THREE DIMENSIONAL GAIT ANALYSIS OF EXERCISE REHABILITATION AND MUSCLE TENSION

ANÁLISE TRIDIMENSIONAL DE MARCHA DE EXERCÍCIOS DE REABILITAÇÃO E TENSÃO MUSCULAR

ANÁLISIS TRIDIMENSIONAL DE MARCHA DE EJERCICIOS DE REHABILITACIÓN Y TENSIÓN MUSCULAR

ORIGINAL ARTICLE
ARTIGO ORIGINAL
ARTÍCULO ORIGINAL

Haojie Dong[1]
(Physical Education Professional)

1. Faculty of Physical Education, Henan University of Science And Technology, Luoyang, Henan, China.

Correspondence
Haojie Dong
Luoyang, Henan, China, 471000.
donghaojie89@163.com

ABSTRACT

Introduction: Timely assessment and correction of post-stroke hemiplegia gait, to improve walking ability, has become an urgent problem for patients with hemiplegia. Objective: In order to improve the effect of exercise rehabilitation and tensile strength testing, a three-dimensional gait analysis method was proposed. Methods: The kinematics, dynamics, ground reaction force and surface EMG of lower limbs were measured by VICON (Nexus 1.8.5), a three-dimensional gait analysis system, and Noraxon, a wireless surface EMG, while 13 healthy subjects walked. The intra-group correlation coefficient (ICC) and standard error of measurement (SEM) were used to compare the relative and absolute reliability of the two test results. Results: the re-testability ICC was 78~0.96, the standard error SEM% of kinematics parameters was 4.18~15.6, and the SEM% of dynamic parameters was 3.31~21.82. The SEM% of ground reaction force was 1.70~16.67, and the SEM% of surface EMG signal was 8.00~11.11. Conclusions: 3D gait analysis can improve the effect of exercise rehabilitation and tensile strength testing, and has good retesting reliability. ***Level of evidence II; Therapeutic studies - investigation of treatment results.***

Keywords: Imaging, three-dimensional; Sports; Rehabilitation.

RESUMO

Introdução: A avaliação e correção oportunas da marcha hemiplégica pós-derrame para a recuperação da habilidade de caminhar tem se tornado um problema premente para pacientes com hemiplegia. Objetivo: Um método de análise tridimensional de marcha foi proposto para melhorar o efeito de exercícios de reabilitação e de testes de força tensil. Métodos: A cinemática, dinâmica, força de reação ao solo e EMG de superfície de membros inferiores foram medidos por VICON (Nexus 1.8.5), um sistema de análise tridimensional de marcha, e Noraxon, um EMG de superfície sem fio enquanto 13 indivíduos saudáveis caminhavam. O coeficiente de correlação intragrupo (CCI) e erro padrão de medida (EPM) foram utilizados para comparar a confiabilidade relativa e absoluta dos dois resultados de testes. Resultados: A retestagem ICC foi de 78~0.96, o erro padrão SEM% de parâmetros cinemáticos foi de 4.18~15.6, e o SEM% de parâmetros dinâmicos foi de 3.31~21.82. O SEM% de força de reação ao solo foi de 1.70~16.67, e o SEM% do sinal EMG de superfície foi de 8.00~11.11. Conclusões: A análise 3D de marcha pode melhorar o efeito de exercícios de reabilitação e testes de forca tensil, além de ter boa confiabilidade de retestagem. ***Nível de evidência II; estudos terapêuticos – investigação de resultados de tratamento.***

