RESEARCH ARTICLE

Biomechanical analysis of college students' running gait and its impact on sports injuries

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Running gait plays a critical role in determining the efficiency of movement and the risk of sports related injuries. Improper gait patterns such as abnormal cadence, stride length, and uneven foot pressure distribution have been associated with increased stress on joints and soft tissues, leading to injuries in physically active populations. Limited research has focused specifically on college students, a group that often engages in running without professional training or gait optimization, making them prone to preventable injuries. This study aimed to investigate the relationship between running gait characteristics and sports injuries among college students through biomechanical analysis. A total of 200 participants were recruited and divided into an experimental group with 100 students having a history of sports injuries and a control group with 100 students without injuries. High speed cameras, motion capture systems, and pressure plates were employed to record gait parameters at different running speeds, while questionnaires and medical diagnoses were used to assess injury history. The results revealed that the experimental group exhibited a significantly higher cadence of 190 steps/min and greater stride length of 1.20 m than that in the control group with 175 steps/min and 1.05 m, respectively. Furthermore, the experimental group demonstrated a shorter gait cycle (0.82 s *vs*. 1.05 s), more concentrated foot pressure on the forefoot and heel, and higher knee joint forces (470 N *vs*. 420 N). These findings indicated that poor gait characteristics including excessive cadence, increased stride length, and uneven foot pressure distribution were closely associated with sports injuries. This study highlighted the importance of gait assessment and adjustment as effective strategies to reduce injury risk in college students, providing a scientific basis for injury prevention and training optimization.

Keywords: running gait; biomechanical analysis; sports injuries; foot pressure.

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Introduction

Running is one of the most common physical activities among college students, offering significant benefits for cardiovascular health, physical fitness, and endurance. However, as the participation in running continues to increase, the incidence of sports related injuries is also raised. Numerous studies have demonstrated that running gait, the pattern of movement during running, plays a critical role in both performance and injury risk. Key biomechanical parameters such as cadence, stride length, gait cycle, and foot pressure distribution are closely linked to impact forces, joint loading, and muscle fatigue, all of which influence the likelihood of developing injuries. Recent advances in biomechanics have provided deeper insights into the relationship between gait characteristics and injury mechanisms. By using high speed imaging, motion capture, and foot pressure analysis, researchers have identified abnormal gait patterns such as excessively high or low cadence, large stride length, and uneven foot pressure distribution as contributing factors to injuries involving the knee, ankle, and plantar fascia. While such correlations have been extensively studied in professional athletes and specific patient populations, research focusing on college students remains limited. This gap is significant as college students often run without systematic training or gait optimization, making them particularly susceptible to preventable injuries [1].

Running gait consists of several factors including cadence, stride length, gait cycle, and foot pressure distribution. Cadence refers to the number of steps taken per unit of time, typically expressed in steps per minute. Stride length is the distance covered in each step and usually influenced by an individual's leg length, running speed, and cadence. The gait cycle is the time that one foot to land and return to the ground again, which is closely related to the overall rhythm and efficiency of running. Foot pressure distribution reflects the variations in pressure on different parts of the foot during running, which has significant biomechanical implications as it indicates the forces on the joints and muscles during running [2]. Biomechanical analysis combining kinematics and dynamics can comprehensively reveal the characteristics of running gait. Kinematics primarily studies the motion trajectory of moving objects and joint angle changes, effectively analyzing dynamic behaviors during running such as the relationships between stride length, cadence, and gait cycle. Dynamics focuses on the forces acting on the body and their effects, especially the ground reaction force and foot pressure distribution. During running, the ground reaction force is the main factor influencing joint load, and uneven foot pressure may lead to various types of sports injuries. Biomechanical analysis not only helps to study the details of running gait but also provides a theoretical basis for preventing sports injuries [3]. The running gait of college students varies significantly between individuals with these differences being influenced by factors such as individual differences, exercise habits, and training levels. Most college students exhibit improper gait due to a lack of sufficient technique guidance and biomechanical knowledge when they start running training. Some students may have a too high or too low cadence, leading to an imbalance in the impact forces during running, which increases the risk of knee and ankle injuries, while others who have not mastered proper running techniques may have a too large or too small stride length, failing to distribute the load on the joints and muscles effectively, which increases the likelihood of sports injuries [4]. Foot pressure distribution is also a common issue in the running gait of college students. During running, some students may concentrate pressure on the forefoot or heel area, and prolonged uneven loading can lead to injuries like plantar fasciitis and knee pain. Some students may not be aware of their abnormal gait, resulting in untimely gait adjustments and the formation of bad running habits. These improper gait issues not only affect running performance but also increase the probability of injuries. Studying the main characteristics of college students' running gait helps to understand the potential risks of sports injuries and provides scientific evidence for gait training and injury prevention [5]. Poor running gait is one of the main causes of sports injuries. Studies have shown that a low cadence can lead to excessive landing impact forces during running, which increases joint load. The impact forces generated during landing are transmitted through the lower limbs to the knee joints, hip joints, and spine. If the cadence is too low, the contact time between the foot and the ground will be prolonged, causing a larger impact with each landing, which increases pressure on the joints and bones. Over time, this can lead to knee osteoarthritis, hip joint injuries, and other issues. On the other hand, excessively high cadence can result in excessive joint load, especially during high-speed running or sprints. A high cadence may lead to over-tightening of the joints, which can easily cause muscle strains, ligament injuries, and other problems [6]. Excessive stride length is also a key factor in sports injuries. When the stride length is too large, the impact force of each step increases, particularly when the foot lands on the knee and hip joints. Excessive stride length increases the load on these two joints, making them prone to knee pain, hip joint injuries, and other issues. Long-term excessive load can lead to accumulated injuries, leaving the joints under constant pressure without sufficient recovery. Abnormal foot pressure distribution is also a major cause of injury. Excessive pressure on the forefoot or heel may lead to plantar fasciitis or other related diseases. Factors such as cadence, stride length, and foot pressure distribution in the running gait all play significant roles in the occurrence of sports injuries.

