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The lower limb kinematics of novice runners and recreational runners before and after 5 km running

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Abstract

The purpose of this study was to compare the kinematics of lower limbs by measuring the range of motion of the lower limbs of runners at different levels before and after 5 km of running. 15 novice runners (weekly running volume: 7.13±2.67 km) and 15 recreational runners (weekly running volume: 35.67±9.23 km) were recruited in this study. There were significant differences in the joint range of motion of runners at different levels, especially in the hip joint. Compared with recreational runners, novice runners showed a higher risk of lower limb injuries in their gait. After 5 km of running, the range of motion of the joint increases. Running 5 km can cause runners to fatigue to a certain extent, which changes the biomechanical characteristics of runners' lower limbs, suggesting a higher risk of injury.

Keywords: kinematics, running, injury, fatigue

1. Introduction

Studies have shown that running can not only improve the cardiovascular function of the human body but also effectively promote the physical and mental health of runners [1]. Although running has a positive impact on physical fitness, with the surge in participation in the sport, running-related sports injuries are also increasing year by year [2,3]. In the process of middle and long-distance running, the runners have to bear the vertical ground reaction force (GRF) equivalent to two to three times their body weight. During this process, the runners will repeatedly bear the impact of vertical GRF [4]. The runners' sports injury survey report shows that the running-related injury rate of runners is as high as 30%-79% [3,5]. Most of the running-related injuries (RRI) (50%-75%) are caused by overuse of the knee and below, and the most common sports-related injuries are the knee and ankle joints [6].

The factors that affect running-related injuries are diverse, both intrinsic and extrinsic. Among them, internal factors refer to the differences in runners' human biomechanics and morphology, age, gender, medical history, body mass index (BMI), etc.; while external factors include training years, physical fitness status, type of running shoes, and other sports equipment [2,7]. Although many clinical and scientific researchers are committed to reducing the rate of running-related injuries, and the design of running equipment such as running shoes have continued to improve and innovate, the incidence of running injuries has not declined over the past 40 years [6,8]. Studies have shown that novice runners with no running experience have a higher risk of running injuries [2,9]. Therefore, it is especially important for novice runners to prevent related losses during running because it will increase the durability of the runner's run, thereby helping to promote the development of public health.

Previous studies have demonstrated differences in the running biomechanics of novice and amateur runners, which can affect the incidence of sports injuries. However, most studies on the biomechanics of the lower limbs of runners at different levels focus on the sagittal plane, and there are fewer biomechanical studies on the coronal and horizontal planes. In addition, most studies at home and abroad focus on the differences in running biomechanics of runners of different levels in the non-fatigue state, and few studies have explored the effects of mid- and long-distance running and runner level on running biomechanics at the same time.

The purpose of this study was to measure the biomechanical parameters of the lower limbs of runners of different levels before and after the 5 km medium and long-distance running, to compare and analyze the basic regular characteristics of the three-dimensional kinematics of the lower limbs, and to explore the effect of medium and long-distance running on the running performance of runners of different levels. On the basis of this, the biomechanical characteristics of runners of different levels and the effect of mid- and long-distance running on running biomechanics were discussed, as well as the interaction between mid- and long-distance running and runner level on running biomechanics. In order to explore how to reduce the injury rate of running and avoid prominent problems such as lower limb injury during long-distance running, it can provide meaningful guidance for the prevention of running and running-related injuries.

2. Methods

2.1 Participants

15 novice runners and 15 recreational runners were recruited to participate in this study, for a total of 30 healthy male runners (Table 1). A novice runner is one who runs between 2 and 10 kilometers per week and has never competed in a running competition or participated in a training program. Recreational runners ran a minimum of 30 kilometers per week and had at least three years of running experience. Participants were heel strikers with right-sided dominant limbs (defined as the leg that preferred kicking a ball). Six months prior to the test, neither novice nor recreational runners had lower limb injuries or musculoskeletal system disorders. Before the study, each runner gave informed consent in writing.

Table 1. Mean (SD) of participant characteristics of novice and recreational runners.

