Biomechanics of Running: Analyzing Gait for Enhanced Performance

Minh Quang Tran[1]*

Abstract

Running biomechanics, a multidimensional examination of human movement, emerges as a critical connection between science and sport. This study digs into the detailed gait examination, illuminating its far-reaching ramifications for athletes, coaches, and researchers. As runners move across the complex world of biomechanics, their gait transforms into a dynamic painting that reflects forces, movements, and structures. A full gait analysis unlocks the key to peak performance by detecting inefficiencies and correcting mechanics for increased speed and endurance. Aside from the goal of podiums, biomechanics emerges as a critical component in injury prevention. For determine the research used SPSS software and generate result included descriptive statistic, correlation coefficient, the regression analysis also that model summary between them. Gait analysis reveals possible danger factors, allowing runners to fix weaknesses and extend their running careers. The study continues with footwear innovation, in which shoes, guided by gait nuances, develop into personalized instruments that improve comfort and reduce injury risks. This research also emphasizes the collaborative character of biomechanics, which is a joint investigation among coaches, players, and researchers. A never-ending cycle of study and invention propels the field into unexplored territory. Wearable technologies and artificial intelligence-driven analysis are providing real-time feedback, altering how athletes approach training and competition as technology advances. Running biomechanics is a study of empowerment, accuracy, and constant progress. Each stride is a step ahead, not just in the quest for quicker times but also in the ongoing study of human potential. Overall result founded that positive and significant relation between biomechanics related to gait enhanced performance. This research captures the dynamic interaction between science and sport, encouraging more investigation into the complexities of human mobility and performance optimization.

Keywords: Biomechanics (BM), Gait (GG), Enhanced Performance (EP), Multidimensional Examination (ME), Human Movement (HM).

Introduction

Aerobic exercises are getting much attention with the growing awareness about maintaining a healthier lifestyle. These aerobic exercises mainly involve running and walking. But with an increase in practice of these exercises, running injuries are becoming way more common than before. Therefore, to tackle this situation, it is mandatory to know about the biomechanics of running, and by performing a detailed analysis of gait, running performance can be enhanced. Biomechanics of running deals with the mechanical features of human running, involving the study of mutual functioning of muscles, ligaments, tendons, bones, and tissues to offer a stable and enhanced running experience. Different elements of a kinetic chain work synchronously and maintain the running experience (Geiringer, 1995). The foot acts as a connection aid between the ambulatory surface and the remaining elements of the kinetic chain (Xu & Li, 2019). The other three main adaptive functions of the foot include maintenance of position and balance through kinesthesia, adaptation to jagged ground, and control for propulsion. Biomechanics of the foot involves different key features involving foot strike patterns, frequency, stride length, joint movement, running gait cycle, muscle activation, ground reaction forces running surfaces, etc. In the foot strike patterns, three further strikes are involved, i.e., heel strike, forefoot strike, and mid-foot strike (Hollander, Hoenig, & Edouard, 2022). The stride frequency and length involve the number of steps taken per minute and the distance covered through each stride. The joint movement covers three main joints, i.e., hip, ankle, and knee. Then comes the running gait cycle involving the contact time with the ground, followed by muscle activation. In muscle activation, primary running muscles (calves) and core muscles (lower back muscles) are involved. The ground reaction forces deal with the propulsion and impact forces produced during push-off or initial contact time (Van Oeveren et al., 2021). Running is a complicated combination of physiological and mechanical systems that appears to be a simple and natural human action. The biomechanics of running come into play as athletes lace up their shoes and hit the pavement, changing their gait and impacting performance. Understanding the complicated mechanics of this fundamental action is critical for athletes, coaches, and

[1] Vietnam National University, Hanoi, Vietnam.

