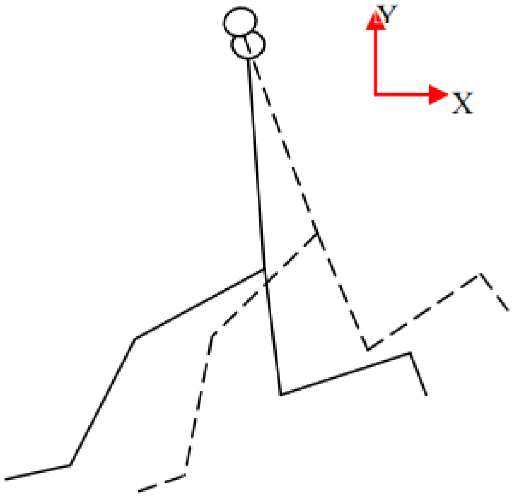

Figure 3. Schematic diagram of the variation of trunk pitch angle.

It can be seen that the pitch angle 1 curve in the whole process of running training is greater than the 0 curve of running on the ground, and in the whole course of the action is greater than running on the ground, that is to say, weight reduction running training makes most of the subjects appear to be leaning forward, which is due to the lower limbs of the subjects can not catch up with the speed of the running platform, and the upper limbs by the weight reduction straps of the tension caused by the pulling force. From the change of the solid line graph to the dashed line graph in **Figure 3**, it is also easy to see why the knee joints of the running table training would be flexed in advance before landing, and the real reason was not the early knee flexion but the backward shift of the landing position due to the forward lean of the body [17]. In this case, there is no significant change in the maximum knee angle, nor is there a significant change in the landing knee angle, but there is a flexion of the knee before landing, which explains why there is no difference in both the maximum knee angle and the landing knee angle between running on the flat and running on the platform with a reduced knee flexion and then landing.

The backward shift of the landing position will cause a series of technical changes, as mentioned above, the knee joint will appear to bend before landing, and the structure of the movement of the ground is seriously damaged. About the landing cushion and pick the ground action, in fact, is the process of knee flexion as a whole, because of this, this action is the human body forward movement of power or resistance in the academic community is still debating, but one thing is undoubtedly, is that the training process should be emphasized to pick the ground action of the positive [18]. Test results from weight loss bench training have found that this type of training is not conducive to the completion of the grounding maneuver. Landing position may also be one of the important reasons for the shortening of the support time mentioned above, the shortening of the support time will inevitably reduce the time of the stirrups, hasty stirrups make the lower limb force is not complete, the stirrups are not sufficient.

