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WEARABLE DEVICES IN CLINICAL GAIT ANALYSIS

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Streszczenie: *Mobilna, efektywna, dokładna, szczegółowa, wczesna i tania kliniczna analiza chodu ma kluczowy wpływ na planowanie, postęp i ocenę strategii i modeli rehabilitacji, jak również przedmiotów zaopatrzenia ortopedycznego. Nowe rodziny mobilnych rozwiązań do klinicznej analizy chodu mogą zapewnić wczesniejsze wykrywanie, dokładniejszą diagnostykęoraz efektywniejszą terapię deficytów chodu. Zdalna integracja ww. rozwiązań ze szpitalnym systemem informacyjnym może zapewnić lepszą i aktualniejszą wiedzę na potrzeby klinicznego podejmowania decyzji. Niniejszy artykuł stanowi przegląd urządzeń do pomiaru wybranych parametrów chodu, w zależności od pożądanej dokładności.*

Słowa kluczowe: *systemy mobilne, eZdrowie, urządzenia do noszenia, analiza chodu, kliniczna analiza chodu.*

Urządzenia do noszenia w klinicznej analizie chodu

Portable, efficient, exact, detailed, early and cost-effective clinical gait analysis (CGA) has key influence for planning, development and assessment rehabilitation strategies and models, as far as for prosthetics assessment. Novel families of mobile CGA solutions may provide earlier detection, more exact diagnosis, and more effective therapy of the gait disorders. Remote integration of aforementioned solutions to hospital information system may provide better and more actual knowledge for clinical decision-making purposes. This study aims at review of the alternative wearable devices to measure selected gait parameters, depending on the desired accuracy level.

Keywords: *mobile system, mHealth, wearable device, gait analysis, clinical gait analysis.*

1. Introduction

Many spatiotemporal parameters of gait such as velocity, cadence, stride length, step time may be associated with physical function in many patients Despita many years of development they are still difficult, time consuming and obtrusive to measure.

Portable, efficient, exact, detailed, early and cost-effective clinical gait analysis (CGA) has key influence for planning, development and assessment rehabilitation strategies and models, as far as for prosthetics assessment. Thus CGA plays crucial role within clinical decision-making process. Traditional measurement of gait parameters requires motion tracking systems combined with force plates. Environment of the gait laboratory is often regarded as “artificial” and has its own limitations: specialized locomotion laboratory, expensive equipment, limited area of walking and associated activities, and time-consuming set up and post-processing. Clinical gait analysis in natural environment of patients allows for recording and analysis of the natural real-life gait of the patients, expected during activities of daily living (ADLs). CGA is closer to every-day life conditions, allows for taking into consideration different aspects of gait, sometimes even in more precise form (e.g. characteristics of patient’s home environment). There is need to admit, that gait analysis using typical walking aids and/or orthoses should be possible, with accepted exactness.

This study aims at review of the alternative wearable devices to measure selected gait parameters, depending on the desired accuracy level.

2. Solutions

Wearable sensors/devices (accelerometers, gyrosensors, force sensors, strain gauges, inclinometers, goniometers, etc.) may be attached to various parts of the patient's body (the most common are foot or waist). Recordings from selected combinations of aforementioned sensors can be used to perform the gait analysis. Review by Tao et al. divided wereable systems for CGA into several subgroups, i.e. systems based on::

- accelerometer, gyroscope, and magnetoresistive sensors,
- flexible goniometr,
- electromagnetic tracking system,
- sensing fabric,
- force sensors,
- electromyography (EMG) [1].

Increasing number of wearable sensors and systems exist or will be developed in the near future. Outwalk protocol is based on wearable sensors and framework guidelines, including amputees [2]. Use of simple markers allow for reasonable accuracy (influenced mainly by inaccuracy of marker placement), even for demonstration of the curvatures angles, and positional and structural deformities [3, 4]. Thus main CGA methods include:

- gait kinematics (analysis of gait phases, gait parameters, and movement of the major joints and components of the lower extremities during human gait),
- gait kinetics (analysis of forces and moments within the movement of body segments during human gait),
- EMG (analysis of muscles force/activity during human gait) [1].

CGA in patients with Parkinson's disease was described by many researchers [5-9], as far as CGA application in post-stroke patients [10, 11], patients after hip or knee arthroplasty [12, 13], and children with cerebral palsy [14-16].

Gait analysis based on wearable sensors may support sport training, improve and maintain performance, and prevent injuries [17-19]. Similar solutions may be applied in exercise-driven interactive entertainment, especially supporting healthy life style and happy aging.

Application of mobile CGA devices will grow due to increased need to monitor health care and early diagnose (screening) of many disorders, such as detection of gait abnormalities in children, observe progression of neurodegenerative diseases and prevention of fall risk in elederly people and stroke survivors [20, 21].

3. Directions for further research

Despite quick development of gait analysis using wearable sensors in the past two decades CGA using wereable devices is still at the beginning ot its development. Many solotions are prototypes, and rare commercial versions can be normally applied in everyday clinical practice.

Low-cost and easy-to-use Kinect sensor is promised solution for gait analysis, providing improved exactness [22-25]. Value of aforementioned solution seem increase according to the evidence-based medicine (EBM) paradigm due to many publications and research concerning this topic [23].

We should put particular attention to solutions for children, e.g. sensors built in toys (even simple robots). Attractive form allow for CGA analysis of the child during the play, what makes it quicker and more objective [22, 24, 25].

Tablets, smartphones, smartwatches, smartbands, wireless networks and many other mHealth solutions open new possibilities, especially thanks to interactive games and virtual environments [26, 27].

Technical matters and clinical procedures should be improved to fully exploit current and future occupations. This may create novel families of mobile CGA solutions providing earlier detection, more exact diagnosis, and more effective therapy of the gait disorders. Remote integration to hospital information system may provide better and more actual knowledge for clinical decision-making purposes. Our research are conducted twofold:

- for early detection and screening purposes: toward semi-automated contact-free CGA methods based on motion capture and advanced analysis based on ordered fuzzy numbers, fractal dimension, and artificial neural networks,
- for therapy monitoring purposes (if aforementioned solutions are not sufficient): toward cheap and patient-friendly family of semi-intelligent solutions such as intelligent soles, mobile applications. cooperating with.

This way we aim at increased use of CGA by physicians, physiotherapists, and other medical specialists, not always involved in gait laboratoratory procedures. Wide dissemination may improve early recognition of gait disorders, decrease number of severe cases, increase efficacy of interventions, and lower costs of the therapy and care.

Taking into consideration popular use of smartphones, smartwatches, smarbands, and similar accesories wise marketed technology of CGA may also constitute important solution for more advanced runners, nordic walkers, and other people imroving their walk or run abilities. This way CGA solutions may be popularized and disseminated, allowing for easier prevention in a way similar to internet-based screening of sight disorders or hearing disorders.

4. Conclusions

We are still looking for more universal, cheaper and less time-consuming CGA methods and tools. Despite more than fifty years of development aforementioned task still seems challenge.

CGA protocols allow not only for comprehensive evaluation of the treatment effects, but also for deeper understanding of the biomechanical features of the healthy and pathological gait. Gait analysis using wearable sensors shows great prospects, not only in the diagnosis and rehabilitation of medical conditions and sport activities. We should be aware that some commonly reported variables cannot be accurately measured using wearable devices, thus assessment and modification of protocols is needed.

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