THE 6th VITAL SIGN

Walking Speed as a measure for functional and overall health status.

BY DIGITAL GAIT LABS

PRODUCT INFORMATION

This white paper refers to Walking speed, commonly known as "gait speed," is a fundamental clinical measure for assessing and monitoring functional status and overall health in various populations.

IMPORTANT SAFETY INFORMATION

Intended Use: The intended use of GaitKeeper is to provide automated collection methods for human movement data. The device is software only. It graphically displays human physiological movement patterns for movement analysis in the fields of gait analysis.

GaitKeeper is a tool that captures human motion using a single mobile phone camera. It is CE marked and registered as a Class 1 Medical Device.

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1. INTRODUCTION

Gait analysis is the systematic study of human locomotion. It involves the collection and analysis of data related to the kinematic (movement patterns) and kinetic (forces involved) aspects of movement, often employing tools such as motion capture systems, force platforms, electromyography, and pressure sensors and observation by qualified clinicians. It is a valuable tool used across many fields:

gait (noun)
/geit/
1. manner of walking or running; bearing

- **Medical Diagnosis and Rehabilitation**: Gait analysis is widely used in medical settings to diagnose and monitor the progression of conditions that affect mobility, such as arthritis, cerebral palsy, stroke, and other neurological disorders. It helps in planning and evaluating the effectiveness of treatments and rehabilitative strategies.
- **Sports Medicine and Performance Enhancement**: In the realm of sports, gait analysis is used to optimise athletes' performance by identifying biomechanics patterns that can be improved. It also helps in preventing injuries by spotting abnormal movement patterns that might lead to stress on muscles and joints.
- **Orthotics and Prosthetics Development**: Gait analysis provides critical data for designing orthotic and prosthetic devices. By understanding the specific gait characteristics of an individual, specialists can create customised devices that enhance mobility and comfort.
- **Ergonomics**: In occupational health, gait analysis helps design safer and more comfortable workspaces.

It can identify how work tasks might impact workers' biomechanics and suggest modifications to reduce the risk of injury.

- **Forensics**: Gait analysis can also be applied in forensic science to assist in criminal investigations. Since each individual's gait is unique, it can be used as evidence to confirm a suspect's presence at a crime scene.
- **Veterinary Medicine**: Similar techniques are used in veterinary practice to assess the gait of animals. This helps in diagnosing injuries and conditions in pets and livestock and in evaluating their response to treatments.
- **Research and Development:** Researchers use gait analysis to study human movement at a detailed level. This research can inform the development of better footwear, sports equipment, medical devices, and training protocols.
- **Robotics and AI**: Insights from human gait analysis are also applied in the development of advanced robotics and artificial intelligence systems, where understanding and replicating human movement can enhance the interaction between humans and machines.

One of the simplest parameters is **walking speed**, commonly known as "gait speed".

It is a fundamental clinical measure and has gained traction because walking speed can be a strong indicator of health and functional status and helps in assessing the risk of falls, mobility limitations, and overall health status. Its validity, reliability, and sensitivity render it an essential metric in clinical settings.

While conceptually simple, walking speed has a far reach as outlined below.

Frailty is a significant concern - as it is a distinctive health state related to the aging process where multiple body systems gradually lose their reserve capacity. As reported by Clegg et al. (2013), frailty affects approximately 20% of those over 65.

Studies have demonstrated that slower walking speeds in older adults are predictive of adverse outcomes like falls, hospitalisation, and even mortality[2].

However regular monitoring of walking speed can guide interventions aimed at preventing mobility loss and maintaining independence in older adults[3]. Understanding and managing frailty is crucial for healthcare professionals and policymakers, given its significant impact on health services and associated costs.

Falls are another significant cause of health decline as people get older, and are associated with over €500 million healthcare costs in Ireland annually. International guidelines have always recommended the importance of gait speed as an important indicator of someone's risk of falling, but for lots of reasons this has been significantly challenging to implement in clinical settings.