Descritores: *Imageamento tridimensional; Esportes; Reabilitação.*

RESUMEN

Introducción: La evaluación y corrección oportunas de la marcha hemipléjica posderrame para la recuperación de la habilidad de caminar ha se convertido en un problema apremiante para pacientes con hemiplejia. Objetivo: Un método de análisis tridimensional de la marcha se propuso para mejorar el efecto de ejercicios de rehabilitación y de pruebas de fuerza tensil. Métodos: La cinemática, dinámica, fuerza de reacción del suelo y EMG de superficie de miembros inferiores se midieron por VICON (Nexus 1.8.5), un sistema de análisis tridimensional de marcha, y Noraxon, un EMG de superficie inalámbrico mientras 13 individuos saludables marchaban. El coeficiente de correlación intragrupo (CCI) y error estándar de medida (EEM) fueron utilizados para comparar la confiabilidad relativa y absoluta de dos resultados de pruebas. Resultados: La reprueba CCI fue de 78~0.96, el error estándar EEM% de parámetros cinemáticos fue de 4.18~15.6, y el EEM% de parámetros dinámicos fue de 3.31~21.82. El EEM% de fuerza de reacción del suelo fue de 1.70~16.67, y el EEM% de la señal EMG de superficie fue de 8.00~11.11. Conclusiones: El análisis 3D de marcha puede mejorar el efecto de ejercicios de rehabilitación y pruebas de fuerza tensil, además de tener buena confiabilidad de reprueba. ***Nivel de evidencia II; Estudios terapéuticos – investigación de resultados de tratamiento.***

Descriptores: *Imagenología tridimensional; Deportes; Rehabilitación.*

DOI: http://dx.doi.org/10.1590/1517-8692202127082021_0367

Article received on 07/29/2021 accepted on 08/18/2021

INTRODUCTION

The research and application of gait analysis has been developing since the beginning of photography in the late 19th century, and has a history of more than 100 years. However, it only takes more than 10 years for the gait analysis to enter the clinical application stage. Gait analysis refers to the rehabilitation evaluation, training and treatment process, the objective and quantitative evaluation of human walking function, fully reflects the patient's rehabilitation function, for traumatic brain injury, the central and peripheral nervous system injury and joint damage to develop rehabilitation treatment and evaluation of rehabilitation in patients with curative effect, operation program and provides objective to assess postoperative curative effect, etc. Objective of clinical gait analysis: (1) Quantitative analysis of various gait indexes, such as stride length, stride frequency, gait speed, time phase and period, standing phase moment, joint Angle, etc., to provide objective data for clinical and scientific research.[1]

Assess the problems in gait, abnormal gait pattern and the improvement degree of lower limb muscle tension and muscle strength before and after rehabilitation treatment, and make rehabilitation treatment and training plan. (3) Evaluate the rehabilitation effect, and compare the gait before and after custom-made braces and orthoses to determine the suitability of braces or orthoses and their use value. The method of three-dimensional gait analysis is applied to the field of rehabilitation medicine, and according to the kinematics parameters, biomechanics parameters and the changes of skeletal muscle electromyography activity parameters, it is feasible to objectively and realtime select the rehabilitation treatment method and evaluate the curative effect.[2]

METHOD

Selecting Objects

From September 2017 to November 2017, a total of 13 patient volunteers from Shanghai University of Traditional Chinese Medicine, postgraduate students and staff of Shuguang Hospital affiliated to Shanghai University of Traditional Chinese Medicine were selected as the research objects. There were 11 males and 2 females, with an average age of (27.64 ± 2.98) years, an average height of (174.18 ± 8.84) cm, and an average weight of (73.36 ± 14.55) kg. All subjects were tested after signing the informed consent form. Inclusion criteria: age 18 ~ 40; He recovered within the last 3 months; No neuromuscular disease affecting gait; Able to take the initiative to complete the test with clear awareness. Exclusion criteria: patients with other neuromusculoskeletal disorders that can cause gait abnormalities; Reluctant to actively cooperate with testers.[3]