sports scientists who want to improve performance, avoid injuries, and push the limits of human ability. The study of the mechanical features of living creatures is at the heart of biomechanics, and when applied to running, it digs into the forces, motions, and structures involved in this dynamic activity. Gait analysis, a crucial component of biomechanical research, examines how people use their limbs when walking or running. This thorough evaluation enables the detection of small anomalies, revealing possible inefficiencies or harm hazards. The human body is an engineering wonder, and each component is critical when it comes to operating. Understanding the complicated interaction of bones, muscles, and joints and the energy transmission processes within the body reveals the secrets to unlocking increased running performance. As a result, gait analysis becomes a potent tool for unlocking the mysteries of efficient and sustainable running. The gait cycle has two main stages involving the stance phase and the swing phase. The swing phase is the one in which neither of the feet is in contact with the ground, whereas the stance phase is the one dealing with the point when both feet are touching the ground. In gait analysis, the gait cycle is the vital and basic unit of measurement. The gait cycle starts when the foot first comes in contact with the ground and ends when the same foot touches the ground again. While walking, almost 50% of the gait cycle carries the stance phase, and in running, the toe-off happens before 50% completion of the gait cycle (Novacheck, 1998). Studying the kinetic and kinematic characteristics that determine a runner's gait is a basic part of running biomechanics. Kinetics is the study of forces acting on the body, such as impact forces during foot striking. In contrast, kinematics is the study of motion, such as joint angles and segmental motions. Researchers can construct a thorough picture of the runner's biomechanical profile by scrutinizing these factors, providing significant information for performance development. Foot striking patterns, a hot issue in running biomechanics, has received a lot of attention in recent years. The choice of foot striking, traditionally classified as heel, midfoot, or forefoot, can substantially influence running mechanics and injury risk (Ali et al., 2022). Understanding how different foot striking patterns impact forces and loading rates allows athletes to make informed judgments regarding their running style and equipment. Furthermore, running biomechanics goes beyond the lower limbs. The mechanics of the gait cycle are influenced by the torso, arms, and even the head. Efficient arm swing, for example, can help with balance and coordination, while torso stability helps to reduce energy waste. Athletes can improve their technique by investigating the holistic aspect of running biomechanics, enhancing efficiency and less fatigue (Abdullah et al., 2022). The analysis of gait is crucial in lowering the injury risks while running and hence can elevate the level of performance. Therefore, gait analysis involves an examination of biomechanics for running so that the runner's strength and weak points can be pinpointed and room for modification can be made. For example, alternate gaps of acceleration and deceleration are made during running, termed absorption and generation. These periods are out of phase as compared to toe-off and initial contact time (Dugan & Bhat, 2005). The body's center mass falls from its maximum height during absorption. This period is further divided into respective stance and swing absorption phases by initial contact. As the stance phase is reversed, the stance phase generation occurs, followed by the propelling of center mass in the forward and upward direction. The next phase of absorption begins with the initiation of the swing phase reversal period (Dugan & Bhat, 2005). Different systematic setups are required to observe and examine running and walking for gait analysis. These methods are of wide variety in the modern era and vary from simpler to modern and accurate ones (Higginson, 2009). The simplest of these analysis methods starts with the visual observation in which a trained professional analyzes the gait. This method can be cost effective, but the results are subjectable and of low precision. The next method is video analysis visualization, in which videos of runners/walkers can be analyzed in frame-to-frame dimensions. However, this method can provide only limited and 2-D data (Zugman et al., 2017). Motion capture is another method that overcomes the cons of video analysis as it involves multiple cameras in different directions and hence can provide a 3-D analysis view to the viewer. This function allows it to provide precise data with accurate joint movements, but the method can be expensive and requires special expertise. Force plates are another method for gait analysis and come up with the knowledge of reaction forces acted upon by the ground during each step. It helps to provide information about the contact time of the foot and quantification of parties (Benson et al., 2018). The only con of this instrument is that it is limited to laboratory analysis only and can alter the natural gait patterns. Similarly, pressure-sensitive insoles are placed inside the shoe and the foot pressure distribution is measured to ensure the foot functionality. It is only related to foot pressure and cannot provide information on full-body running mechanics (Turan et al., 2020). Electromyography (EMG) can also be used to measure the electrical signal produced by muscle activation while running. It can help in recording muscle patterns while running, but the method is invasive and requires the attachment of electrodes. Gyroscopes and Accelerators are modern devices that can be used to notify rotation and acceleration of the foot while running. They are cheaper and provide real-time gait analysis but are subjected to joint movement information only. Moreover, marker-less motion capture is another technique that works by recording gait data through computers and does not involve any marker attachments (Napier, Goom, & Rankin, 2020). The choice of method to be used for gait analysis depends on the factors that need to be analyzed, the resources available, and the environment provided. The advantages of gait analysis are many and can range from injury prevention, early detection of issues, footwear recommendation, real-time feedback, running mechanics, enhanced performance, and individualized training to biomechanical efficiency and rehabilitation planning (Phinyomark et al., 2018). By joining multiple methods, a more comprehensive approach can be applied to the analysis of gait so that an improved routine can be ensured.

Literature Review

Researchers claim that running is a form of exercise that provides great physical and mental health benefits. but despite the tremendous health benefits of running, it increases the risk of Musco-Skeletal injury. running biomechanics is an approach used to understand the risk factors involved in causing injury. also, Gait running is a biomechanics-related approach that helps in the identification process of injury-associated risk factors. The gait running biomechanics approach is used clinically to assess the inured runners' health condition (Gaudette et al., 2022). Studies suggest that the gait running approach is specialized to assess risk factors the individual runner faces.by wearing advanced gait easement, the running performance of sports athletes improves (Adhaye et al., 2023). Studies show that various runner athletes have different running potentials. the dynamics of the running ability of players determine their performance as a running athlete (Bernans, 2023). Studies explain that error related to measurement is observed using the PPMS during the running-based protocol. the wireless pressure measuring system is used during the benchtop testing (Blades et al., 2023).