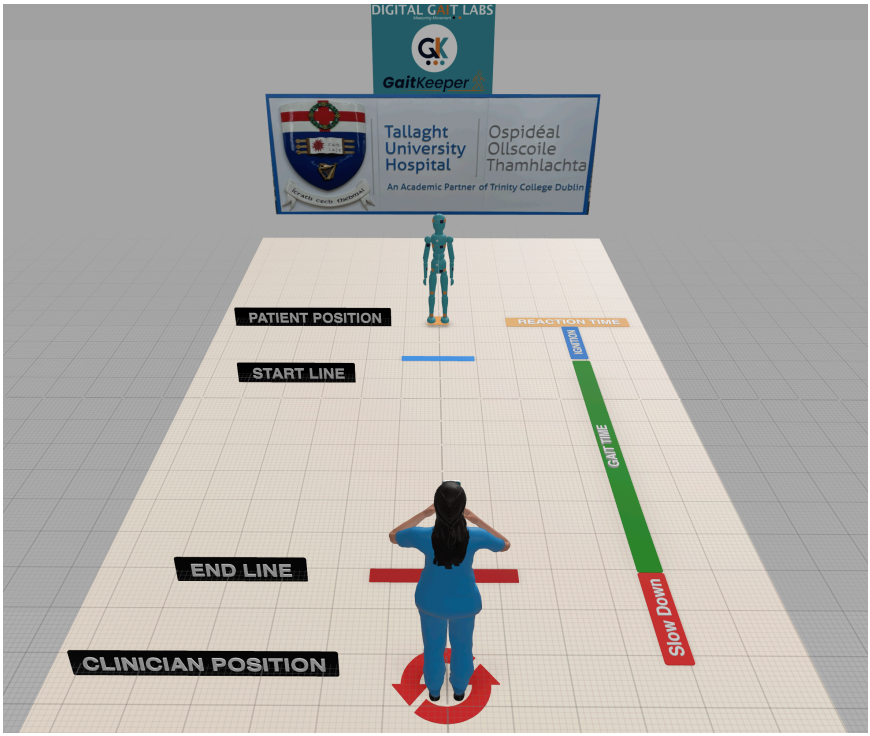
In the following sections, the challenges, benefits and technical approaches are described.

2. MEASURING WALKING SPEED

Collection of Gait Speed in Clinical Practice

Gait speed is typically measured by timing how long it takes for a person to walk a predetermined distance, often 4 or 10 meters. The process involves:

- **Standardised Walking Course**: A marked pathway in a clinic or hospital setting.
- **Timing Device**: A stopwatch or similar timing device is used to measure the time taken to cover the distance.
- **Minimal Equipment Requirement**: The test requires minimal equipment, often just a measured walkway and a timing device.



Cost of Performing a Gait Speed Tests

One of the advantages of using gait speed as a clinical measure is its cost-effectiveness:

- **Low Equipment Costs**: The test requires minimal equipment, which is inexpensive and often already available in clinical settings.
- **Time-Efficient**: The test is quick to administer, usually taking less than 5 minutes, including setup and measurement.
- **No Need for Specialised Training**: Healthcare professionals can easily perform the test without needing specialised training.

Note that the benefits of using Gait Speed, described above, can really only be realised through the standardisation, automation and digitisation of the data collection:

- Without standardisation, it is unlikely that results collected from different locations or by different clinicians can be easily compared.
- Without automation, it is unlikely that sufficient coverage of the population will be achieved.
- Without digitisation, the integration of gait speed data will not be easily available for across healthcare domains.

Validity of Walking Speed

Walking speed effectively mirrors an individual's functional capabilities. It correlates strongly with various health parameters, including balance, strength, and endurance. This correlation has been extensively validated across different age groups, clinical conditions, and healthcare settings.

- **Elderly Population**: Studies have demonstrated that slower walking speeds in older adults are predictive of adverse outcomes like falls, hospitalisation, and even mortality (Studenski et al., 2011).
- **Chronic Conditions**: In patients with chronic diseases such as Parkinson's disease, multiple sclerosis, or arthritis, walking speed serves as an indicator of disease progression and response to treatment (Matsuda et al., 2013; Goldman et al., 2008).

Reliability of Walking Speed Measurements

The reliability of walking speed as a clinical measure is supported by its consistency and reproducibility under standardised conditions.

- **Standardised Testing Conditions**: When measured over a fixed distance in a controlled environment, walking speed yields highly reproducible results (Graham et al., 2008).
- **Inter-Rater Reliability**: Various studies have shown that walking speed measurements remain consistent across different evaluators and testing sessions (VanSwearingen et al., 2011).