Currently, there is a lack of evidence-based strategies for identifying and correcting poor running gait in college students to prevent sports injuries. This study aimed to examine the relationship between running gait characteristics and sports injuries among college students using biomechanical analysis. The results of this research would provide scientific evidence linking specific gait abnormalities to sports injuries in college students to enhance understanding of the biomechanical factors underlying running related injuries and offer practical guidance for injury prevention through gait adjustment, which would contribute to the development of safer and more effective running practices for the college student population.

Materials and methods

Participant recruitment

A total of 200 college students were recruited from Beijing School of Sports Science and divided into experimental group (100 students with a history of sports injuries) and a control group (100 students without a history of sports injuries). All participants underwent a medical examination to confirm their injury status before testing. All procedures of this study were approved by the Institutional Review Board of Beijing School of Sports Science (Beijing, China) (Approval No. IRB-2025-021). All participants were informed of the study objectives, procedures, and potential risks, and provided written informed consent prior to participation.

Data collection

Running gait data were collected by using Phantom VEO 710 high-speed cameras (Vision Research, Wayne, NJ, USA) to record motion trajectories and joint angle changes. Vicon MX motion capture system (Vicon Motion Systems Ltd., Oxford, UK) was employed to track stride length, cadence, and gait cycle in real time. Novel emed®-x foot pressure plates (Novel GmbH, Munich, Germany) were used to measure plantar pressure distribution including forefoot, heel, and arch areas. Visual3D biomechanical analysis software (C-Motion, Inc., Germantown, MD, USA) was used to process and analyze kinematic and kinetic data. Briefly, all participants performed running tests on a treadmill at three preset speeds of 8 km/h, 10 km/h, and 12 km/h. For each speed, participants ran for 5 minutes while gait data was recorded. High-speed cameras and the motion capture system were synchronized to capture dynamic joint movements, while the foot pressure plates were embedded in the treadmill to record plantar pressure during each step. Each participant completed all tests under identical conditions to minimize external variability.

Data processing

SPSS version 26.0 (IBM Corp., Armonk, NY, USA) was employed for statistical analysis of this research. All data were expressed as mean ± standard deviation (SD). Group comparisons

Table 1. Relationship between cadence and sports injuries.

Group	Speed (km/h)	Average cadence (steps/min)	Standard deviation	t-value	*P* value
Experimental	8	180	8	3.12	0.003
Experimental	10	185	7	3.08	0.004
Experimental	12	190	6	3.15	0.002
Control	8	170	6	3.02	0.004
Control	10	172	5	3.10	0.003
Control	12	175	5	3.05	0.004

Table 2. Relationship between stride length and sports injuries.