Methods

Five groups of dynamic Clusters were placed on the bilateral thighs, the outer edge of the calf, and the back of the pelvis. Bilateral tibialis anterior muscle, peroneus externalis muscle, peroneus internus muscle, vastus externus muscle, vastus internus muscle, biceps femoris (long head) and semitendinosus muscle were selected as the lower limb muscles. Experimental data collection: Before the biomechanical test, the subjects recorded their height, weight, age, gender and other basic information. Then, 44 passive cursors were placed on the bone markers of the subjects according to the CAST mode, the 14 groups of surface EMG electrodes were placed at the corresponding positions, and the subjects were asked to build a Static Model by standing in an anatomical position. Then the subjects were asked to do 5 to 15 walking adaptation exercises, adjust the starting point of the corresponding walking test to ensure that when the subject passes through the force measuring table area in a natural walking state, one side foot can only contact one force measuring table at a time (two side feet shall not contact the same force measuring table at the same time, or one side foot shall not fully contact the force measuring table).[4,5]

RESULTS

In this study, ICC was used to study the relative reliability of repeated tests, and the results showed that the step speed repeatability (ICC: 0.93) and absolute reliability (SEM% : 2.27) were good. (Table 1) The maximum motion Angle and moment of hip joint, knee joint and ankle joint in sagittal plane and coronal plane showed good repeatability (ICC: 0.78~0.95) and absolute reliability (SEM% : 4.18~21.82). (Table 2 and 3) The repeatability (ICC: 0.91-0.95) and absolute reliability (SEM%: 1.70-16.67) of the ground reaction force in the vertical direction, the inside direction and the front and back direction are good. (Table 4) The peak amplitude of surface EMG of the femoris externalis, femoris internus, semitendinosus, biceps femoris (long), tibialis anterior muscle, peroneal muscle and peroneal muscle also showed good repeatability (ICC: 0.88-0.96) and absolute reliability (SEM%: 8.00-11.11).[6] (Table 5)

Clinical gait analysis will provide a strong basis for the key factors of gait abnormality in patients with injury, thus assisting in clinical diagnosis and treatment. Specific application scope includes: (1) Identifying the abnormal gait: three-dimensional gait analysis can accurately determine the rule of abnormal gait, dyskinesia of key joints and muscles, pedestrian barriers and the relationship between trunk and arm movements, walking assisted with the value of efficiency and safety of walking and walking way, etc., to determine the clinical diagnosis and treatment of provide the scientific basis. (2) Evaluation of treatment effect: 3D gait analysis is the best tool to evaluate the rehabilitation and clinical treatment effect of walking function of patients with sports injury, which has an irreplaceable

Table 1. Test results of time and space parameters.

Time space parameter	The first test (m/s)	Weight measurement (m/s)	ICC (95%IC)	SEM (m/s)	SEM (%)
Pace	1.32±0.12	1.30±0.12	0.93	0.03	2.27

Table 2. Test results of kinematics parameters.

The maximum joint Angle in the full gait cycle	The first test (°)	Weight measurement (°)	ICC (95%IC)	SEM (°)	SEM (%)
Angle of hip flexion	27.75±6.61	26.52±6.22	0.91	2.13	7.85
Hip extension Angle	-13.33±4.64	-14.35±4.46	0.84	1.84	13.29
Adductive Angle of hip joint	7.77±2.56	8.97±2.70	0.88	0.92	10.99
Hip abduction Angle	-7.62±3.17	-6.11±2.92	0.92	0.88	12.83
Knee flexion Angle	58.3±4.8	60.7±6.1	0.80	2.49	4.18
Knee valgus Angle	-4.42±2.13	-3.91±1.72	0.90	0.61	14.6
Knee varus Angle	6.47±3.58	7.71±4.79	0.93	1.11	15.6
Ankle dorsiflexion Angle	10.96±3.10	13.43±2.87	0.86	1.16	9.51
Ankle joint plantarflexion Angle	-19.69±7.85	-15.96±7.91	0.85	3.07	16.75
Ankle varus Angle	9.14±3.27	10.49±3.39	0.80	1.50	15.28
Ankle valgus Angle	-3.93±2.35	-3.16±2.38	0.95	0.53	14.9

Table 3. Dynamic parameter test results.