Variable	Novice	Recreational	p Value
Age (years)	23.80±1.97	23.65±1.67	0.398
Height (m)	1.76±0.49)	1.75±0.56	0.702
Body weight (kg)	71.93±7.70	72.73±6.44	0.794
BMI (kg/m^2)	23.13±1.18	23.65±1.67	0.456
Running experience (years)	1.53±0.74	6.07±1.62	<0.001
Running volume (km/week)	7.13±2.67	38.33±7.72	<0.001

2.2 Experimental Procedures

All runners wore tight pants and neutral running shoes (ART NO. 117255997, ANTA). On each participant, thirty-nine (12.5 mm in diameter) retroreflective markers were placed in order to define the trunk, hip, knee, and ankle segments (Figure 1). Running biomechanical data was captured using an eight-camera Vicon motion capture system (Vicon Metrics Ltd., Oxford, UK) and a force plate (AMTI, Watertown, MA, USA). The force plate was installed in the center of an elevated runway. The frequencies at which kinematics data were recorded were 200 Hz and 1000 Hz, respectively. Before the test began, the runners had 10 minutes to warm up and become acquainted with the laboratory and testing procedures. At their preferred running speed (pre-5 km running), which was deemed their "natural running pace," baseline running data (pre-5 km running) were collected. The self-selected running speed was used to collect all running data, both before and after a 5 km run. Timing gates were used to measure and control each runner's running speed. Only if runners maintained their running pattern while striking the force plate with their right foot fully on were running trials considered successful, and each participant completed three successful running trials. After completing the baseline running test, runners ran 5 kilometers at their preferred speeds on a treadmill. During the treadmill run, the heart rate of each runner was continuously monitored (RS 400; Polar Electro Oy, Kempele, Finland), and the Borg Scale was used to assess perceived exertion. The participants completed post-5 km running tests within 5 minutes of completing the treadmill run, with the same protocols as the baseline test. All retroreflective markers remained on participants for the duration of the test.

Figure 1. Illustration of markers placement

2.3 Data Analysis

Using Visual 3D software (c-motion Inc., Germantown, Maryland, United States), lower limb joint kinematics of the running stance phase were calculated. Kinematics and ground reaction forces were filtered at 10 Hz, by a fourth-order low-pass Butterworth filter for the denoising of marker trajectories [10]. The stance phase was determined when the vertical GRF exceeded 20 Newtons. The ankle, knee, and hip joint kinematics were calculated using a Cardan X–Y–Z rotation sequence. Using Matlab version 2019b, the kinematic data of the running stance phase were time normalized to 101 points (The Math Works, Natick, MA, USA).

2.4 Statistical Analysis

A two - way repeated - measures analysis of variance (ANOVA) was used (runner× time) to test for group differences (novice runner vs. recreational runner) and to evaluate if there were any group by 5 km run interaction. Firstly, ANOVA assumptions (normality and homogeneity of residuals) were examined. When assumptions were met, a two - way repeated measures ANOVA was used to evaluate the main effects of the 'runner' and 'time' factors and the interaction of the two factors. When the assumptions of ANOVA were not satisfied, a permutation procedure was performed. The alpha level was set to $\alpha = 0.05$. While the interaction effect was significant ($p < 0.05$), posthoc pairwise comparisons with a Bonferroni correction ($\alpha = p/6 = 0.008$) were applied. The statistical calculations were carried out using SPSS version 25.0 software (IBM, Armonk, NY, USA).

3. Results

The three-dimensional range of motion of the ankle, knee, and hip joints of runners at different levels before and after 5 km running is shown in Table 2. The statistical results showed that, whether before or after the 5 km run, the frontal range of motion of the ankle joint (F=4.720, p=0.035) and the frontal range of motion of the hip joint (F=23.459, p<0.001) of the novice runners were greater than those of recreational runners, and in sagittal motion of knee joint, novice runners had smaller range of motion than recreational runners (F=57.932, p<0.001). In both novice runners and recreational runners, the frontal range of motion of the knee joint (F=12.818, p=0.001) and the frontal range of motion of the hip joint (F=13.369, p=0.001) were greater than before 5 km running. There was an interaction effect on the range of motion in the frontal plane of the knee joint (F=21.117, p<0.001).