Sensitivity of Walking Speed

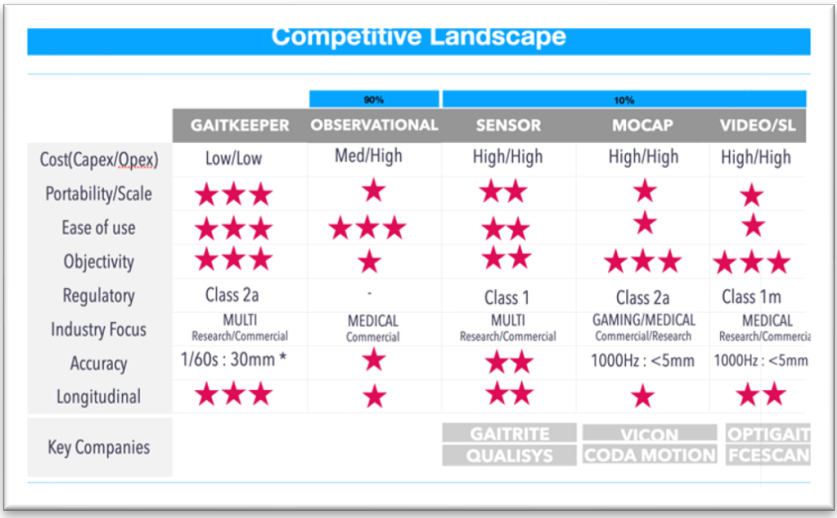
The sensitivity of walking speed as a measure lies in its ability to detect subtle changes in an individual’s functional status.

- **Detecting Functional Decline**: Even small decreases in walking speed can indicate the onset of functional decline or the need for medical intervention (Verghese et al., 2009).

- **Monitoring Rehabilitation Progress**: Incremental improvements in walking speed can reflect positive responses to rehabilitation therapies in post-surgical patients or those recovering from injuries (Shumway-Cook et al., 2007).

3. TECHNOLOGY SUPPORT

The main types of system (or approaches) to gathering motion capture data can be grouped into four main categories and compared against a range of characteristics as shown in figure aside. A detailed examination of each type and the key operators in the field is then provided.



Observational: This is the manual approach where a qualified person observes a subject carrying out a defined task while measuring various temporal and spatial events.

Observation Gait Analysis[1] is widely used in clinical settings as it allows assessments to be easily carried out in a variety of settings, with minimal infrastructure. Research and clinical practice has created many well defined procedures to perform various tests (e.g. timed up and go, 5m turn test).

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[1] Observation Gait Analysis: A visual guide. Adams, Cerny. 2018. ISBN: 978-1630910402

Observational approaches tend to be subjective and require more administrative work on the part of the clinician.

Sensor Based: Sensor based systems fall into two categories – (a) Those that use pressure sensors (e.g. floor mat, insole of a shoe) (b) Those that use IMU[2] sensors to measure 3D motion at a particular point of the body. The gold standard in clinical settings is considered to be GAITRite[3]. GAITRite uses a mat with an array of pressure sensors attached to capture foot position, pressure and movement over the length of the walkway. GAITRite has over 3500 installations across 50 countries and is used in research and clinical settings. GaitKeeper has used the GAITRite system during its technical and clinical testing to validate its results.

3D Motion Capture: Motion capture refers to approaches which use an array of Infra-red cameras that record positions of reflective markers placed on the subject under test. The Vicon system used to test GaitKeeper has 16 IR cameras, mounted permanently to walls and ceilings in a dedicated room. The body worn markers can either be passive (reflective stickers) or active (IR LED sensors). Active systems (where markers are sensors) make the setup and synchronisation of systems easier and in some instances also stream IMU data. These systems achieve very high positional accuracy, use very high sample rates so can capture very small movements. However, they are highly complex systems to operate and to develop applications for, typically needing dedicated resources to manage them. In clinical applications they are rarely used outside research due to cost, complexity and patient comfort concerns. A

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[2] IMU: Inertia measurement units measure 3D force/ acceleration

[3] GAITRite: Gold Standard in Gait Analysis. https:// www.gaitrite.com/

variant of these systems project a pattern of light on the object under test. Remote sensors (typically an Infrared camera) is used capture surfaces on the object and restructure a 3D position of objects. They are typically used in conjunction with a treadmill, pressure mat or other sensor technology.

