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A Pilot Investigation into Spatiotemporal Gait Differentiation Between Competitive and Recreational Runners Using OptoGait Technology

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ABSTRACT

Purpose: This pilot investigation aims to elucidate biomechanical disparities in gait characteristics between competitive and recreational runners through high-resolution spatiotemporal assessment using the OptoGait system. The goal is to discern performance-enhancing mechanisms and injury susceptibility patterns across varying athletic populations.

Methods: A cross-sectional, quasi-experimental study design was employed involving thirteen adult participants (6 competitive, 7 recreational), evaluated using an instrumented treadmill integrated with OptoGait optical sensors. Spatiotemporal parameters such as stride length, contact time, flight time, cadence, and angular displacement were quantified and statistically analyzed via independent t-tests ($p < 0.05$).

Results: Competitive runners exhibited a significantly elevated step cadence (161.00±0.89 steps/min) and reduced step angle (0.54±0.01 rad) relative to recreational runners (157.71±2.05 steps/min, 0.57±0.01 rad), with a notable reduction in step length (103.50±1.04 cm vs. 107.29±1.38 cm, $p < 0.001$). No significant intergroup differences emerged in contact and flight times.

Conclusion: This comparative gait analysis underscores distinct biomechanical adaptations among competitive runners characterized by a more compact stride, heightened cadence, and attenuated angular strike pattern−features conducive to running economy and injury mitigation. These findings support the utility of individualized training paradigms and biomechanical profiling for optimizing performance outcomes and preventive strategies in heterogeneous runner cohorts.Keywords: Digital therapeutics, Dual Task, Proprioceptive Exercise, Postural Stability, Positioning Sensation, Cognition.

1. INTRODUCTION

Running is one of the most popular forms of physical activity, offering numerous health benefits including cardiovascular fitness, weight management, and mental well-being.1,2) The number of runners and running events has grown substantially over the past years because it is of low cost and can be easily implemented with minimal equipment.3) Among runners, there are distinct differences in training intensity, goals, and performance outcomes between competitive and recreationally engaged runners.4) These differences often manifest in various biomechanical parameters, which can influence running efficiency and injury risk.5)

Kinematic gait profiling is a valuable tool for understanding the biomechanics of running. Parameters such as stride length, ground contact duration, and aerial phase duration are critical indicators of running efficiency and potential injury risk.6,7) Stride length reflects the distance between the tip of two subsequent footprints of the same foot or the distance between the heel of two subsequent footprints of the same foot depending on the settings. Contact time denotes the duration the foot spends on the ground, and aerial phase duration indicates the period when both feet are off the ground.7,8) Step frequency also known as the step rate or cadence, is the number of ground contact events per minute. In this study, the term cadence will be utilized. Variations in these parameters can provide insights into the running mechanics of different groups of runners.

OptoGait technology offers a sophisticated method for capturing and analyzing gait parameters with high precision. This system uses a series of LEDs and sensors to track the movement of runners in real-time, providing detailed data on various aspects of their gait.9) The LED bars detect interruptions in light signals to automatically calculate spatiotemporal parameters. The automatic calculation of running parameters is clinically desirable and efficient. It offers a reliable means of evaluating spatiotemporal parameters while running on a treadmill, making it a valuable tool for potential utilization in clinical, training, or research environments.10,11) By leveraging this technology, researchers can gain a deeper understanding of the biomechanical differences between competitive and recreationally engaged runners.

Despite the considerable health advantages associated with running, runners commonly experience musculoskeletal injuries related to their activity.12,13) These injuries, known as running-related musculoskeletal injuries, often result from the cumulative impact of relatively small forces applied repeatedly over time (overuse injuries). Numerous studies have investigated the prevalence and incidence rates of these injuries among runners, revealing a wide-ranging spectrum from 3.2% to 84.9%.14,15) Previous studies have highlighted that performance-oriented runners often exhibit biomechanical advantages such as longer stride lengths and shorter ground contact durations compared to their recreational counterparts.16) These characteristics contribute to greater running efficiency and speed, but they may also be associated with different patterns of injury risk.17) For instance, performance-oriented runners might be more prone to overuse injuries due to the higher intensity and volume of their training .