The surfaces on which runners train and compete are also important in biomechanics. The connection between the foot and the ground governs the forces sent through the body, whether on a track, trail, or treadmill. Impact forces, joint loads, and even the probability of certain injuries can all be affected by surface changes. As a result, an in-depth examination of running biomechanics should consider runners' environmental circumstances. Technological advancements have transformed the subject of biomechanics, giving researchers the instruments to capture and analyze movement with unparalleled accuracy. Three-dimensional motion analysis, force plates, and wearable sensors are just a few of the technologies that have ushered in the current era of gait analysis. These systems capture data in real-time, allowing athletes and coaches to make quick modifications for peak performance. Biomechanics improves performance and plays an important role in injury prevention. Identifying movement patterns that create undue stress on certain joints or muscles enables focused therapies such as strength training or remedial exercises (Ab-Rahim et al., 2021). A proactive approach to biomechanics can help athletes avoid overuse problems and extend their running careers. studies explain that novice runners lack skillful running efficiency.to improve the running skills of athletes, they are trained to run on a treadmill. While running on the treadmill, the runners listen to music that helps them to improve their running skills. The GRF increases in novice treadmill runners.

Also, the non-fatigue condition faced by novice treadmill runner's increases injury risk in them. using the running gait approach for analyzing or measuring the SW holds importance (Cunningham & Zordan, 2023). Studies suggest that using wearable technology in the sports field is essential for improving athletes' performance. technology-based running shoes are developed to enhance running sports athletic performance. the biomechanical movements performed by running athletes are observed using virtual reality-based techniques .these virtual reality wearable techniques are cost-effective and provide efficient results about the athlete physical performance (Dorschky, 2023; Yang, 2022). Furthermore, to engage the runner athletes in high-intensity sports, RSPs are used as a biomechanical technique. athletes with lower limb amputations engage in high-intensity spirits using the RSPs (Hadj-Moussa, Ngan, & Andrysek, 2022). Studies of scholars reveal that the running shoes are made using modern technology to evaluate the biomechanics behind the treadmill runner. The familiarization time can be estimated by assessing the lower limb movement of treadmill runners (Huang et al., 2023). Studies suggest that neuromuscular coordination found in runners is identified using the dynamic movement stimulation technique. Neuromuscular movements due to skeletal muscle coordination help assess athletic performance ability. For identifying the Musco-skeletal based structure, the use of open SIM software is made in sports file. The open Sim software allows the creation of human models for assessing the range of athletic movements (Jiang & Bíró, 2023; Wu, 2023). Studies explain that bone health is related to bone stress. the stress on bone results in injury and increases the risk of bone damage. Different models are used to estimate the extent of bone injury in running athletes. The vertical COM displacement model is the best model used for identifying bon-related injury risk (Joachim, Kliethermes, & Heiderscheit, 2023). Studies highlight that running gait is an analysis tool for efficient performance evaluation. The risk of injury in athletes is identified using the running gait analysis tool.in different environments, the use of running gait techniques have been made for assessing different game-related tactics (Mason, Godfrey, et al., 2023). Studies determine that laboratory-based technologies are used for assessing the running gait-related performance of athletes. Using their dimensional movement capturing technique is an efficient technique for analyzing the running skills of athlete. continuous monitoring of athletes provides on-time information regarding any injury condition faced by athlete (Mason, Pearson, et al., 2023). Studies predict that for improving the physical performance of athlete, running is considered one of the important exercises. despite the advancement in the technology-based running tools, the injury risk due to running is still higher. By improving the biomechanical characteristics of running athletes, the chance of injury onset in these athletes is reduced. The risk factor associated with running athlete injury is the Foot strike pattern. Disturbing these patterns results in injury (Cao, 2024; Molina Molina, 2023). Studies claim that running is a sport that people of any age group can perform. running is beneficial for athletic health, but the risk of injury occurrence in runners is higher. The evaluation of the mechanics behind running helps identify the cause of injuries.

The technique used for identifying running mechanics is video gait technology. This technique uses video images to assess the motion of specific body parts of runners (Pipkin & Heiderscheit, 2023). Scholars explained that the Design of background interval training is influenced by different factors This type of interval training affects the kinetics of running-based patterns. the gait patterns are affected by the acute effects of interval training as it changes the endurance of runners. Also, the cardio metabolic factors are monitored using the running gait analysis technique for improving the fatigue condition faced by runner (Rodríguez-Barbero et al., 2023). Studies elaborate that the design of each running shoe for runners has its unique effects on the running performance of athletes.