Group	Speed (km/h)	Average stride length (m)	Standard deviation	t-value	*P* value
Experimental	8	1.15	0.08	3.65	0.0010
Experimental	10	1.18	0.07	3.72	0.0009
Experimental	12	1.20	0.06	3.80	0.0007
Control	8	1.05	0.05	3.52	0.0020
Control	10	1.08	0.04	3.60	0.0015
Control	12	1.10	0.03	3.55	0.0020

between the experimental and control groups were performed using independent samples t-tests to determine statistically significant differences with *P* value less than 0.05 as statistically significant [7].

Results

Relationship between cadence and sports injuries

Past research showed that a faster cadence led to greater impact forces during each foot landing, which increased the load on the joints, especially the knee and hip joints, and the athletes with higher cadences were more likely to experience fatigue during exercise, which might lead to technical errors due to the rapid cadence, further increasing the chances of injury [8]. The experimental group had a higher cadence at all running speeds than the control group with significant differences ($P < 0.05$) (Table 1), which suggested that the experimental groups experienced greater impact forces during running, and a faster cadence was somewhat related to the occurrence of sports injuries.

The impact of stride length on injuries

A larger stride length tends to concentrate more impact force on the knee and hip joints, increasing the risk of sports injuries. When the stride length is too large, the joints, especially the knee joint, experience higher pressure during landing, which, if maintained over time, can lead to joint wear, inflammation, and other sports injuries. The experimental group had a significantly larger stride length than the control group at all speeds ($P < 0.05$), which suggested that increased stride length was associated with a higher likelihood of sports injuries, particularly due to the pressure on the knee and hip joints. Further, the difference in stride length was particularly notable at higher speeds, which could lead to more concentrated impact on the knee and hip joints, increasing the risk of sports injuries (Table 2).

Analysis of gait cycle and landing method

A short gait cycle and forefoot landing may lead to injuries such as plantar fasciitis. A shorter gait cycle means that the runners land more frequently in a shorter time, increasing the impact force with each landing. Specifically, forefoot landing, while increasing cadence, can cause excessive pressure on the forefoot area, raising the risk of plantar fasciitis [9]. The results

Table 3. Analysis of gait cycle and landing method.

Group	Speed (km/h)	Gait cycle (seconds)	Forefoot landing proportion (%)	Standard deviation	t-value	*P* value
Experimental	8	0.90	60	0.05	4.21	0.0003
Experimental	10	0.85	62	0.04	4.33	0.0002
Experimental	12	0.82	64	0.03	4.45	0.0001
Control	8	1.05	40	0.04	4.01	0.0004
Control	10	1.00	42	0.03	4.05	0.0003
Control	12	0.98	44	0.02	4.10	0.0002

Table 4. Foot pressure distribution patterns.

Group	Speed (km/h)	Max foot pressure (N/cm)	Mean foot pressure (N/cm)	Forefoot pressure (%)	Heel pressure (%)	t-value	*P* value
Experimental	8	0.85	0.55	45	35	4.12	0.0004
Experimental	10	0.88	0.58	47	37	4.05	0.0005
Experimental	12	0.90	0.60	50	40	4.08	0.0003
Control	8	0.70	0.50	30	25	3.90	0.0006
Control	10	0.72	0.52	32	28	3.85	0.0007
Control	12	0.75	0.55	35	30	3.95	0.0005

showed that the experimental group had a generally shorter gait cycle and a higher proportion of forefoot landings with all differences being statistically significant ($P < 0.05$) (Table 3). A shorter gait cycle and a higher proportion of forefoot landings likely resulted in excessive pressure on the forefoot, increasing the risk of injuries such as plantar fasciitis.

Foot pressure distribution patterns

The excessive pressure concentration could lead to injuries such as plantar fasciitis and ankle joint damage [10]. The experimental group had significantly higher max foot pressure, mean foot pressure, and a higher proportion of pressure on the forefoot and heel at all speeds than the control group ($P < 0.05$) (Table 4), which suggested that the experimental group experienced greater pressure during running, particularly in the forefoot and heel areas, indicating that uneven foot pressure distribution could be a significant factor in injuries. In contrast, the control group's pressure distribution was more even with lower pressure on the forefoot and heel. Therefore, optimizing foot pressure distribution is an important factor in reducing sports injuries. Athletes should adjust their gait and landing methods to avoid excessive foot pressure concentration, reducing the risk of injuries.

