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Manual comparison of Gait Pattern analysis in Normal and Abnormal conditions (Limping and Weight Carrying)

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Abstract

Gait evaluation is an important area of biomechanics and forensic science used to study walking patterns under different physical conditions. The gait parameters, including step duration, stride length, cadence, walking time, and overall step pattern, were manually recorded under three different walking conditions: normal walking, limping, and walking while carrying weight. A quasi experimental within subject design was used with 30 healthy female participants aged 19–26 years from Viddyottama Girls Hostel, Ujjain. Gait parameters such as step length, stride length, cadence, walking time, and total steps were measured manually. The findings showed that limping caused the greatest changes in gait, while weight carrying produced smaller effects. The study highlights manual gait evaluation as a practical and low-cost method for gait analysis.

Keywords: Gait Analysis, Normal and Abnormal Gait, Limping Gait, Weight-Carrying Walking, Cadence, Step Length, Stride Length, Biomechanics, Forensic Gait Analysis, Manual Gait Assessment.

Introduction

Background of the Study: Gait is the way someone walks, which includes the motion and coordination of different body elements during on foot. This is considered an important indicator of balance, posture, coordination, and human locomotion[1]. Gait analysis is the study of walking patterns and is widely used in biomechanics, rehabilitation, sports science, and forensic investigations to understand normal and abnormal movement[2]. Earlier gait studies mainly relied on visual observation, while modern methods use motion capture systems and computerized tools for detailed analysis[3]. However, manual gait analysis is still useful because it is simple, affordable, and suitable for studies conducted in resource limited settings[4].

Important gait parameters include step duration, stride length, cadence, walking time, and the overall pattern of steps during walking. Changes in these parameters may indicate movement abnormalities caused by injury, fatigue, limping, or carrying additional weight[5].

Recent studies have suggested that abnormal walking conditions such as limping and carrying additional weight can significantly affect gait performance. Researchers observed changes in step length, stride length, cadence, and walking efficiency under altered gait conditions[18,19].

Recent studies suggest that unusual walking conditions, such as limping and carrying loads, can significantly affect cadence, stride length, balance, and overall walking efficiency[16,17].

Existing Evidence: Previous research has shown that limping affects walking symmetry, posture, and movement efficiency[6]. Weight carrying has also been found to influence balance, walking speed, and step characteristics because of increased physical load[7]. Although advanced gait analysis systems provide accurate biomechanical data, they are expensive and not always accessible. Researchers have reported that simple manual measurements such as cadence, stride length, and walking speed can still provide meaningful information about human movement[5].

Research Gap: Many existing studies focus on clinical patients, elderly populations, or laboratory-based gait analysis systems. Limited research has examined manual gait analysis among healthy young adults in India, particularly female students. In addition, very few studies compare normal walking, limping, and weight carrying together using low cost manual methods. Therefore, the present study attempts to address this gap through practical gait evaluation in a real-life setting.

Research Objective: The study aims to compare gait parameters under normal walking, limping, and weight-carrying conditions using manual gait analysis techniques. The gait parameters measured in the study included step length, stride length, cadence, walking time, and the total number of steps taken during walking.

Scope: This study was conducted on healthy female students aged 19–26 years residing in Viddyottama Girls Hostel, Ujjain, Madhya Pradesh. Manual tools such as measuring tape, stopwatch, and footprint analysis were used for gait assessment under different walking conditions.

Literature review: Overview of Gait Pattern Analysis: Gait analysis refers to the examination of the way people walk and body movement during locomotion[2]. It is widely used in biomechanics, rehabilitation, sports science, orthopaedics, and forensic science to evaluate posture, balance, coordination, and movement efficiency[3]. Human gait is a complex activity that involves proper coordination between muscles, joints, the nervous system, and skeletal structures[8]. A normal gait pattern allows smooth forward movement with balanced and symmetrical limb motion while using minimum energy[1].

The study of gait originally began through simple visual observation by physicians and anatomists. With developments in biomechanics and technology, advanced systems such as motion-capture devices, force plates, and pressure-sensitive walkways were introduced for detailed gait assessment[9]. Although these technologies provide highly accurate biomechanical data, manual gait analysis continues to remain useful because it is affordable, simple, and suitable for field-based studies and resource-limited environments[4].

