THE POTENTIAL OF GAIT ANALYSIS: HOW AI CAN AID IN EXAMINING HUMAN PHYSIOLOGY TO MAINTAINING HOMEOSTASIS

IL POTENZIALE DELL'ANALISI DELL'ANDATURA: COME L'INTELLIGENZA ARTIFICIALE PUÒ AIUTARE NELL'ESAMINARE LA FISIOLOGIA UMANA, PER MANTENERE L'OMEOSTASI

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Double Blind Peer Review

Citazione
Martella, G., & Peppe, A. (2024). The potential of gait analysis: how ai can aid in examining human physiology to maintaining homeostasis. *Giornale Italiano di Educazione alla Salute, Sport e Didattica Inclusiva*, 8(2), Edizioni Universitarie Romane.

Doi:
https://doi.org/10.32043/gsd.v8i3.1155

gsdjournal.it
ISSN: 2532-3296
ISBN 978-88-7730-494-0

ABSTRACT
Walking is a marvel of adaptability in healthy humans. It follows the 'golden ratio' and adjusts to specific demands.
Artificial intelligence provides a world of possibilities for gait analysis. The utilized system incorporates 29 sensors, 6 acquisition chambers, and dynamic rhythm sensors. This tool assesses movement harmony and identifies pathology. Its diverse uses include rehabilitation, motor and non-motor re-education, and primary education, hinting at its vast potential.

Camminare è un esempio di adattabilità nell'individuo sano. Segue il 'rapporto aureo' e si adatta alle esigenze specifiche.
L'intelligenza artificiale può analizzare l'andatura. Il sistema da noi utilizzato incorpora 29 sensori, 6 camere di acquisizione e rilevatori del ritmo dinamico; e valuta l'armonia del movimento cosi come il movimento patologico. I suoi diversi usi includono la riabilitazione, la rieducazione motoria e non motoria e l'istruzione primaria, suggerendo un vasto potenziale.

KEYWORDS
Gait analysis, movement, movement disorders; IA.
Analisi del cammino, movimento, disordini del movimento, intelligenza artificiale.

Received 01/05/2024
Accepted 17/06/2024
Published 24/06/2024

Introduction

Luria coined 'kinetic melody, or golden ratio' to describe the self-organized rhythmic stream of motor control. Motor skill development involves combining individual impulses into integral kinesthetic structures (Pervichko and Zinchenko 2014). The fractal structure of physiological walking and its relationship to the golden ratio (approximately 1.618) is reported in the mathematical formula proposed by Iosa and their collaborators (Iosa et al. 2013)
The relationship between the gait cycle and the stance phase has been accurately calculated to correspond with the number defined as the "Aurea section." The subunits of the gait cycle also follow this exact proportionality, as seen in larger structures such as the relationship between one stride and one stance concerning an entire stride (Coldea et al. 2010; Yamagishi and Shimabukuro 2008)(Iosa et al. 2022).
Parkinson's disease (PD) is a chronic neurologic disorder that results from the loss of dopaminergic neurons from the substantia nigra nucleus in the brain, causing dopamine deficiency. This deficiency is responsible for the major motor symptoms such as tremors, slowness of movement, rigidity, and imbalance, which affect the gait of people with PD. Individuals with PD often face movement issues that disrupt gait harmony (Belluscio et al. 2021; Iosa et al. 2013, 2022)
Frailty is a geriatric condition. As people age, their physical function often declines, leading to a loss of independence. Gait can indicate overall health and function, especially in frail older adults. Assessing gait offers insights into cognitive and motor decline, giving us a better understanding of aging (Bortone et al. 2021; García-de-Villa et al. 2023).
Combining video-imaging systems, sensors, and mathematical algorithms through artificial intelligence has enabled various gait analysis systems to develop.
Our analysis will use a BTS-gait system and a G-WALK system to study motor control rhythm in healthy, PD and elderly individuals.

1. Material and Methods

Gait analysis is a precise method that meticulously evaluates each component of the three phases of ambulation. This comprehensive approach aids in diagnosing various movement disorders, assessing subject progress during eventual treatment or rehabilitation, and evaluating the effects of musculoskeletal injuries, diseases, or locomotor deficiencies.
To realize our project, we used a BTS System formed by (figure 1):
·6 Smart-dx EVO2 cameras (2,3 Mpixel-200Fps)

•BTS brain-smart –AI
•Gaitlab marker kit
•User Console
•SMART software
•Sonde wireless FREEMG 1000

Figure 1: set up realization by BSMART group.

The markers, meticulously positioned on the joints and the corresponding areas at the nerve points, ensure a precise evaluation of the locomotor system.
The cameras detect each marker with high precision and track the subject's stationary state and movements along the three axes, including rotation (figure 2). The AI acquires real-time measurements of the marker's position, which then converts them into points. These points are used to create an avatar corresponding to the subject, and the operator can omit certain points if necessary (Belluscio et al. 2021).

