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Analysis of Abnormal Gait in the Diagnosis of Early Neurodegenerative Diseases: A Review

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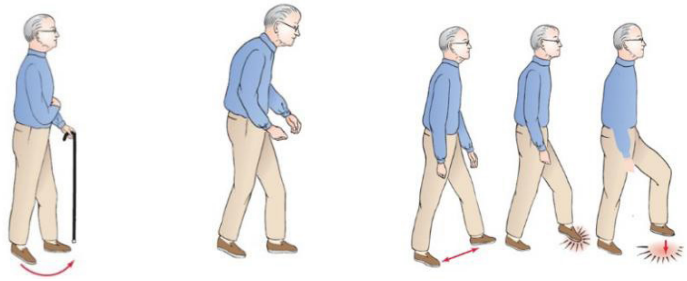
Abstract: Early detection of neurodegenerative diseases can increase the possibility to access to treatment, and assist in advance care planning. At present, most of the gait researches focus on the design and application of recognition tools for disease diagnosis, such as recording the walking and movement status through wearable sensor devices, while, relatively less non-contact machine vision is used to measure gait. The non-contact gait detection method is characterized by the advantages, including the absence of human cooperation, non-invasive nature and so on, which is also suitable for long-distance perception. In this paper, we focused on some non-contact analysis methods for abnormal gait, and it is hoped that it can provide guidance for the diagnosis of neurodegenerative diseases.

Keywords: Neurodegenerative Diseases; Early Diagnosis; Abnormal Gait; Non-Contact Detection

1. Introduction

With the aggravation of the aging of the population, neurodegenerative diseases suffered by the elderly have gradually evolved into a significant social problem. Some of most known and serious neurodegenerative diseases are Parkinson's (PD), S.L.A., Alzheimer's (AD), Huntington Korea (HD) and Dementias (DD).The pathological changes associated with the onset of neurodegenerative diseases are irreversible. When patients show cognitive impairment, the course of disease is often in the middle or late stage. By that moment, treatment is only available for slowing down the development of the disease, instead of fundamental reversion of the damage of neural network. The conventional diagnosis of neurodegenerative diseases largely depends on the subjective measures obtained from observations and questionnaire of the clinicians to require a UPDRS score. These descriptive symptoms may cause misclassification and low efficiency. To formulate appropriate treatment protocols, and improve patient care during rehabilitation, it is important to promptly and accurately identify gait abnormalities[1]. By the time neurodegenerative diseases are diagnosed, sufficient neuronal injury has occurred to the extent that reversal of the disease is unlikely Gait(see Fig.1) is regarded as a complex task requiring higher control of cognitive processing that involves attention, planning, memory and other motor, perceptual and cognitive processes and is shown to have a robust relationship with cognition.So early diagnosis is facing great challenges.



(a) (b) (c)

Fig.1 The abnormal gait due to neurodegenerative diseases. (a)Hemiplegic gait (b) Parkinson's gait (c) Ataxic gait [2]

Patients with hemiplegic gait(Fig.1(a)), always have the leg is stiff, and with each step is rotated away from the body, then toward it, forming a semicircle(without flexion of knee and ankle,). Patients with Parkinson's gait often present with abnormal posture and hands shake(Fig.1(b)). Patients with ataxic gait, often have the deformity seen with foot drop(Fig.1(c)).

However, the cost of these analysis systems is extremely high, and the fixed installation set-up is needed. Meanwhile, traditional disease detection methods are difficult to eliminate the impact of subjective differences among diversified testers, which is not conducive to

longitudinal observation of patients' condition, and the evaluation of disease progression. Gait abnormalities associated with neurodegenerative diseases are due to protein aggregates in different brain regions, which may lead to cell dysfunction or death . More advanced diagnostic techniques such as computed tomography scans that measure brain function, can be cost prohibitive and may expose patients to radiation and other harmful effects. Increasing gait-based detection technologies are proposed as alternative, fast, low-cost and non-invasive detection methods. So it's trend that cooperating with medical institutions to diagnose early neurodegenerative diseases in a non-intrusive way.