Therefore, this study aims to compare the gait parameters of competitive and recreationally engaged runners using OptoGait technology. By analyzing differences in stride length, ground contact duration, and aerial phase duration, the study seeks to uncover how these biomechanical factors influence running performance and injury risk. Understanding these differences can inform targeted training and injury prevention strategies, ultimately enhancing the safety and effectiveness of running practices for both competitive and recreational athletes.

2. MATERIALS AND METHODOLOGY

Research design

This study was a quasi-experimental cross-sectional study conducted in the Department of Physical Therapy at Sun Moon University, Korea. Subjects were assigned to one of the two groups, performance-oriented runners and recreationally engaged runners.

Research participants

Subjects were competitive and recreationally engaged runners between the ages of 18~45 years, recruited from running clubs and sport centers. Competitive runners were those with minimum of 3 years of competitive experience, training an average of 5 days per week, regularly participating in competitions. Recreational runners were those with minimum of 3 years of recreational running experience, training an average of 3 days per week, no competitive history. Inclusion criteria included

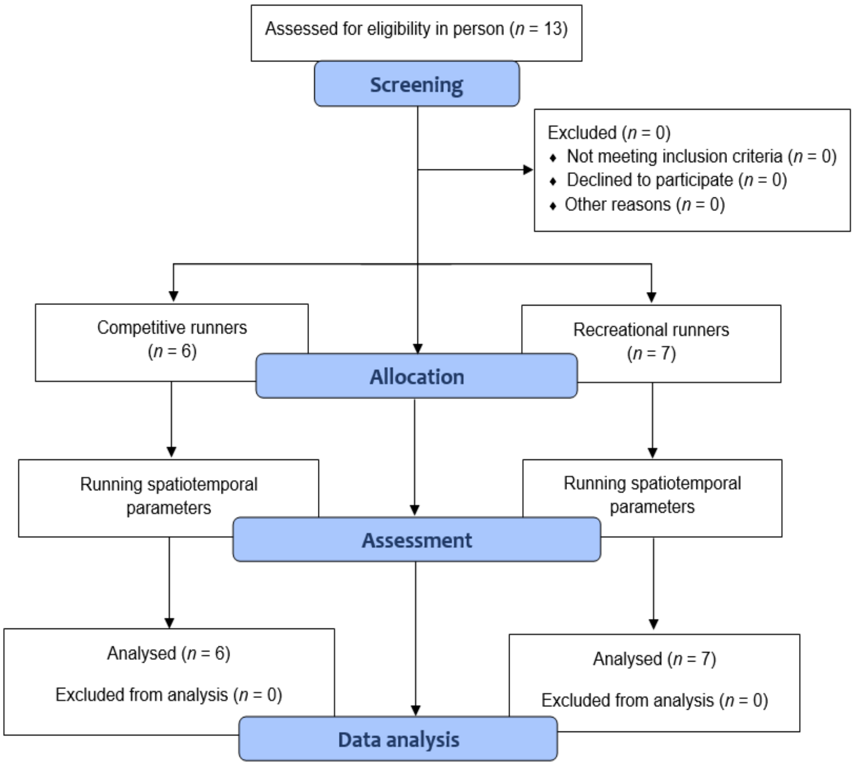

Figure 1. Study flow diagram

(1) no history of lower limb injuries in the past 6 months, (2) ability to run 5 km without stopping and exclusion criteria included (1) any neurological or musculoskeletal disorders affecting gait, (2) current injury or illness that could influence running performance. After receiving detailed information on the objectives and procedures of the study, each participant signed an informed consent form, which complied with the ethical standards of the World Medical Association's Declaration of Helsinki (2013); it was made clear that participants were free to withdraw from the study at any moment. Study flow diagram is presented in Figure 1.