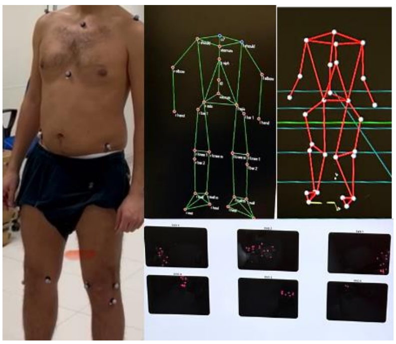

Figure 2: cameras detect each marker, realize an avatar and visualize the movement. AI analyses the movement.

2. Statistical analysis

Analysis of line is performed by Origin-microcal-software to determinate statistical significance. Anova two-way test were applied to compare group of subjects; while variance of the same subject in the time is evaluated by non-parametric Mann-Whitney test followed by Bonferroni post hoc test.
The association between PD or frailty and locomotor disturbance was assessed by means binomial logistic regression, adjusting the model for age and gender.

3. Results

Patients with Parkinson's disease exhibit more significant impairment in gait processes than older adults with articular inflammatory disorders.
Parkinson's Disease (PD) is the second most crucial neurodegenerative pathology that uniquely damages neuronal circuits, especially the dopaminergic neurons and their striatal projections. The disease presents a myriad of motor and non-motor features, including tremors at rest, rigidity, akinesia, bradykinesia, and postural instability (figure 3). These features also significantly impact gait.

Gait phases differed significantly in patients vs. healthy subjects, and alterations in gait correlated significantly with UPDRS motor score. In particular, the stance and double support phases. Our research employs three meticulously designed indices to assess gait, ensuring the precision and reliability of our findings:

	Gait parameter	Control group
Spatio-temporal gait parameters	Walking speed [m/s]	1.09 ± 0.16
	Stride length [m]	1.17 ± 0.12
	Stride duration [s]	1.11 ± 0.30
	Stance [%]	62.02 ± 1.90
	Swing [%]	38.00 ± 1.89
	Double support [%]	24.05 ± 3.89
Gait indices	SRI	0.99 ± 0.91
	GA	2.146 ± 1.577
	PCI	2.769 ± 2.427
	GR_0	1.614 ± 0.049
	GR_1	1.639 ± 0.140
	GR_2	1.628 ± 0.307

1. Gait Asymmetry Index (GA): This is calculated by taking the absolute value of the logarithm of the ratio between the shorter and longer swing times (Hobert et al. 2017; Plotnik, Giladi, and Hausdorff 2009).
2. Phase Coordination Index (PCI): This index assesses the accuracy and consistency of in-phase walking (Plotnik, Giladi, and Hausdorff 2009).
3. Gait Ratio (GR): This index is the ratio between the stance and swing phases (GR1) (Dzeladini, van den Kieboom, and Ijspeert 2014; Iosa et al. 2013, 2022) ; table 1.

The gait failure process was anticipated, but what was truly unexpected was the discovery that a significant group of aged people could show the nonsignificant but aberrant process of walking (n= 12; p= 0,0061; figure 4).

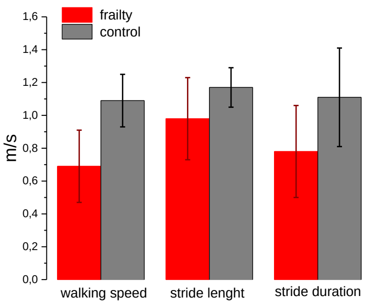

Figure 4: subject included in frailty group compared to healthy subject show a tendency in reduction of waking speed, stride length and stride duration (n= 12; p= 0,0061; Mann Witney test).

The expected gait failure processes were observed in aged individuals, but a significant number of them also displayed abnormal walking patterns that were insignificant but with a tendency towards a gait ratio resembling the 'golden ratio' a term used to describe a specific mathematical proportion often found in nature. Although gait analysis in patients with movement disorders is an excellent marker for the progression and worsening of specific conditions like Parkinson's disease, we propose that geriatricians primarily focus on the mobility of older individuals (Iosa et al. 2022). Frailty in old age is characterized by weight loss, weakness, fatigue, and loss of muscle mass (sarcopenia; (Bales and Ritchie 2002; Cederholm 2015; Martin et al. 2006). It often leads to decreased food intake, gait abnormalities, and osteopenia. As we age, frailty becomes a common occurrence. However, with proper care and treatment, it can be managed. Although treatments such as replacement therapies, cardiac extenders, pacemakers, and ventricular assist devices have limitations, they cannot prevent the wear and tear of other biological systems. We propose measuring frailty regarding postural instability and loss of walking parameters as an index of noncorrect aging processes.

Conclusions

The ongoing study, a crucial endeavour in gait analysis, is being conducted on a limited number of subjects. While statistical significance cannot be established at this stage, the emerging trend is intriguing. It suggests that some subjects may lose

their step harmony due to a lack of regular movement. The limitation of this study is due to its preliminary status and the number of subjects examined that is insufficient to perform an excellent statistical analysis. Anymore, we want to underline the importance of our work and the potential for re-education, which could have significant implications for rehabilitation therapies. Also, we can underline the importance of AI in this kind of studies.
Further work was necessary to create the right scenario for the three groups described in the study, and we are working to do this.

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