3.5. Comparative analysis of changes in knee joint angles

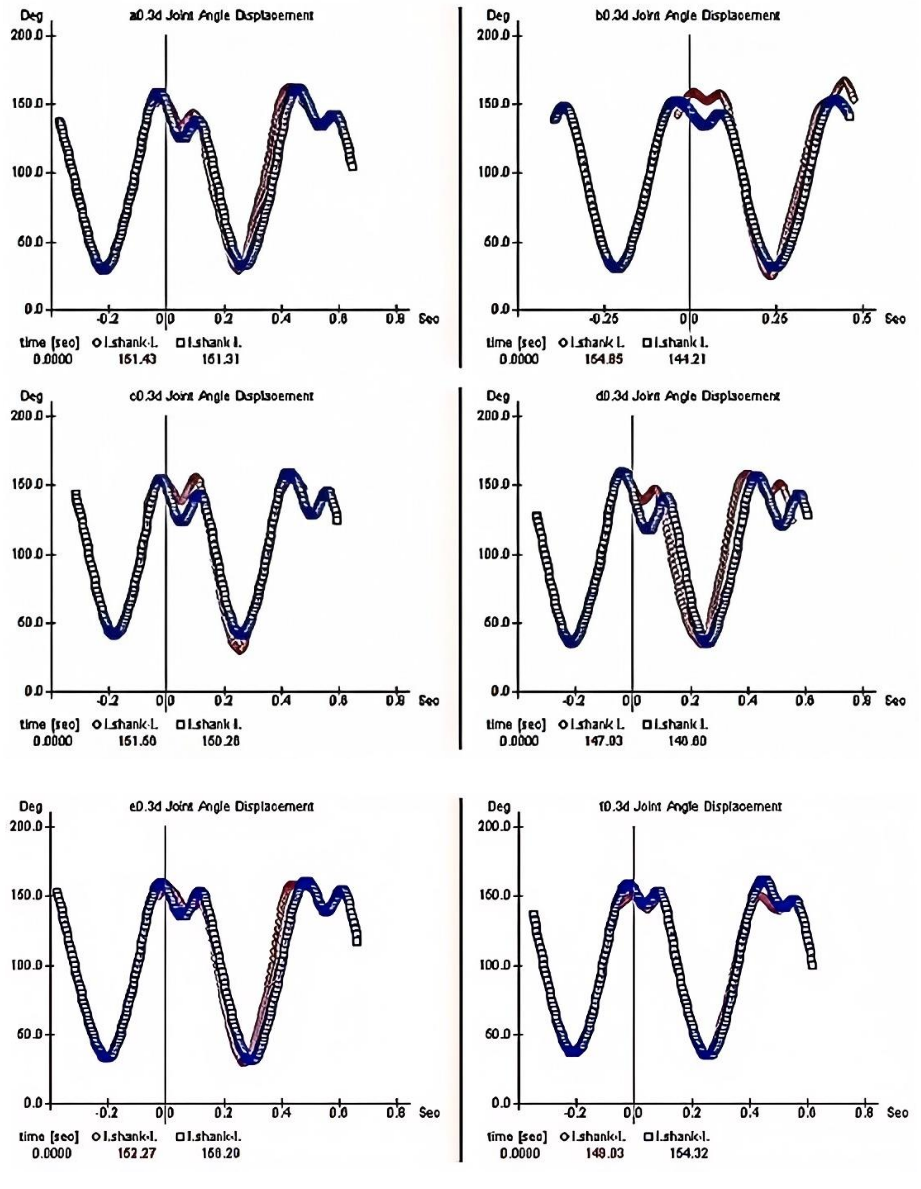

Figure 4. Comparative curves of knee angle changes in subjects.

The subject’s knee joint changes throughout the weight loss training maneuver were generally consistent with running on a flat surface, with the exception of flexion of the knee prior to touching the ground. The main purpose of the “weight-loss running platform” is to provide a safe and conducive to accelerate the stride frequency of the weight-loss training environment to train the stride frequency ability of athletes, which focuses on high-speed or ultra-high-frequency, and as for the variation of the technique is a side effect, as long as the technique generally matches with the competition technique, it can be useful for the athlete’s high-frequency training [19]. The comparison curves of the subjects’ knee angle changes are shown in **Figure 4**.