The ability of the athlete to improve his ruining skill depends upon his shoe quality. The better the shoe quality, the better the ability of the runner to exhibit his running skill during competition (Ruiz-Alias et al., 2023). Studies reveal that with time, the trend of running sports has increased in adolescents. this increase in running sports create the need for understanding the running gait mechanism. the running mechanism in every individual varies, which results in variability in the athlete's running pattern (Sudlow et al., 2023). Studies predict that motion-capturing technology provides great applications for assessing the biomechanics ability of athletes. The lower body movement of runners is essential for their better performance in the sports field. the motion-capturing technique helps identify the runner's lower body movement (Tang, 2023). Studies claim that running-related injuries are analyzed using the running analysis-based screening technique. Furthermore, for investigating inter-rater reliability, the gait analysis technique is used in clinical practices (Tripodi et al., 2023). Studies explain that to use the most appropriate gait technique, the features of various gait running techniques are analyzed. the gait running technique with optimized features is used for recognizing the patterns of movement of runners (Xu et al., 2023). Studies highlight that the running posture of athlete is determined using the rod model. The accuracy of speed running athletes is identified to optimize athlete posture (Yang, Shi, & Huang, 2023).

Table 1

Results of Descriptive Statistics

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Biomechanics 1	60	1.00	4.00	1.7167	.78312
Biomechanics 2	60	1.00	4.00	2.1000	.91503
Biomechanics 3	60	1.00	3.00	1.5500	.59447
Gait 1	60	1.00	5.00	2.1000	.93337
Gait 2	60	1.00	4.00	1.7667	.72174
Enhanced Performance 1	60	1.00	4.00	1.6833	.72467
Enhanced Performance 2	60	1.00	3.00	1.9333	.75614
Enhanced Performance 3	60	1.00	4.00	1.9667	.82270
Valid N (List Wise)	60				

The above results of Table 1 describes that descriptive statistical analysis shows that minimum value, maximum values, the mean values, and the standard deviation rates of each indicator. The biomechanics 1,2 and 3 its consider as independent variables according to the result the mean values are 1.7167, 2.1000 and 1.55000 its shows that positive average value of mean rates. The standard deviation rates are 0.78, 0.91, and 0.59 its shows that 78%, 59% and 91% deviate from the mean. The gait1,2 is considered a mediator value. According to the results, the mean values are 2.1000 and 1.7667, presenting positive rates. The standard deviation rates are 93%, and 72% deviate from the mean.

According to the result, the enhanced performance is considered as a dependent variable. The mean values are 1.6833, 1.9333, and 1.9667. These all show positive average rates; the standard deviation rates are 72%, 75%, and 82%, which deviate from mean values. According to the result overall minimum rate is 1.000 the maximum rate is 4.000 the number of observation is 60 respectively.

Table 2

Results of Correlations

Correlations

		Biomechanics 1	Biomechanics 2	Biomechanics 3	Gait 1	Gait 2	Enhanced Performance 1	Enhanced Performance 2	Enhanced Performance 3
Biomechanics 1	Pearson Correlation	1	.206	-.351**	.179	-.059	.407**	.139	.222
	Sig. (2-tailed)		.115	.006	.172	.654	.001	.288	.088
	N	60	60	60	60	60	60	60	60
Biomechanics 2	Pearson Correlation	.206	1	-.259*	.107	.036	-.105	-.235	.185
	Sig. (2-tailed)	.115		.046	.415	.785	.426	.070	.158
	N	60	60	60	60	60	60	60	60
Biomechanics 3	Pearson Correlation	-.351**	-.259*	1	.082	-.012	-.022	.045	-.066
	Sig. (2-tailed)	.006	.046		.531	.928	.870	.731	.617
	N	60	60	60	60	60	60	60	60
Gait 1	Pearson Correlation	.179	.107	.082	1	-.216	.273*	.442**	.380**
	Sig. (2-tailed)	.172	.415	.531		.097	.035	.000	.003
	N	60	60	60	60	60	60	60	60
Gait 2	Pearson Correlation	-.059	.036	-.012	-.216	1	-.176	.126	-.070
	Sig. (2-tailed)	.654	.785	.928	.097		.178	.336	.593
	N	60	60	60	60	60	60	60	60
Enhanced Performance 1	Pearson Correlation	.407**	-.105	-.022	.273*	-.176	1	.363**	-.103
	Sig. (2-tailed)	.001	.426	.870	.035	.178		.004	.432
	N	60	60	60	60	60	60	60	60
Enhanced Performance 2	Pearson Correlation	.139	-.235	.045	.442**	.126	.363**	1	.187
	Sig. (2-tailed)	.288	.070	.731	.000	.336	.004		.152
	N	60	60	60	60	60	60	60	60
Enhanced Performance 3	Pearson Correlation	.222	.185	-.066	.380**	-.070	-.103	.187	1
	Sig. (2-tailed)	.088	.158	.617	.003	.593	.432	.152	
	N	60	60	60	60	60	60	60	60

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The above results of Table 2 determine that correlation coefficient analysis result describe Pearson correlation also that significant analysis. The enhanced performance shows that 13% positive and significant correlation between them. according to the result some negative and some positive correlation between them. The constant advancement of technology in biomechanics gives up new avenues for research and application. Athletes receive real-time input via wearable devices, sensor technologies, and artificial intelligence-driven analytics. This improves training and allows athletes to make quick changes during events. Biomechanics allows for continual performance monitoring. Athletes may measure changes in their gait over time, allowing them to discover possible concerns or improvements early on. This long-term strategy to performance monitoring helps athletes achieve sustained success and longevity in their careers. The scientific community will benefit from biomechanical studies in running. The information acquired helps our understanding of human mobility and may be used to inform research in domains such as orthopedics, physical therapy, and rehabilitation sciences. This multidisciplinary approach encourages collaboration and the creation of novel solutions. In summary, studying the biomechanics of running has transformational implications for sports performance, injury treatment, and our knowledge of human mobility. As technology advances, the potential for new discoveries and applications in this sector remains bright, providing exciting opportunities for athletes, researchers, and the sporting community as a whole.