Table.2 Range of motion of lower limb joints

Range of motion (°)		Novice/Pre	Novice/Post	Recreational /Pre	Recreational /Post	Runner effect	5 km effect	Interaction Effect
Ankle	Sagittal	44.80±9.17	41.71±6.41	44.55±6.41	45.41±7.96	F=0.878; p=0.355	F=2.270; p=0.139	F=3.515; p=0.078
	Frontal	17.16±4.82	17.21±4.75	15.32±2.91	16.04±1.91	F=4.720; p=0.035*	F=1.442; p=0.236	F=1.104; p=0.299
	Horizontal	14.94±2.97	14.20±1.50	13.77±2.41	14.07±2.84	F=1.978; p=0.167	F=0.720; p=0.401	F=4.024; p=0.051
Knee	Sagittal	26.18±4.05	27.14±3.26	32.23±3.55	29.90±2.94	F=57.932; p<0.001*	F=1.941; p=0.171	F=5.917; p=0.035
	Frontal	2.85±0.63	3.90±1.55	3.38±0.79	3.43±1.20	F=0.025; p=0.876	F=12.818; p=0.001#	F=21.117; p<0.001^
	Horizontal	6.62±2.28	6.70±1.98	7.73±2.67	7.73±2.40	F=0.033; p=0.857	F=4.675; p=0.057	F=2.572; p=0.090
Hip	Sagittal	43.17±3.12	42.81±3.05	41.98±3.91	43.12±5.41	F=0.503; p=0.482	F=0.676; p=0.415	F=5.406; p=0.025
	Frontal	14.10±3.66	14.76±4.68	10.37±1.90	12.00±1.22	F=23.459; p<0.001*	F=13.369; p=0.001#	F=2.967; p=0.092
	Horizontal	10.96±4.44	12.66±6.26	10.48±3.31	10.69±2.61	F=1.378; p=0.247	F=6.664; p=0.013	F=5.682; p=0.022

4. Discussion

This study compared the basic regular characteristics of the parameters related to the three-dimensional joint range of motion of the lower limbs of runners with different levels before and after 5 km of running. It is found that there are differences in the three-dimensional kinematics of runners of different levels before and after long-distance running, which enriches the theoretical content of running biomechanics and provides meaningful guidance for running sports and the prevention of running-related injuries.

The range of motion of a joint refers to the maximum radian (angle) that a joint can reach when it is active, and it is also one of the most basic and important indicators for evaluating the function and state of the motor system. Novice runners have a greater ankle coronal range of motion during the stance phase than amateur runners, and Vtasalo et al. [11] identified greater ankle valgus range of motion as one of the factors that cause running-related injuries. By comparing the ankle biomechanical characteristics of injured runners and uninjured runners, Kuhman et al. [12] found that the ankle valgus activity of uninjured runners was greater than that of injured runners, which may be related to the ankle joint of injured runners. Coronal plane range of motion is limited. The sagittal range of motion of the knee joint varies among runners of different levels. The sagittal range of motion of the knee joint of novice runners is smaller than that of amateur runners. This is consistent with the research results of Cavanagh et al. [13]. The degree of knee flexion in runners is greater than that of ordinary runners, and greater knee flexion may indicate better running performance in amateur runners. Novice runners have a significantly greater range of motion in the frontal hip joint than recreational runners, a finding similar to the findings of Quan et al. [14] that runners have less range of motion in the frontal plane of the hip. The greater variability in hip range of motion in novice runners may be associated with hip instability.

A comparative study of before and after 5 km running found that both novice runners and recreational runners had a significantly greater range of motion in the frontal plane of the knee joint after 5 km running than before 5 km running. When the runners finish running a 5 km run, the neuromuscular control ability will be weakened to a certain extent due to fatigue, resulting in an increase in the range of motion of the knee joint, which is the same as the findings of Yu et al. [15]. Among them, the frontal range of motion of the knee joint also has an interactive effect at the runner level and the 5 km running. The increase in the frontal range of motion of the knee joint in novice runners after the 5 km run is significantly greater than that of recreational runners. Decreased control due to greater fatigue after the 5 km run. Whether it is a novice runner or a recreational runner, the range of motion in the frontal plane of the hip joint is significantly greater after the 5 km run than before the 5 km run. The hip joint plays an important role in the movement of the lower limbs. It is thought to be related to the rate of running-related injuries [16]. Hip instability has also been identified as an important mechanism for lower extremity sports injuries, and increased frontal range of motion of the hip is associated with iliotibial band syndrome and patellar pain [17].

5. Conclusion

This study investigated the biomechanical characteristics of runners of different levels before and after 5 km running, hoping to explore how the runner's level affects mid- and long-distance running at the biomechanical level and how to reduce the injury rate of running and avoid the process of mid- and long-distance running. Prominent issues such as lower extremity injuries provide meaningful guidance for running and the prevention of running-related injuries. There are significant differences in the kinematics of runners of different levels during the stance phase of running gait, especially in the range of motion of the hip joint. Compared with recreational runners, gait characteristics of novice runners were characterized by a higher risk of lower extremity running injuries, and a greater hip range of motion indicated a higher injury risk.

6. References

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