Several important gait parameters are commonly measured during gait evaluation. Step length is the distance covered between the point where one foot touches the ground and the point where the opposite foot makes contact[2]. Stride length is the distance covered between two consecutive placements of the same foot and, during normal walking, it is usually equal to twice the step length[1]. Cadence is the number of steps a person takes in one minute and helps in assessing walking rhythm and speed[7]. Walking time measures the duration required to cover a fixed distance and reflects overall gait efficiency[5]. Alterations in these parameters may indicate abnormal gait caused by injury, pain, fatigue, neurological disorders, or carrying additional weight[8].

Previous Research on Normal and Abnormal Gait: Many researchers have studied the biomechanical characteristics of normal and abnormal gait patterns. Perry and Burnfield described normal gait as a coordinated process involving stable posture, efficient weight transfer, and symmetrical movement of the lower limbs[2]. Their study highlighted step length, stride length, cadence, and walking speed as key factors used in gait assessment.

Research on abnormal gait shows that limping significantly affects walking symmetry and movement efficiency. Limping gait often causes reduced step length, slower walking speed, shorter stance time, and increased energy expenditure[6]. According to Whittle, limping usually develops as a protective response to pain or discomfort in one limb, resulting in compensatory changes in posture and balance[1]. Other studies have also reported that limping may lead to asymmetrical pelvic motion and trunk deviation, creating instability during walking[10].

Weight-carrying gait has also received attention in biomechanics research. Rosenbaum and colleagues found that carrying additional loads alters posture, trunk inclination, and walking mechanics[7]. People carrying weight often shorten their step length and increase cadence to maintain balance and stability. Similar findings were reported by Winter, who explained that carrying loads shifts the body's centre of gravity and increases muscular effort during walking[8].

Researchers have further emphasized the role of gait analysis in forensic science. Forensic gait analysis is used to identify individuals from surveillance footage by examining distinctive walking patterns[11]. Studies suggest that gait can function as a behavioural biometric because everyone has unique movement characteristics[12]. However, temporary conditions such as limping, fatigue, or carrying heavy loads may influence gait patterns and affect identification accuracy[11].

Manual Versus Instrumented Gait Analysis: Modern gait-analysis laboratories use advanced technologies such as infrared motion capture, stereophotogrammetry, and computerized pressure systems[9]. These methods provide detailed information related to joint movement, force distribution, and muscular activity. However, these systems are costly, need specialized technical knowledge, and are not easily accessible in many small educational institutions or field research environmen[4].

Manual gait analysis, on the other hand, involves the use of low-cost tools such as measuring tape, stopwatches, footprints, and observational methods[4]. Studies have shown that manual methods can effectively evaluate spatio-temporal gait parameters when proper procedures are followed[7].

Therefore, manual gait analysis remains valuable for preliminary gait screening and practical research conducted in resource-constrained environments.

Research Gap: Although extensive research exists on gait biomechanics, several gaps remain in the current literature. Most previous studies have focused on clinical populations, elderly individuals, or technologically advanced laboratory-based gait analysis systems[3,9]. Limited research has examined manual gait analysis among healthy young adults, particularly female hostel students in India.

In addition, many studies have investigated limping gait and weight-carrying gait separately, while comparatively fewer studies have compared normal walking, simulated limping, and weight-carrying conditions together using manual techniques[2].

There is also limited evidence regarding the usefulness of low-cost gait analysis methods in resource-limited settings. Therefore, the present study attempts to address these gaps by evaluating gait parameters under different walking conditions using simple manual tools among healthy female participants.

Methodology

Research Method: The present study used a quantitative research method to examine and compare gait parameters under normal walking, simulated limping, and weight-carrying conditions. A quantitative research approach was appropriate for this study because it involved measuring and comparing numerical gait variables such as step length, stride length, cadence, walking time, and the total number of steps[13]. The study followed an observational and comparative approach in which the same participants were observed under different walking conditions. Manual gait analysis was selected because it is simple, affordable, and useful in resource-limited settings where advanced biomechanical systems are unavailable[1].