Joint force analysis

Overloading the knee joint is a major factor in knee injuries such as knee pain and arthritis [11]. The experimental group had significantly higher maximum and mean knee joint forces at all speeds compared to the control group ($P < 0.05$) (Table 5). The maximum knee joint force in the experimental group increased with speed, suggesting that poor gait, high cadence, large stride length, and uneven foot pressure distribution could lead to higher pressure on the knee joint. The control group's knee joint forces were lower, indicating that normal gait resulted in a lighter load on the knee joint.

Discussion

The preventive role of running gait adjustment

Table 5. Joint force analysis.

Group	Speed (km/h)	Max knee joint force (N)	Mean knee joint force (N)	t-value	*P* value
Experimental	8	450	300	4.23	0.0002
Experimental	10	460	310	4.12	0.0003
Experimental	12	470	320	4.15	0.0002
Control	8	400	280	3.8	0.0005
Control	10	410	290	3.85	0.0004
Control	12	420	300	3.9	0.0003

Cadence and stride length are two important factors that influence the impact forces during running. Studies have shown that appropriately increasing cadence and reducing stride length can effectively reduce the impact forces on the body during running, thereby reducing the load on the joints and muscles. When the cadence is too low, the landing impact lasts for a longer period, while a high cadence, although reducing the impact of each step, increases the load on the joints. By adjusting the cadence to an appropriate range, the impact force during each landing can be effectively reduced, thus reducing the occurrence of sports injuries [12]. An excessive stride length can lead to greater pressure on the knee and hip joints, increasing the risk of injury. An appropriate stride length should be adjusted according to an individual's leg length, body weight, and running speed. By reducing the stride length, the runner can reduce the landing impact, thus decrease joint load and lower the probability of sports injuries. Through biomechanical analysis, scientific gait adjustments can help runners not only improve running efficiency but also effectively prevent common sports injuries such as knee pain, ankle sprains, *etc*. Proper adjustments to cadence and stride length are crucial to protecting the health of athletes' joints and muscles [13].

The impact of foot pressure distribution on injuries

Foot pressure distribution plays a vital role during running as it directly impacts the load on the lower limb joints and muscles. By analyzing the data collected from the foot pressure plates in this study, areas of concentrated pressure that could lead to injury were identified. The results indicated that eexcessive pressure on the forefoot or heel over time could cause plantar fasciitis or ankle joint injuries. Optimizing running posture to prevent excessive pressure concentration in certain areas may effectively reduce the occurrence of these injuries. Uneven foot pressure distribution may lead to sports injuries during running. Understanding and adjusting the distribution of foot pressure is the key to reducing injuries. Through biomechanical analysis, runners can identify poor posture during running and adjust accordingly. By improving running techniques, ensuring that foot pressure is evenly distributed across the entire foot, athletes can reduce excessive load on any specific area and lower the risk of sports injuries. Optimizing foot pressure distribution not only improves running comfort but also reduces damage to the knees, ankles, and feet [14].

The relationship between gait abnormalities and different types of injuries

Running gait abnormalities are often closely related to specific types of sports injuries. A fast cadence is one of the most common gait abnormalities, which may cause excessive knee flexion with each landing, thereby increasing the load on the knee joint. A high cadence results in frequent landings in a short time, and each landing requires the knee joint to absorb a larger impact force. This repeated impact may lead to knee pain, knee osteoarthritis, or meniscus damage. An excessively large stride is another common gait abnormality, especially at higher speeds, where increased stride length causes greater impact force with each step, particularly increasing the load on the hip and knee joints. An excessively large stride not only increases gait instability but may also cause chronic injuries to the hip, knee, and lower back, such as hip pain and cartilage damage in the knees [15]. While forefoot landing may increase cadence and make running more agile, it also increases the pressure on the forefoot area, which can lead to injuries like plantar fasciitis. When landing on the forefoot, pressure is concentrated on the arch and bottom of the foot, which over time can cause muscle fatigue and strain, potentially resulting in severe plantar fasciitis. For different types of injuries, runners can adjust their gait to reduce these negative effects. For instance, runners with knee injuries may reduce cadence or shorten stride length to lessen the knee joint load and avoid prolonged high-impact stress, while runners with plantar fasciitis may adjust their landing style to avoid excessive pressure on the forefoot, thus reducing the risk of plantar fasciitis [16]. Through personalized gait adjustments, athletes can improve their running posture based on their sports injury history and gait characteristics, reducing the likelihood of specific sports injuries. Gait adjustments help reduce pressure on joints and soft tissues and can effectively improve athletic performance and extend an athlete's career. By analyzing everyone’s gait characteristics in detail, a running program that suits their physical condition can be designed, allowing athletes to improve running efficiency while avoiding sports injuries. Effective correction of gait abnormalities is crucial in preventing various types of injuries.