Table 3

Results of Model Summary

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.513[a]	.263	.195	.65026

a. Predictors: (Constant), Gait 2, Biomechanics 3, Gait 1, Biomechanics 2, Biomechanics 1

The above results of Table 3 describes that model summary results represent R values and also that R square of model 1. According to the result, its present adjusted R square values and the standard error of the estimate rates between them. The R rate is 0.513, the R square value is 0.263 the adjusted R square rate is 0.195, and the standard error of the estimated value is 0.65026 its shows that 65% error of the estimate rates between them.

Implications

Exploring the biomechanics of running and analyzing gait for improved performance has far-reaching and far-reaching ramifications across several fields. Let's look at some of the most important implications:

Sports Performance Enhancement

The first implication is sport performance enhancement research Understanding running biomechanics helps athletes and coaches to fine-tune training plans for peak performance. Athletes can improve their running efficiency and speed by recognizing inefficient movement patterns and working on focused treatments to improve their gait.

Injury Avoidance

One of the most major consequences is injury prevention. The injury avoidance is another implication related to the performance. Gait analysis can aid in identifying biomechanical issues that may contribute to overuse injuries. Athletes can then follow specialized training programs or make changes to their running form to lessen the risk of problems, including stress fractures, shin splints, and the runner's knee.

Individualized Training Programs

Gait analysis offers personalized insights into a person's running mechanics. The individualized training program is another important implication related to the sport performance. This enables training programs to be tailored to an athlete's specific biomechanical profile. Tailored therapies can correct individual deficits or imbalances, such as strength training, flexibility exercises, or running technique improvements.

Innovation in Footwear

Running shoe design and development rely heavily on biomechanical studies. The innovation in footwear is basic implication related to the sport performance. Gait analysis insights lead to the development of footwear that accommodates various foot strike patterns and running styles. This, in turn, can improve comfort, reduce tiredness, and lessen the risk of injuries linked with poor shoe selection.

Rehabilitation Techniques

Understanding biomechanics is critical for injured athletes in establishing efficient rehabilitation programs. By detecting compensatory movements or imbalances that may have contributed to the injury, gait analysis can help guide rehabilitation efforts. This tailored strategy makes the recuperation process more efficient.

Education in Coaching and Training

Biomechanical insights are extremely beneficial to coaches and trainers. It enables them to teach athletes optimal running mechanics and form, improving communication and understanding between coach and athlete. Coaches who have received training may implement evidence-based training practices, creating a collaborative approach to performance development.

Table 4

Results of Coefficients

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.079	.504		2.142	.037
	Biomechanics 1	.396	.119	.428	3.328	.002
	Biomechanics 2	-.153	.097	-.194	-1.575	.121
	Biomechanics 3	.075	.158	.062	.478	.635
	Gait 1	.148	.096	.190	1.537	.130
	Gait 2	-.102	.120	-.102	-.850	.399

a. Dependent Variable: Enhanced Performance 1

The above results of Table 4 describes that coefficient analysis called regression analysis result presents that unstandardized coefficient analysis, the beta value, and standard error value of each independent variable. the result describes the t-statistic rate and significant value of independent variables. The Biomechanics 1,2 and 3 show that the beta values of the unstandardized coefficient are 0.396, -0.153, and 0.075.

The standard error rates are 0.119, 0.097, and 0.158. Its shows 11%, 9%, and 15% error rates. The t-statistic values are 3.328, -1.575, and 0.475, showing some positive and some negative links between them. The significant values are 0.002, 0.121 and 0.635 shows that 2%, 12% and 63% significant analysis between them. The gait 1, and 2 represent the mediator variables its shows that beta values are 0.148, -0.102 the t statistic rates are 1.537, and -0.850 respectively. The significant values are 0.130 and 0.399, showing that there are 13% and 39% significant values between them.

Table 5

Results of Test Statistics

Test Statistics								
	Biomechanics 1	Biomechanics 2	Biomechanics 3	Gait 1	Gait 2	Enhanced Performance 1	Enhanced Performance 2	Enhanced Performance 3
Chi-Square	30.000[a]	12.000[a]	21.900[b]	38.167[c]	34.667[a]	36.133[a]	3.100[b]	24.933[a]
Df	3	3	2	4	3	3	2	3
Asymp. Sig.	.000	.007	.000	.000	.000	.000	.212	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.0.
b. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 20.0.
c. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 12.0.