Maximum moment in the supporting phase	The first test (NM/kg)	Weight measurement (NM/kg)	ICC (95%IC)	SEM (NM/kg)	SEM (%)
Hip extension moment	0.96±0.24	0.91±0.24	0.86	0.04	4.28
Adductive torque of hip joint	0.87±0.18	0.78±0.17	0.84	0.18	21.82
Knee flexion moment	0.55±0.24	0.52±0.21	0.86	0.07	8.79
Adductive torque of knee joint	0.38±0.10	0.37±0.11	0.78	0.02	5.33
Ankle dorsal extension moment	1.47±0.12	1.55±0.16	0.89	0.05	3.31
Ankle valgus moment	0.17±0.09	0.16±0.09	0.86	0.03	18.18

Table 4. Ground reaction force test results.

Maximum ground reaction in the supporting phase	The first test (BW)	Weight measurement (BW)	ICC (95%IC)	SEM (BW)	SEM (%)
Ground reaction force (vertical)	1.18±0.09	1.17±0.07	0.93	0.02	1.70
Ground reaction force (inside)	0.06±0.02	0.06±0.01	0.91	0.01	16.67
Ground reaction (propulsion)	-0.19±0.04	-0.19±0.04	0.96	0.01	5.26
Ground reaction (obstruction)	0.22±0.04	0.21±0.03	0.95	0.01	4.65

Table 5. Surface EMG test results.

Peak muscle contractions in the gait cycle	The first test (mV)	Weight measurement (mV)	ICC (95%IC)	SEM (mV)	SEM (%)
Shares outside the muscle	0.11±0.09	0.10±0.04	0.88	0.01	9.52
Shares in muscle	0.09±0.02	0.09±0.02	0.90	0.01	11.11
Half tendons	0.13±0.04	0.12±0.04	0.89	0.01	8.00
Femoral biceps	0.09±0.04	0.09±0.04	0.88	0.01	11.11
Pretibial muscle	0.21±0.10	0.18±0.09	0.96	0.02	10.26
Phil. Within the muscle	0.23±0.07	0.22±0.07	0.93	0.02	8.89
Phil. Outside the muscle	0.26±0.12	0.24±0.10	0.92	0.02	8.00

role. In particular, it should be emphasized that the goal of gait training should be to make the patient walk with the least effort and the most safe, not just to be close to the normal person in appearance. Excessive pursuit of "normal gait" at the expense of walking efficiency and safety is unscientific, and is also a clinical misunderstanding of walking function training for patients with sports injuries.[7-8]

DISCUSSION

In addition to kinematics, dynamics and ground reaction forces, the EMG signals of lower limb muscles in this study also had good repeatability (ICC0.88-0.96), which was not only related to the use of low-pass filtering cutoff frequency (20Hz) of a higher frequency for filtering in this study, but also related to the use of wireless surface EMG. In previous studies, wired surface EMG was used, and longer data conduction lines would hinder the walking of the subjects to some extent, which might affect the final results.[9] However, wireless surface EMG minimized the errors caused by the instrument as much as possible, so it had better repeatability. Previous studies have shown that if SEM% < 15% is acceptable, in this study, kinematics, dynamics, ground reaction force, SEM% of surface EMG signal (1.70%-21.82%), except for hip joint adductive moment (21.82%), The valvus moment (18.18%) and the medial direction of ground reaction force (16.67%) of the ankle joint were slightly higher than the reference range, and the rest were within the standard range. Therefore, it is suggested that 3D gait analysis combined with EMG can be used to evaluate the biomechanics of lower limbs during human walking.[10-11]

CONCLUSION

This paper presents a new method for 3D gait analysis. The specific content of this method was to use VICON (Nexus 1.8.5) three-dimensional gait analysis system and Noraxon wireless surface EMG to test the kinematics, dynamics, ground reaction forces of lower limbs and the retestability of surface EMG signals in the walking process of 13 healthy people. Intra-group correlation coefficient (ICC) and standard error of measurement (SEM) were used to compare the relative and absolute reliability of the two test results. Through the experimental observation of the walking process, the pace, lower limb kinematics, dynamics, ground reaction force and surface EMG signal all have good retestability ICC0.78~0.96, the kinematics parameter measurement standard error SEM% is 4.18~15.6, the dynamics parameter SEM% is 3.31~21.82. The SEM% of ground reaction force is 1.70~16.67, and the SEM% of surface EMG signal is 8.00~11.11. It is proved that 3D gait analysis can improve the effect of exercise rehabilitation and tensile strength test, and has good retestment reliability.