Training and running technique optimization

The runners can gain a deeper understanding of their gait characteristics through biomechanical analysis and make targeted adjustments to their gait by developing personalized training plans. Optimizing running techniques improves running efficiency, while effectively reducing the occurrence of sports injuries. Since everyone has different physical fitness, gait characteristics, and exercise habits, training plans need to be tailored to each person’s specific situation. Biomechanical analysis helps athletes identify issues with cadence, stride length, gait cycle, and other aspects, allowing for improvement through personalized training programs. For example, if an athlete's cadence is too fast, cadence training can be implemented to bring it into an appropriate range, thus reducing the impact on the joints. If the stride length is too long, technical guidance can help the athletes adjust their stride length to reduce the burden caused by an excessive stride [17]. Optimizing running technique is not just about adjusting gait. Training intensity and frequency are also crucial. Proper training intensity and frequency can effectively improve running performance, while excessive training may lead to fatigue accumulation and injuries. Overtraining can cause excessive fatigue, reduce exercise efficiency, and increase the risk of injury. On the other hand, insufficient training may lead to stiff gait and poor coordination, thus affecting running performance and safety. By adjusting the training plan appropriately, runners can improve their technique without overloading their bodies, thereby reducing the risk of injury [18]. With technological advancements, athletes can use biomechanical analysis tools to monitor and evaluate the effects of running technique optimization in real-time, which allows runners to understand changes in their gait at any moment and adjust their training plans promptly. In the future, combining sensor technology and advanced analytical methods, runners can receive more precise feedback on their running techniques and injury prevention advice, which will help athletes improve performance and significantly reduce injuries caused by improper techniques, thereby enhancing overall training results and athletic performance. Through biomechanical analysis and personalized training, both running technique optimization and injury prevention can be achieved.

Limitations of the study and future directions

Although this study revealed the relationship between running gait and sports injuries, there were still some limitations. The sample size was relatively small with only 200 participants, which might limit the representativeness and generalizability of the findings. Future research should expand the sample size to include runners of different age groups, genders, and fitness levels to increase the applicability of the results. This study mainly focused on the biomechanical features of running gait and their relationship with sports injuries. However, it overlooked other external factors such as the choice of running shoes, running environment, and type of running surface. These factors might also influence sports injuries. Future studies should further explore the combined effects of these external factors on running gait and injuries [19]. Individual differences were an important factor influencing running gait and sports injuries. Factors such as weight, height, leg length, and flexibility varied from person to person, and there were significant differences in how individuals' running gait performed and their susceptibility to injuries. Future research needs to place more emphasis on individualized analysis, creating personalized running training plans based on biomechanical models for different athletes to achieve optimal performance and minimize the risk of injuries. With the development of sensor technology and real-time monitoring equipment, future studies could dynamically track changes in runners' gaits, providing more accurate training feedback, which would help adjust training plans in real time, prevent injuries in advance, and further enhance the athlete's athletic ability and training effectiveness. As technology advances and research deepens, personal running training and injury prevention will become an important direction for future sports science research. By combining biomechanical analysis with advanced technologies, a more comprehensive assessment of a runner's physical state can be made, providing scientific guidance and recommendations to ensure better health and improved athletic performance.

Conclusion

This study explored the relationship between running gait characteristics and sports injuries in college students through biomechanical analysis. The results showed that the experimental group had significantly higher cadence, stride length, and gait cycle compared to the control group. These undesirable gait characteristics might lead to excessive loading on the knee, ankle joints, and other areas, thus increasing the risk of sports injuries. The foot pressure distribution analysis revealed that the experimental group had excessive pressure on the forefoot and heel, and this uneven pressure distribution was a key factor in injuries. The results highlighted the importance of gait adjustment in reducing sports injuries. For the college student running population, optimizing running gait, particularly adjusting cadence, stride length, and gait cycle, and avoiding excessive foot pressure concentration could effectively prevent common sports injuries. Future training should focus on personalized gait adjustments by using scientific gait analysis and training methods to provide safer and more efficient running guidance for college students, thus reducing the risk of injuries caused by improper gait. Further, future research could expand the sample size and explore other factors influencing running gait and sports injuries to further optimize injury prevention strategies.

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