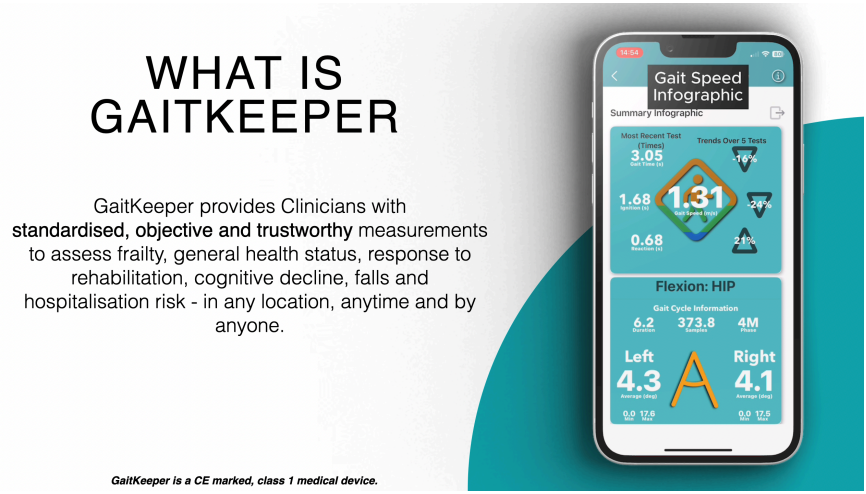
Deep Learning Approaches: Deep learning refers to a suite of computer vision algorithms which have shown excellent performance in the identification, segmentation and feature detections from images and video. In particular, face detection, hand detection has become very popular in mobile applications for gaming, video chat and social media. These approaches depend on the availability of trained AI models or the ability to train such AI models. In the area of human pose estimation, deep learning algorithms are capable of extracting key point information. A number of high quality key point models already exist (e.g. OpenPose, DensePose) which can form the basis for gaming, healthcare and sports performance applications. In general terms, these models need to be run using memory hungry GPU resources. It is vital to understand that “pose” is not movement and is not gait and that significant development and IP is needed to make effective use of pose machines.

Mobile Application Approaches: The Android and Apple app stores contain dozens of mobile applications which leverage computer vision algorithms to provide visual feedback and analytics to the user for sports, fitness, gaming and wellbeing. In general, these applications either provide basic functions with low accuracy or require “depth/structure” sensor hardware attached to the mobile. These apps are limited by the memory, GPU and disk space constraints of mobile devices. They also typically fail to provide the multi-site longitudinal comparison abilities.

4. WALKING SPEED USING GAITKEEPER

Technology Overview

GaitKeeper is a state of the art digital gait analysis platform. By fusing innovations in Augmented reality and Artificial Intelligence, GaitKeeper enables anyone to record a standardised 4m walking test in any location and have the system compute a vast range of gait related measurements.



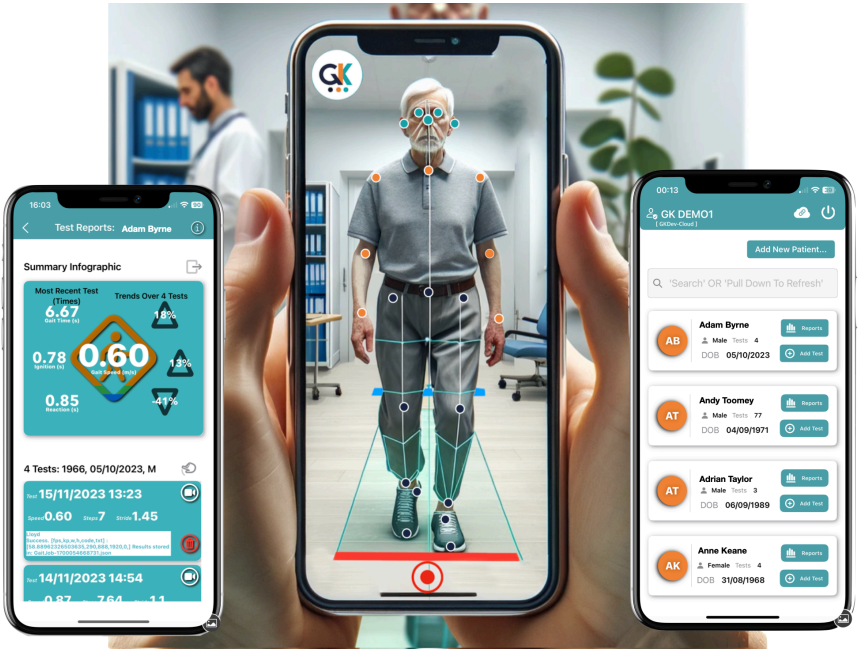
GaitKeeper does not require the use of sensors, pressure mats or special clothing. Its augmented reality app ensure standardised recording of assessments before its cloud based artificial intelligence algorithms process videos of the assessments to produce a complete spatial and temporal descriptions of the movement of the subject.