ACKNOWLEDGMENT

Henan University of Science and Technology Youth Fund. Project Title: Crisis Management of Sports Fitness and Entertainment Industry in Luoyang City in the Post-Financial Crisis Era. Project Number: 2015SQN008.

The author declare no potential conflict of interest related to this article

AUTHORS' CONTRIBUTIONS: The author made significant contributions to this manuscript. Haojie Dong: writing and performing surgeries; data analysis and performing surgeries; article review and intellectual concept of the article.

REFERENCES

1. Kim S, Lim J, Lee K, et al. Prevalence and association of self-reported anxiety, pain, and oral parafunctional habits with temporomandibular disorders in Japanese children and adolescents: a cross-sectional survey. Chinese Journal of Oceanology & Limnology. 2016;34(6):1199-208.
2. **Kim, Ok-Ju, Lee, et al. Study on factor for cultivation of character of rehabilitation exercise volunteer worker via in-depth analysis. Korean Journal of Sports Science. 2017;26(2):201-20.**
3. Smith T, Gilleard W. Three-dimensional analysis of a lofted instep kick by male and female footballers. Eur J Sport Sci. 2016;16(1):57-64. doi: 10.1080/17461391.2014.992477
4. Kjellgren A, Sundequist U, Norlander T, Archer T. Effects of flotation-REST on muscle tension pain. Pain Res Manag. 2001 Winter;6(4):181-9. doi: 10.1155/2001/768501
5. Merino-Marban R, Mayorga-Veja D, Fernandez-Rodriguez E, Estrada V. Effect of a physical education-based stretching programme on sit-and-reach score and its posterior reduction in elementary schoolchildren. European Physical Education Review. 2015;21(1):83-92. doi: 10.1177/1356336X14550942
6. Kim SK, Lee J, Song M, Kim M, Hwang SJ, Jang H, et al. Combination of three angiogenic growth factors has synergistic effects on sprouting of endothelial cell/mesenchymal stem cell-based spheroids in a 3D matrix. J Biomed Mater Res B Appl Biomater. 2016;104(8):1535-43. doi: 10.1002/jbm.b.33498
7. Dunagan J, Adams J, Cheng D, Barton S, Bigej-Cerqua J, Mims L, et al. Development and evaluation of a treadmill-based exercise tolerance test in cardiac rehabilitation. Proc (Bayl Univ Med Cent). 2013;26(3):247-51. doi: 10.1080/08998280.2013.11928972
8. **Shiotani M, Watanabe T, Murakami K, Kuge N. Research on detection method for abnormal gait using three-dimensional thigh motion analysis with inertial sensor. Transactions of Japanese Society for Medical and Biological Engineering. 2019;57(1):1-7.**
9. Khoddami SM, Ansari NN, Jalaie S. Review on Laryngeal Palpation Methods in Muscle Tension Dysphonia: Validity and Reliability Issues. J Voice. 2015;29(4):459-68. doi: 10.1016/j.jvoice.2014.09.023
10. Choi SY, Choi JH. The effects of cervical traction, cranial rhythmic impulse, and Mckenzie exercise on headache and cervical muscle stiffness in episodic tension-type headache patients. J Phys Ther Sci. 2016;28(3):837-43. doi: 10.1589/jpts.28.837
11. Kawagoshi A, Kiyokawa N, Sugawara K, Takahashi H, Sakata S, Satake M, et al. Effects of low-intensity exercise and home-based pulmonary rehabilitation with pedometer feedback on physical activity in elderly patients with chronic obstructive pulmonary disease. Respir Med. 2015;109(3):364-71. doi: 10.1016/j.rmed.2015.01.008.