3.6. Comparative analysis of hip joint angle changes

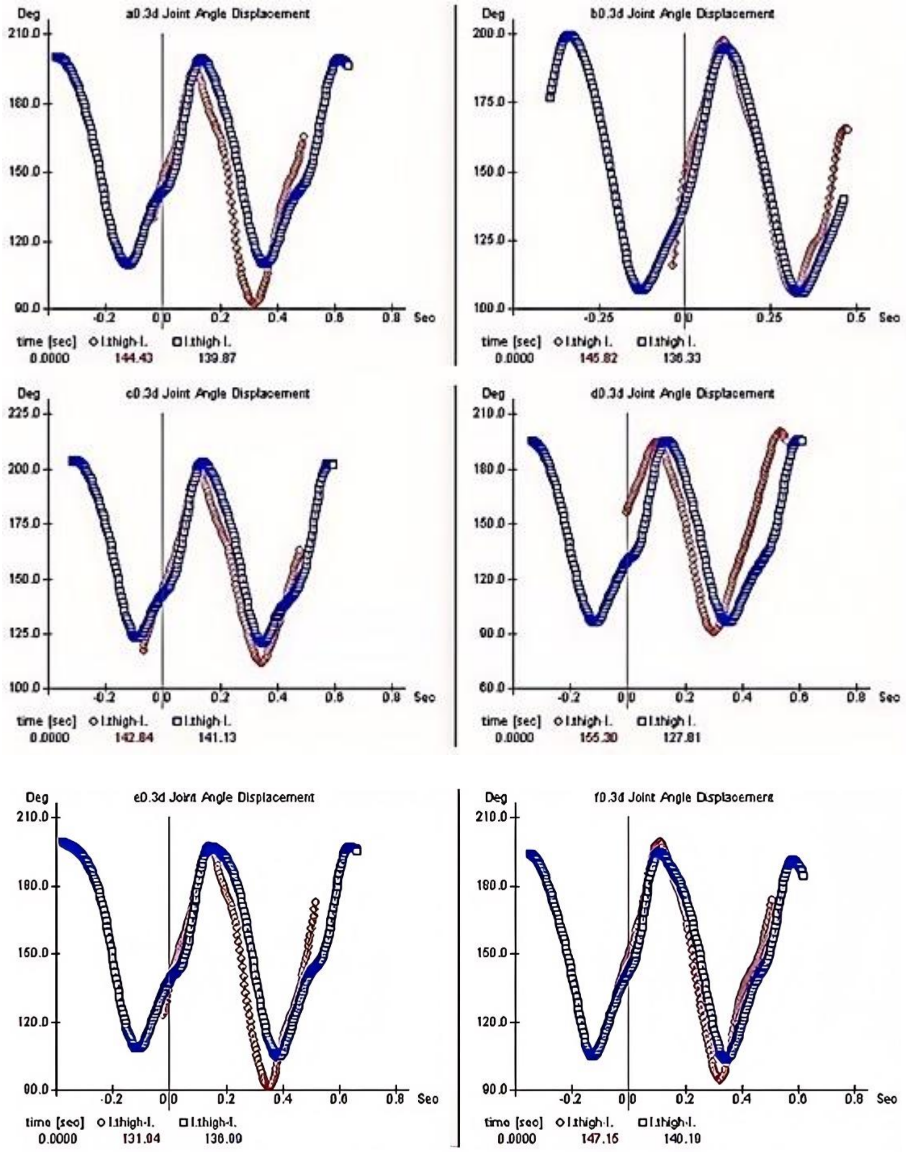

Figure 5. Comparative curves of hip joint angle changes in subjects.

A comparison of the hip angle change curves of the subjects is shown in **Figure 5**. As can be seen from the figure, the hip joint angle change curves of the two training methods are basically in the shape of “V”, the landing point is located in the middle and lower part of the right branch of the “V”, and the two curves have a weak pause in the position, and the rest of the indicators such as amplitude of change and angular velocity, no significant difference was found between the two. In the other indicators such as change amplitude and angular velocity, no significant difference was found between the two curves [20]. It can be seen that the hip joint angle changes of the two training methods in the 6 subjects were quite consistent, so that the weight loss training on the hip joint is in good agreement with the flat running training. In summary, the training of the main joints of the lower limbs by weight reduction running platform training has the same basic characteristics as flat running training, therefore, the weight reduction running platform is suitable for the pacing training of sprinting events.

4. Conclusion

In this paper, from the kinematics perspective of sports biomechanics, the method of high-speed digital video shooting and image analysis was used to analyze the training methods of weight-loss running platform training and flat-ground running training, to find out the technical differences between the two training methods, and to analyze the reasons for these technical differences, and the main conclusions of the study are as follows:

(1) Weight-loss running platform training can be used to perform high stride frequency training due to its safety and high degree of coincidence in the technical performance of the major joints of the lower limbs;

(2) The upward pull of the weight reduction device and the high-speed rotation of the running platform during high-speed training on the weight reduction running platform can easily cause the body to lean forward and trigger certain technical changes;

(3) Athletes will experience unconscious technical adaptations during weight reduction running table training, reducing support time and increasing vacating time, which are related to the size of the weight reduction force, the level of movement, and the state of movement;

The movement curves of the main joints of the lower limbs in the training of “weight loss running platform” have the same basic characteristics as that of flat running. The use of the safety protection of “weight loss running platform” can increase the density of athletes’ high-speed training, but athletes will produce involuntary technical adaptation in the training of “weight loss running platform”, and some different technical characteristics will appear, mainly: The torso leans forward due to weight loss traction and backward movement of the track; When the athletes are training on the weight reduction platform, there will be involuntary technical adaptation, the support time will be reduced, and the air time will be increased. Because the torso leans forward, the knee knees are raised before landing, which affects the training effect of lifting the floor polarity.

Combined with the above conclusions, in order to minimize the technical variation when using the weight reduction running platform, a new means of sprinting technical training, attention should be paid to the position of the athlete as far forward as possible during the running platform training, and the degree of weight reduction should be adjusted according to the athlete’s ability to minimize the amount of weight reduction. At the same time, it should also be noted that the weight loss bench training is not conducive to the training of athletes' ability to pick up the ground, long-term use must have the corresponding means to make up for this deficiency, such as weight loss running and uphill running combined training. In short, in the use of reduced weight running platform should be done to avoid the shortcomings, make full use of the advantages of its can be safe for high frequency training, so that the athlete's neuromuscular adaptation to high-speed working condition.

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