The above results of Table 5 describes the test statistic related to the chi-square analysis of each indicator. The result shows that chi square values are 30.00, 12.000, 21.900, and chi-square rates of biomechanics 1,2, and 3. Gait 1 and 2 show 38.167 and 34.667, respectively. The enhanced performance 1,2, and 3 are considered dependent variables. Its chi square values are 36.133, 3.100, and 24.933, respectively, showing positive chi squares between them. according to the result, the significant rate is 0.000, which shows 100% significant values between them.

Conclusion

Finally, investigating the biomechanics of running and the subtle study of gait for improved performance opens the door to many advantages in sports, science, and personal well-being. As we explore this complex landscape of human mobility, several major implications arise, emphasizing the enormous effect of knowing and applying biomechanical truths. The intersection of science and sport in running biomechanics provides a road map for athletes seeking peak performance. Athletes may improve their running mechanics by decoding the intricate interaction of forces, movements, and structures. This results in enhanced efficiency, speed, and endurance. This knowledge becomes a powerful tool for coaches and trainers, allowing them to design personalized training regimens and treatments corresponding to individual athletes' biomechanical characteristics. Importantly, the ramifications exceed the desire for quicker speeds and greater podium finishes. Running biomechanics emerges as a cornerstone in the domain of injury prevention. Identifying possible risk factors with gait analysis enables athletes to address weaknesses proactively, resulting in long, sustainable careers. It becomes an important participant in rehabilitation, leading patients via individualized recovery procedures based on a thorough grasp of their biomechanical complexities. For determine the research study used SPSS software and generate informative results included descriptive statistic, correlation coefficient analysis, the model summary, also that explain the regression analysis between them.

Another important effect is footwear innovation, which demonstrates the biomechanical narrative's versatility. Running shoes influenced by gait analysis grow into personalized instruments that improve comfort, performance, and reduce the risk of injury. This not only improves the athlete's experience, but it also fuels the continuous conversation between technology and human potential. In a larger sense, running biomechanics serves as a catalyst for education and collaboration. Coaches, players, and scholars collaborate on an examination of human movement that fosters a deeper knowledge that transcends individual objectives. The never-ending cycle of study and invention pulls the area ahead, revealing new aspects of knowledge and applications that spread across other fields. The technology environment promises further disclosures as we move forward. Wearable gadgets and AI-powered analytics serve as beacons of real-time feedback and fast modifications, altering the way athletes approach training and competition.

Running biomechanics is thus not a static discipline but a dynamic force moving us into unexplored regions of human performance. the overall research concluded that positive and significant relation between them. Finally, running biomechanics is an enthralling topic that combines science with athletics, providing a greater knowledge of the mechanics that drive human movement. Gait analysis is a valuable tool for athletes and coaches because it provides insights into running mechanics that may lead to improved performance and injury avoidance. As technology advances, the future of biomechanics promises even more accuracy and personalized insights, pushing the limits of human ability in quest of quicker, more efficient, and sustainable running. In summary, running biomechanics is a study of empowerment a research that provides athletes with information, coaches with insights, and the scientific community with paths for investigation. It's a narrative about accuracy, personalization, and the never-ending pursuit of greatness. Each stride becomes a step forward through this lens, not just in the chase of quicker times, but also in the ongoing growth of our understanding of what it means to be a runner.

Reference

Ab-Rahim, S. N., Tuan-Ismail, T. S., Ibrahim, H. A., & Hassan, M. N. (2021). High peak of carbamylated hemoglobina discordant with urea level: a case report. *Jornal Brasileiro de Patologia e Medicina Laboratorial, 57*, 1-5. https://doi.org/10.5935/1676-2444.20210029

Abdullah, A. H. J., Abdullah, S. A., Ziyadi, M. S. F., & Al-Faiz, N. A. (2022). Investigation of changes in the fish assemblage building and abundance in the Garmat Ali River, Southern Iraq. *FishTaxa-Journal of Fish Taxonomy, 25*, 31-40. https://fishtaxa.com/menuscript/index.php/ft/article/view/80

Adhaye, A. M., Jolhe, D. A., Loyte, A. R., Devarajan, Y., & Thanappan, S. (2023). Biomechanical investigation of tasks concerning manual materials handling using response surface methodology. *Scientific Reports, 13*(1), 16718. https://doi.org/10.1038/s41598-023-43645-2

Ali, A. A., Malak, O. A., Salem, K., Alkhoury, G., Sridharan, N., Chaer, R. A., & Avgerinos, E. D. (2022). Acute Deep Vein Thrombosis Involving the Inferior Vena Cava: Interventional Perspectives. *Vascular & Endovascular Review, 5*, e04. https://doi.org/10.15420/ver.2021.08