Measurement and instrumentation

Subjects completed a baseline assessment including height, weight, and a brief health questionnaire to record any relevant medical history. Warm-up: 10 minutes of light jogging on a treadmill to ensure participants are sufficiently warmed up. The running biomechanics were assessed using the OptoGait (OptoGait, Microgate, Bolzano, Italy) mounted along the treadmill platform (DRAX REDON NR20 XA, Anyang, Korea). OptoGait is a portable system that can be mounted to a treadmill, to collect data. OptoGait uses high-density photoelectric cells between transmitting and receiving bars with each bar containing 96 LEDs that are positioned 1 centimeter (cm) apart and 3 millimeters (mm) above the base. The bars detect interruptions in light signals to automatically calculate spatiotemporal parameters.9) The automatic calculation of running parameters is clinically desirable and efficient.

The intraclass correlation coefficients for spatiotemporal parameters fell within the range of ICC 0.83~0.99.[10] Compared to high-speed video analysis of running biomechanics, García-Pinillos et al. (2022) found a high level of agreement (ICC > 0.89) in spatiotemporal parameters with the OptoGait system. This suggests that OptoGait offers a reliable means of evaluating spatiotemporal parameters while running on a treadmill, making it a valuable tool for potential utilization in clinical, training, or research environments. Figure 2 shows the running analysis using OptoGait on a treadmill.

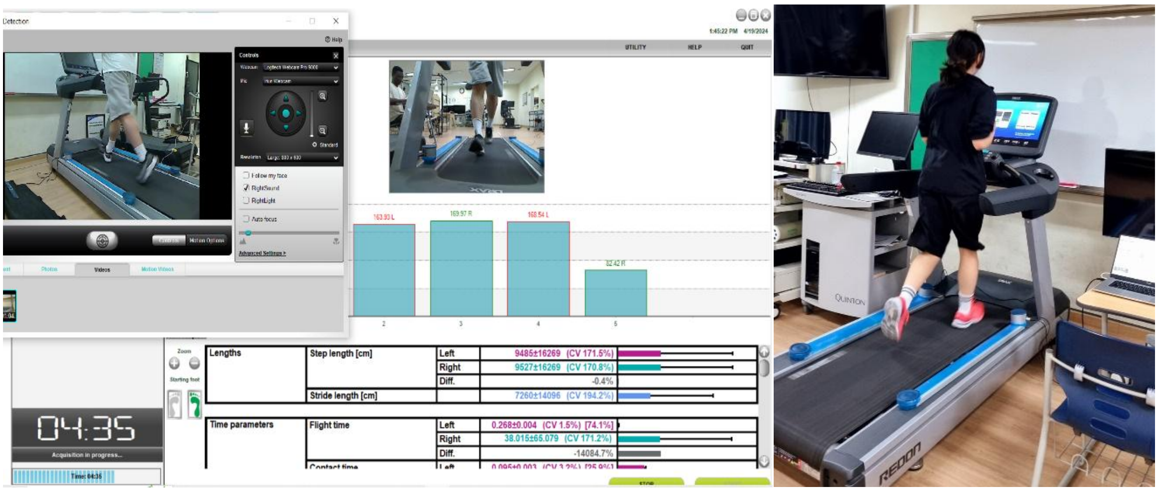

Figure 2. Running analysis

Running procedures

Before the running protocol, participants performed a warm-up, with 5 min of continuous running and 5 min of active joint mobilization and dynamic stretching. Subjects performed three 5-minute running trials on a treadmill set to a standardized speed, which is based on each participant's self-reported average 5 km pace. The treadmill speed was adjusted to ensure moderate intensity, monitored by maintaining the heart rate at 60-70% of the maximum heart rate. During each 5-minute trial, the OptoGait system was record the following parameters: Stride Length: The distance covered in one stride; Contact Time: The duration of foot contact with the ground; Flight Time: The duration of the non-contact phase (when both feet are off the ground). Subjects rested for 5 minutes between trials to prevent fatigue from influencing the results.