2. Abnormal gait analysis in the early diagnosis of neurodegenerative diseases

Many previous studies have analyzed the gait variables in neurodegenerative diseases, including Parkinson's disease, for various applications. these tests is that they may not be efficient at early-stages of cognitive impairment. Recent studies have demonstrated that some gait abnormalities may appear particularly early in neurodegenerative diseases, although these early features remain to be elucidated fully [3]. According to the research of Ríona McArdle of Newcastle University, by studying the unique walking patterns of patients with cognitive impairment, clinicians can accurately diagnose whether they are suffering from Alzheimer's disease or Lewy body dementia. The results showed that these two special gait characteristics were enough for the identification of 60% of dementia subtypes. The research of Panyakaew et al. illustrates that patients with early Parkinson's disease may not complain about gait difficulties, however, when they are confronted with dual tasks, subtle gait abnormalities may be revealed as part of "preclinical gait syndrome". To maintain the speed, patients with early Parkinson's disease develop compensatory mechanism by increasing beat, and reducing swing time and cycle time. In addition, temporal gait variability and arm kinematics are also promising markers of preclinical Parkinson's disease. As per the research of Mole [4], the clinical symptoms of early neurodegenerative dementia have impact on the movement disorder or human gait cycle to a great extent. The experimental results suggest that this method is available for the effective distinguishing of the gait dynamics characteristics of pathological group and healthy control group. Barrett Blake [5] et al. described the changes of gait and the balance ability caused by cognitive decline in the early stage of dementia, and pointed out that early detection of gait changes and centralized intervention would reduce mortality. Amyotrophic lateral sclerosis (ALS) is characterized by gradual muscle atrophy, difficulty in autonomous movement, and cognitive dysfunction due to the damage of motor neurons in the cerebral cortex, brain stem and spinal cord. Literature proposed a method for early diagnosis of this disease, and abnormal gait was proved to be effective.In addition, certain early neurological symptoms show the characteristics, including some gait disorders, such as Alzheimer's disease, isolated adrenocortical hormone deficiency, hemophilia, early childhood ataxia or developmental coordination disorder , Huntington's disease, rheumatoid arthritis [6], etc.

In conclusion, gait is of guiding significance for the early diagnosis of neurodegenerative diseases, especially Parkinson's disease. At present, in most cases, the mature gait analysis methods are suitable for the detection and analysis of moderate and severe frozen gait. Besides, the method of characterizing gait disorder has irreplaceable advantages for the early diagnosis of neurodegenerative diseases.

3. Abnormal gait detection method

Currently, most of the gait researches for disease diagnosis focus on the design and application of recognition tools which use wearable sensor systems to record gait dynamics characteristics, including force contact sensors (such as foot switch and sole pressure insole) , accelerometers, gyroscopes and inertial measurement units. In recent studies, motion sensors (dedicated to smart phones) are also utilized to determine the characteristics of the disease, usually by ensuring that the waist and legs and other parts of the sensor, which are integrated into a wearable device. But assessment techniques based on behavioral tests such as rotarod, grip strength or scoring systems are characterized by several limitations. Some sensors will be limited by non-physiologic test conditions, while some devices will depend on the users and motivational factors. As a non-contact measurement tool, the depth camera is employed for the collection of the gait data of the elderly in the room, which can identify the walkers without interference, and the generation of the probability method of automatic gait estimation over time. Besides, it can also provide the residents with fall risk assessment data based on gait parameters at home. Diagnostic techniques and treatment optimization are of important academic theory and practical application value. Balaji E. [7]proposed gait classification framework with several classifiers (i.e DT, SVM, EC and BC), and utilized the vertical ground reaction force (VGRF) gait dataset, the minimal feature

vector using the statistical analysis. The results reveal that the proposed method outperforms several other PD classification methods.

The monitoring of gait parameters collected in the above-mentioned literatures involves highly accurate but expensive systems, such as three-dimensional gait analysis, infrared camera, photoelectric system and force sensor. As non-mobile devices, these sensory systems are only operable in controlled environment, therefore, it is difficult to analyze the continuous gait cycle of long-term application, especially in the case of free walking. In contrast, non-contact measurement methods, such as depth camera are more suitable for home measurement, unfortunately, there is no evaluation on early diagnosis of related diseases.

Conclusion

At present, there is a lack of effective methods to detect gait disorders in early degenerative diseases from the perspective of visual cognition. This is due to the fact that the extracted abnormal motion features can not only have a good "distinguishing" description for the behavior types of different diseases, but also have a good 'invariance' description for the same behavior under various complex conditions. Human vision can easily capture the key areas in walking gait, it is therefore very important to model the human behavior and key point feature extraction mechanism in the process of visual cognition, starting from the characteristics of human visual attention and the individual processing mechanism.

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