Benson, L. C., Clermont, C. A., Bošnjak, E., & Ferber, R. (2018). The use of wearable devices for walking and running gait analysis outside of the lab: A systematic review. *Gait & Posture, 63*, 124-138. https://doi.org/10.1016/j.gaitpost.2018.04.047

Bernans, E. (2023). Assessing changes in running kinematics at different intensities: a case study. *Journal of Physical Education and Sport, 23*(5), 1279 - 1286. https://doi.org/10.7752/jpes.2023.05157

Blades, S., Jensen, M., Stellingwerff, T., Hundza, S., & Klimstra, M. (2023). Characterization of the Kinetyx SI Wireless Pressure-Measuring Insole during Benchtop Testing and Running Gait. *Sensors, 23*(4), 2352. https://doi.org/10.3390/s23042352

Cao, W. (2024). Chinese Characters and Cultural Inheritance: Exploring the Important Role of Chinese Characters in the Inheritance of Chinese Culture. *Cultura, 21*(1), 345-355. https://culturajournal.com/submissions/index.php/ijpca/article/view/14

Cunningham, N. J., & Zordan, R. (2023). Listening to music while running does not impair lateral balance or increase ground impact forces in non-fatigued novice treadmill runners. *Research Square*, 1-12. https://doi.org/10.21203/rs.3.rs-3031553/v1

Dorschky, E. (2023). *Optimal Control and Machine Learning in Biomechanics: Hybrid Models for Inertial Sensor-based Gait Analysis and Virtual Footwear Testing* [Doctoral Dissertation, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)]. https://open.fau.de/handle/openfau/21325

Dugan, S. A., & Bhat, K. P. (2005). Biomechanics and analysis of running gait. *Physical Medicine and Rehabilitation Clinics, 16*(3), 603-621. https://doi.org/10.1016/j.pmr.2005.02.007

Gaudette, L. W., Bradach, M. M., de Souza Junior, J. R., Heiderscheit, B., Johnson, C. D., Posilkin, J., Rauh, M. J., Sara, L. K., Wasserman, L., & Hollander, K. (2022). Clinical Application of Gait Retraining in the Injured Runner. *Journal of Clinical Medicine, 11*(21), 6497. https://doi.org/10.3390/jcm11216497

Geiringer, S. R. (1995). The biomechanics of running. *Journal of Back and Musculoskeletal Rehabilitation, 5*(4), 273-279. https://doi.org/10.3233/BMR-1995-5404

Hadj-Moussa, F., Ngan, C. C., & Andrysek, J. (2022). Biomechanical factors affecting individuals with lower limb amputations running using running-specific prostheses: A systematic review. *Gait & Posture, 92*, 83-95. https://doi.org/10.1016/j.gaitpost.2021.10.044

Higginson, B. K. (2009). Methods of Running Gait Analysis. *Current Sports Medicine Reports, 8*(3), 136-141. https://doi.org/10.1249/JSR.0b013e3181a6187a

Hollander, K., Hoenig, T., & Edouard, P. (2022). Biomechanics of running. In *The Running Athlete: A Comprehensive Overview of Running in Different Sports* (pp. 3-11). Springer. https://doi.org/10.1007/978-3-662-65064-6_1

Huang, M., Mo, S., Pak-Kwan Chan, P., Chan, Z. Y., Zhang-Lea, J. H., & Cheung, R. T. (2023). The influence of running shoes on familiarization time for treadmill running biomechanics evaluation. *Sports Biomechanics, 22*(3), 459-472. https://doi.org/10.1080/14763141.2022.2046144

Jiang, X., & Bíró, I. (2023). Muscle force estimation in running gait analysis after a prolonged running session via OpenSim. In *2023 4th International Conference on Computer Engineering and Application (ICCEA)* (pp. 498-502). IEEE. https://doi.org/10.1109/ICCEA58433.2023.10135503

Joachim, M. R., Kliethermes, S. A., & Heiderscheit, B. C. (2023). Preseason Vertical Center of Mass Displacement During Running and Bone Mineral Density Z-Score Are Risk Factors for Bone Stress Injury Risk in Collegiate Cross-country Runners. *Journal of Orthopaedic & Sports Physical Therapy, 53*(12), 761-768. https://doi.org/10.2519/jospt.2023.11860

Mason, R., Godfrey, A., Barry, G., & Stuart, S. (2023). Wearables for running gait analysis: A study protocol. *PLoS One, 18*(9), e0291289. https://doi.org/10.1371/journal.pone.0291289

Mason, R., Pearson, L. T., Barry, G., Young, F., Lennon, O., Godfrey, A., & Stuart, S. (2023). Wearables for running gait analysis: A systematic review. *Sports Medicine, 53*(1), 241-268. https://doi.org/10.1007/s40279-022-01760-6

Molina Molina, A. (2023). *Biomechanical assessment and efficacy of the implementation of running retraining programs in long distance runners* [Doctoral dissertation, University of Granada]. https://hdl.handle.net/10481/80701