Data analysis

Data analysis was performed using SPSS (version 26, SPSS Inc., Chicago, IL, USA) and descriptive statistics are presented as mean and SD. The normal distribution of data and homogeneity of variances were confirmed through the Kolmogorov-Smirnov and Levene´s tests, respectively ($p > 0.05$). An independent sample t-test was conducted to compare the running spatiotemporal outcomes between the competitive and recreationally engaged runners, with the level of significance was set at $p < 0.05$.

III. Findings

Thirteen participants were included in this study, six in the competitive running group and seven in the recreational running group. The mean and standard deviation age were 26.71 ± 6.84 years for the performance-oriented runners and 27.24 ± 5.12 years for the recreationally engaged runners. Their running experience per week was 5.36 ± 1.06 sessions for the competitive group and 3.25 ± 1.12 sessions for the recreational group. Height and weight distribution were statistically similar between both groups, as was their body mass index (BMI). There were no statistically significant differences in age, height, weight, BMI, and running sessions per week at baseline for all the participants. The demographic characteristics of the participants are presented in Table 1.

Table 1. General characteristics of the subjects

	CP runners (n=6)	RC runners (n=7)	*p*-value
Age (years)	26.71±6.84	27.24±5.12	0.265
Body height (cm)	176.1±0.08	176.8±0.11	0.174
Body weight (kg)	74.86±3.35	75.31±2.81	0.098
BMI (kg·m-2)	22.41±1.87	22.72±1.22	0.226
Running experience	5.36±1.06	3.25±1.12	0.056

mean±standard deviation, CP runners: competitive runners, RC runners: recreational runners

Running analysis showed that performance-oriented runners have a lower ground contact duration (0.337 ± 0.001 seconds) and aerial phase duration (0.038 ± 0.001 seconds) compared to the recreationally engaged runners (0.338 ± 0.001 seconds, 0.040 ± 0.001 seconds, respectively). However, the independent sample t-test showed no significant difference between the groups (t = -1.726, p = 0.112 for ground contact duration and t = -1.816, p = 0.097 for aerial phase duration). The competitive running group showed a lower stride displacement (103.50 ± 1.04 cm) compared to the recreational running group (107.29 ± 1.38 cm) with a significant difference between the groups (t = -5.485, p < 0.000). Regarding the cadence, the competitive running group presented a higher cadence (161.00 ± 0.89 steps/min) compared to the recreational running group (157.71 ± 2.05 steps/min) with a significant difference between the groups (t = 3.611, p = 0.005). The angular strike pattern was lower in the competitive running group (0.54 ± 0.01 degree) compared to the recreational running group (0.57 ± 0.01 degree) with a significant difference between the groups (t = -5.490, p < 0.000). The results of the running analysis are presented in Table 2.

Table 2. Comparison of running spatiotemporal parameters between the groups

	CP runners (n=6)	RC runners (n=7)	*t*-value	*p*-value
Contact time (s)	0.337±0.001	0.338±0.001	-1.726	0.112
Flight time (s)	0.038±0.001	0.040±0.001	-1.816	0.097
Step length (cm)	103.50±1.04	107.29±1.38	-5.485	<0.000**
Step frequency (step/min)	161.00±0.89	157.71±2.05	3.611	0.005*
Step angle (°)	0.54±0.01	0.57±0.01	-5.490	<0.000**

mean±standard deviation, CP runners: competitive runners, RC runners: recreational runners

3. INTERPRETATION

The primary objective of this study was to compare the gait parameters of competitive and recreationally engaged runners using OptoGait technology. By analyzing differences in stride length, ground contact duration, aerial phase duration, cadence, and angular strike pattern, we sought to uncover how these biomechanical factors influence running performance and injury risk. Our results reveal significant differences in several gait parameters between the two groups, providing valuable insights into their respective running mechanics and potential injury risks.