Research Design: A quasi-experimental within-subject design was used in the study. In this design, all participants performed each walking condition, allowing direct comparison between normal and altered gait patterns[2]. The three walking conditions included: Normal walking pattern, Simulated limping, Weight-carrying walking.

Figure-1: Normal gait pattern.

Sources of Data: Both primary and secondary sources of data were used in the study. Primary data were collected directly from the participants through walking trials and normal gait measurements. Secondary data were obtained from books, journal articles, and previous studies related to biomechanics and gait analysis.

Population and Sampling: The study focused on healthy female students aged 19–26 years residing in Viddyottama Girls Hostel, Ujjain, Madhya Pradesh. A convenience sampling method was used because participants were easily accessible within the study setting[14]. A total of 30 participants were included.
Inclusion Criteria; Healthy female students aged 19–26 years, Ability to walk independently ,Voluntary participation.

Exclusion Criteria: Neurological or musculoskeletal disorders, Recent lower-limb injury or surgery, Use of mobility aids.

Data Collection Procedure: Data collection was conducted on a 7-meter walking path. Red dye footprints, measuring tape, and a stopwatch were used to record gait parameters. Participants completed walking trials under all three conditions at a comfortable speed. Step length, stride length, cadence, walking time, and total steps were measured and recorded manually[5].

Tools and Instruments: The study used simple manual tools including Measuring tape, Stopwatch, Red dye footprints, Weighing scale, Notebook for observations.

These low-cost instruments allowed effective gait measurement without advanced computerized equipment.

Ethical Considerations: All ethical guidelines were carefully followed during the study. Participants were clearly informed about the aim and procedure of the research before their consent was obtained. Their privacy and confidentiality were protected throughout the study, and they were free to leave the study at any time without any consequences.

Results and Discussion

Participant Characteristics: The study included 30 healthy female participants aged between 19 and 26 years from Viddyottama Girls Hostel, Ujjain, Madhya Pradesh. All participants completed gait trials under three walking conditions: normal walking, simulated limping, and weight-carrying walking. The study measured several gait parameters, including step length, stride length, cadence, walking time, and observations related to body posture during walking.

Step Length Analysis: The findings showed that normal walking produced the highest average step length of 39.7 cm. During simulated limping, the average step length reduced noticeably to 21.6 cm, while the weight-carrying condition showed a moderate reduction to 34.5 cm.

These observations suggest that limping created the greatest disturbance in forward movement. Participants naturally shortened their steps during limping to reduce pressure on the affected side and maintain stability. In the weight-carrying condition, participants adjusted their body posture and walking rhythm to compensate for the additional load, which helped maintain relatively stable movement.

Stride Length Analysis: The average stride length during normal walking was 79.9 cm, which was the highest among all conditions. During limping, stride length reduced considerably to 48.7 cm, while weight carrying resulted in a moderate decrease to 73.8 cm.
The reduced stride length observed during limping reflects instability and reduced walking efficiency. Participants demonstrated compensatory gait patterns while attempting to

maintain balance. In contrast, weight carrying produced only mild changes because healthy participants were able to adapt their walking style more effectively.

Cadence Analysis: Cadence during normal walking averaged approximately 70 steps per minute. During limping, cadence slightly decreased to around 66 steps per minute. However, in the weight-carrying condition, cadence increased to nearly 77 steps per minute.

The increased cadence during weight carrying indicates that participants compensated for shorter step lengths by taking faster and more frequent steps to maintain walking speed. The lower cadence during limping reflects slower and more cautious walking patterns caused by discomfort and reduced balance.

Walking Time Analysis: The average time required to complete the 7-meter walking path was 4.8 seconds during normal walking. In the limping condition, walking time increased significantly to 8.9 seconds, indicating slower and less efficient movement. The weight-carrying condition showed only slight variation, with walking time remaining close to normal walking values.

These results demonstrate that limping had a stronger impact on gait efficiency than carrying weight. Healthy individuals were generally able to adjust to moderate load carriage without major reductions in walking speed.