Napier, C., Goom, T., & Rankin, A. (2020). Infographic. Remote running gait analysis. *British Journal of Sports Medicine, 55*(9), 512-513. https://doi.org/10.1136/bjsports-2020-102994

Novacheck, T. F. (1998). The biomechanics of running. *Gait & Posture, 7*(1), 77-95. https://doi.org/10.1016/S0966-6362(97)00038-6

Phinyomark, A., Petri, G., Ibáñez-Marcelo, E., Osis, S. T., & Ferber, R. (2018). Analysis of big data in gait biomechanics: Current trends and future directions. *Journal of Medical and Biological Engineering, 38*(2), 244-260. https://doi.org/10.1007/s40846-017-0297-2

Pipkin, A., & Heiderscheit, B. (2023). Clinical Aspects of Running Gait Analysis. In *Endurance Sports Medicine: A Clinical Guide* (pp. 269-284). Springer. https://doi.org/10.1007/978-3-319-32982-6_15

Rodríguez-Barbero, S., González-Mohíno, F., Carranza, V. R., Santos-Garcia, D. J., Boullosa, D., & González-Ravé, J. M. (2023). Acute effects of interval training on running kinematics in runners: A systematic review. *Gait & Posture, 103*, 19-26. https://doi.org/10.1016/j.gaitpost.2023.04.009

Ruiz-Alias, S. A., Molina-Molina, A., Soto-Hermoso, V. M., & García-Pinillos, F. (2023). A systematic review of the effect of running shoes on running economy, performance and biomechanics: analysis by brand and model. *Sports Biomechanics, 22*(3), 388-409. https://doi.org/10.1080/14763141.2022.2089589

Sudlow, A., Galantine, P., Vercruyssen, F., Peyrot, N., Raymond, J.-J., & Duché, P. (2023). Which Factors Influence Running Gait in Children and Adolescents? A Narrative Review. *International Journal of Environmental Research and Public Health, 20*(5), 4621. https://doi.org/10.3390/ijerph20054621

Tang, H. (2023). Comparison Marker-Based and Markerless Motion Capture Systems in Gait Biomechanics During Running. *Electronic Theses and Dissertations*, 2611. https://digitalcommons.georgiasouthern.edu/etd/2611

Tripodi, N., Dagiandis, T., Hameed, A., Heilberg, L., Olbinski, E., Reid, C., White, A., & McLaughlin, P. (2023). Inter-rater reliability between osteopaths of differing clinical experience on sagittal plane running gait analysis: A pilot study. *International Journal of Osteopathic Medicine, 47*, 100653. https://doi.org/10.1016/j.ijosm.2022.11.006

Turan, C., Ali, U., Gürlek, M., & Doğdu, S. A. (2020). DNA Barcodes for Identifications of Two Lionfish Species Pterois miles (Bennett, 1828) and Pterois volitans (Linnaeus, 1758) in the Mediterranean. *FishTaxa, 16*, 29-36. https://fishtaxa.com/menuscript/index.php/ft/article/view/24

Van Oeveren, B. T., de Ruiter, C. J., Beek, P. J., & van Dieën, J. H. (2021). The biomechanics of running and running styles: a synthesis. *Sports Biomechanics, 23*(4), 1-39. https://doi.org/10.1080/14763141.2021.1873411

Wu, H. (2023). A Case Study of the Sustainability Narratives in the 2022 Beijing Winter Olympics. *Cultura, 20*(1), 189-201. https://doi.org/10.3726/CUL012023.0015

Xu, D., Zhou, H., Quan, W., Jiang, X., Liang, M., Li, S., Ugbolue, U. C., Baker, J. S., Gusztav, F., & Ma, X. (2023). A new method proposed for realizing human gait pattern recognition: Inspirations for the application of sports and clinical gait analysis. *Gait & Posture, 107*, 293-305. https://doi.org/10.1016/j.gaitpost.2023.10.019

Xu, Y., & Li, Y. (2019). The Fate of the Superior Mesenteric Artery in Fenestrated Endovascular Repair of Complex Abdominal Aortic Aneurysms. *Vascular & Endovascular Review, 2*, 38-39. https://doi.org/10.15420/ver.2019.1.1

Yang, Q. (2022). Canonization and Variations of Shakespeare's Work in China. *Cultura, 19*(2), 115-129. https://doi.org/10.3726/CUL022022.0008

Yang, Y., Shi, B., & Huang, X. (2023). Running Posture Optimization in the Process of Track and Field Sports Based on Biomechanical Principle. *Research Square*, 1-19. https://doi.org/10.21203/rs.3.rs-3291609/v1

Zugman, M., Guesser, M. W., Collaço, L. M., & Sebastião, A. P. M. (2017). Comparison of cythopathology and frozen section methods in the intraoperative evaluation of breast sentinel lymph node. *Jornal Brasileiro de Patologia e Medicina Laboratorial, 53*, 276-280. https://doi.org/10.5935/1676-2444.20170044