One of the most striking findings was the significantly shorter stride length observed in performance-oriented runners compared to recreationally engaged runners. This result is somewhat counterintuitive, as longer stride lengths are often associated with more efficient running and greater speed.19) However, shorter stride lengths can also reduce the impact forces exerted on the lower extremities, potentially lowering the risk of overuse injuries.20) Competitive runners may adopt shorter strides to mitigate injury risks associated with high training volumes and intensities. Moreover, shorter stride lengths can facilitate a higher cadence, which can contribute to improved running economy.21)

Although performance-oriented runners exhibited slightly lower contact and aerial phase durations compared to recreationally engaged runners, these differences were not statistically significant. Reduced ground contact duration is generally indicative of a more efficient running gait, as it suggests a quicker transition between steps and less time spent decelerating during foot-ground contact.22) Similarly, shorter aerial phase durations can imply a more controlled and efficient use of energy, as excessive airtime can lead to higher impact forces upon landing.19) The lack of significant differences in these parameters suggests that both competitive and recreationally engaged runners in this study may have similar ground contact mechanics, despite differences in other gait characteristics.

The performance-oriented runners demonstrated a significantly higher cadence compared to recreationally engaged runners. Higher step frequencies are often associated with better running economy and reduced risk of injury.21) Increased cadence can decrease the vertical oscillation of the center of mass and reduce braking forces, leading to smoother and more efficient running mechanics.23) This finding aligns with the notion that performance-oriented runners, through their intensive training regimens, may develop more optimized gait patterns to enhance performance and minimize injury risk.

Another notable finding was the significantly lower angular strike pattern in performance-oriented runners. The angular strike pattern reflects the orientation of the foot at initial contact with the ground. A lower angular strike pattern can indicate a more midfoot or forefoot strike pattern, which is often associated with reduced loading rates and lower risk of certain types of injuries, such as stress fractures and plantar fasciitis.24) This adaptation may be beneficial for performance-oriented runners, who are likely to experience higher cumulative loading due to greater training volumes. The biomechanical differences observed between competitive and recreationally engaged runners have important implications for injury risk and prevention strategies. Competitive runners, with their higher cadence and lower angular strike pattern, appear to adopt gait patterns that enhance running efficiency and potentially reduce injury risk. However, their shorter stride lengths and intensive training volumes may predispose them to specific overuse injuries, such as tendinopathies and stress fractures.25) Recreational runners, on the other hand, with their longer stride lengths and lower cadence, might be at higher risk for impact-related injuries, such as shin splints and knee pain.20)

This study has several limitations that should be acknowledged. The sample size was relatively small, which may limit the generalizability of the findings. Additionally, the cross-sectional design precludes any conclusions about causality. Longitudinal studies are needed to better understand the causal relationships between gait parameters, running performance, and injury risk. Furthermore, the study focused on a specific age range and excluded individuals with recent injuries, which may limit the applicability of the results to other populations. Future research should explore the effects of various training interventions on gait parameters and injury outcomes in both competitive and recreationally engaged runners. Investigating the role of fatigue, different running surfaces, and footwear on gait mechanics could also provide valuable insights. Additionally, incorporating advanced biomechanical modeling and machine learning techniques could enhance the precision and predictive power of gait analysis.

4. SYNTHESIS

This study highlights significant biomechanical differences between competitive and recreationally engaged runners, particularly in stride length, cadence, and angular strike pattern. These findings underscore the importance of tailored training and injury prevention strategies for different types of runners. By understanding and addressing the unique gait characteristics and injury risks of competitive and recreationally engaged runners, coaches, therapists, and athletes can work together to enhance performance and ensure the long-term health and well-being of runners.

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