Features and Capabilities

- **Accessibility and Ease of Use**: GaitKeeper allows for frailty assessments to be conducted by anyone,

anywhere, at any time, without the need for specialised equipment like sensors, mats, or special clothing.

- **Advanced Data Collection**: It captures over 20 points on the subject's body 60 times per second, detecting gait events with high precision and spatial accuracy.
- **Comprehensive Gait Analysis**: The tool collects longitudinal data on walking speed, support base, swing, flexion, and symmetry measures.
- **Clinical Validation**: GaitKeeper has been clinically validated using the GaitRite system and technically validated with the Vicon motion capture system.
- **Regulatory Compliance**: It is a CE Marked, class 1 medical device, regulated under EU-MDR regulations.



GaitKeeper for Frailty Measurement.

Frailty is a significant concern, particularly in the aging population. It is a distinctive health state related to the aging process where multiple body systems gradually lose their reserve capacity. This condition is characterised by a state of vulnerability to poor resolution of homeostasis after a stressor event, resulting from the cumulative decline in various physiological systems over a lifetime. This decline depletes homeostatic reserves to a point where even minor stressors can trigger disproportionate changes in health status. As reported by Clegg et al. (2013), frailty affects approximately 20% of those over 65.

Why Understanding Frailty is Important

In Acute Hospitals

- **High Occupancy**: People aged 65 and over occupy 54% of acute hospital inpatient beds.
- **Dementia Prevalence**: About 30% of older people admitted to acute hospitals have dementia, often leading to longer hospital stays.
- **Delayed Discharges**: This age group accounts for 90% of delayed discharges from acute hospitals.
- **Extended Emergency Department Stays**: Those aged 75 and over spend three times longer in the Emergency Department than those under 65.
- **Post-Hospital Functional Decline**: 35% of patients over 70 show functional loss at discharge, rising to 65% for 90-year-olds.

In Nursing Homes

- **High Proportion of Elderly Residents**: 88% of nursing home residents are over 65.
- **Continuous Care Need**: Approximately 22% of those aged 85+ require continuous care.

- **Dementia Impact**: 50% of nursing home residents live with dementia.

Impact on Health and Social Care

Frailty ranges from mild (pre-frail) to advanced states, necessitating varying levels of intervention. It is a strong predictor of healthcare use, emergency department visits, hospitalisation, extended hospital stays, readmissions, and in-hospital mortality. Understanding and managing frailty is crucial for healthcare professionals and policy makers, given its significant impact on health services and associated costs.

5. CONCLUSION

Walking speed is a valid, reliable, and sensitive clinical measure for assessing and monitoring functional status and overall health. Its simplicity, non-invasiveness, and applicability to a wide range of populations make it an invaluable tool in healthcare settings. Incorporating walking speed assessments into regular clinical practice can significantly enhance patient care by providing a clear and objective measure of an individual's functional abilities and overall health status.

GaitKeeper is a state of the art digital gait analysis platform. By fusing innovations in Augmented reality and Artificial Intelligence, GaitKeeper enables anyone to record a standardised 4m walking test in any location and have the system compute a vast range of gait related measurements.

6. REFERENCES

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ABOUT DIGITAL GAIT LABS

Digital Gait Labs Ltd is a spin out company from Dublin City University (Insight Centre for Data Analytics) and achieved certification as a Class 1 Medical Device with CE marking in 2022.