Comparative Findings: Comparison of all walking conditions showed that limping produced the greatest alteration in gait mechanics. The reduction in step length from 39.7 cm to 21.6 cm reflected a major decline in movement efficiency. Similar reductions were observed in stride length and cadence, while walking time increased substantially.

Statistical comparison revealed significant differences between limping and weight-carrying conditions ($p < 0.05$). However, differences between normal walking and weight carrying were comparatively smaller. These findings suggest that limping affects gait biomechanics more severely than moderate weight carriage.

Table-1: Summary of statistical output.

Comparison	T-value	P-value	Interpretation
Normal vs limping	1.35	0.188	Not significant
Normal vs weight-carrying	-1.68	0.104	Not significant
Limping vs weight-carrying	-2.39	0.024	Significant

Postural Observations: Qualitative observations also revealed noticeable changes in posture and balance across different walking conditions. During normal walking, participants maintained upright posture, symmetrical arm swing, and balanced movement. Limping produced visible trunk lean, uneven arm movement, shorter stance phase, and reduced balance stability.

In the weight-carrying condition, participants showed mild forward trunk inclination and slightly reduced arm swing, although overall gait coordination remained relatively stable. These findings indicate that abnormal walking conditions influence both movement mechanics and body posture.

Discussion: Interpretation of Findings: The present study examined gait variations under normal walking, simulated limping, and weight-carrying conditions using manual gait analysis methods. The findings clearly showed that limping caused the greatest changes in gait performance, these included decreased step length, shorter strides, reduced walking speed, and noticeable changes in posture during walking. These results suggest that limping disrupts gait symmetry and reduces walking efficiency.

The shorter steps and reduced stride length seen during limping may be considered protective adjustments made by the participants to reduce pressure on the affected leg. The longer walking time also suggests more careful movement and lower walking efficiency.

Comparison with Existing Literature: The results of the study agree with earlier biomechanical research showing that abnormal walking patterns can decrease movement efficiency and disturb normal walking rhythm. Earlier studies have described limping as a compensatory walking pattern characterized by shortened stride length, slower speed, and asymmetrical movement.

The findings related to weight carrying also support previous research showing that additional load alters posture, balance, and gait mechanics. Participants in the present study compensated for carrying weight by increasing cadence and adjusting posture to maintain walking stability.

Meaning of Findings in the Present Context: The study highlights the adaptability of human gait under altered walking conditions. Healthy participants were able to maintain relatively stable walking patterns during weight carrying by making small biomechanical adjustments. However, limping caused more severe disturbances because it directly affected balance, limb support, and movement symmetry.

The study also demonstrates that simple manual gait analysis methods can successfully identify meaningful gait changes without the need for expensive computerized systems. Measuring step length, stride length, cadence, and walking time together provided useful understanding of gait adaptations.

Clinical and Forensic Relevance: The findings have practical importance in both clinical and forensic settings. Clinically, gait analysis can help identify movement abnormalities associated with injury, rehabilitation, or musculoskeletal problems. In forensic investigations, gait characteristics may assist in identifying individuals through surveillance footage and behavioural movement patterns.

The study also shows that temporary conditions such as limping or carrying weight can significantly influence gait patterns. Therefore, contextual factors should always be considered during gait interpretation.

Limitations and Future Scope: Certain limitations should be acknowledged in the study. Simulated limping may not completely represent real pathological gait conditions. In addition, manual measurements using stopwatches and measuring tape may introduce minor observational errors.

Future research should include larger sample sizes, clinical populations, and advanced instrumented gait-analysis systems for more accurate biomechanical evaluation. Further studies may also examine the influence of different load weights, walking surfaces, and longer walking distances on gait performance.

Conclusion

The study examined gait patterns during normal walking, simulated limping, and weight-carrying conditions using simple manual gait analysis methods among healthy female participants. The findings showed that different walking conditions clearly affect gait performance, posture, balance, and movement efficiency. Normal walking produced the most stable gait pattern, while limping caused major changes such as shorter steps, slower movement, and reduced balance. Weight carrying created only moderate changes, as participants adjusted their posture and walking rhythm to maintain stability. The study shows that manual gait analysis is a simple, cost-effective, and practical approach for examining variations in walking patterns, particularly in places where advanced biomechanical equipment is not available.

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