

ORIGINAL RESEARCH

ALTERATION OF THE LOAD-RESPONSE MECHANISM OF THE KNEE JOINT DURING HEMIPARETIC GAIT FOLLOWING STROKE ANALYZED BY 3-DIMENSIONAL KINEMATIC

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Lucarelli PRG, Greve JMA. Alteration of the load-response mechanism of the knee joint during hemiparetic gait following stroke analyzed by 3-dimensional kinematic. Clinics. 2006;61(4):295-300.

PURPOSE: The aims of this study were to evaluate the variables found in the alteration of the load-response mechanism on 3-dimensional kinematic analysis of the knee joint during hemiparetic gait following stroke.

METHODS: We evaluated 66 adult patients (33 men and 33 women), aged 45.4 ± 8.5 years (mean \pm SD), with a diagnosis of ischemic cerebrovascular accident either right or left hemiparesis and brachial prevalence. All the participants underwent 3-dimensional gait evaluation with a Vicon 370, and the values of the angular kinematics of the knee joint were selected for analysis.

RESULTS: There were no statistically significant differences (by the Kruskal-Wallis test) between the subjects regarding the following variables: angular knee position at initial contact and time of peak knee flexion in the stance. The clinically relevant characteristics found were: an increase in knee joint flexion during the initial contact and a movement amplitude below that anticipated in this phase of the walking cycle. These should be taken into account when choosing the best treatment, because they are the ones which exhibit the most important alteration in the load-response mechanism in all patients.

CONCLUSION: There is still no consensus among the different specialists regarding the variations in kinematics during the hemiparetic gait. One of the most frequently discussed joints is the knee—the way the main changes take place during the gait cycle and whether the gait velocity changes the patterns of joint mobility.

KEYWORDS: Hemiplegia, Knee, Biomechanics, Gait, Neurologic Gait Disturbance.

INTRODUCTION

The leading gait cycle changes that take place as sequelae of neurological disorders and the walking patterns in cerebral palsy are the most studied. The large number of gait studies in cerebral palsy led the scientific community to a better understanding of how the pattern of biomechanics of normal gait is changed in this population. As a result, some changes were found and some walking patterns were defined in an attempt to find the best treatment strategy for each kind of change¹⁻⁸. One of the most clarifying

studies on walking pattern in cerebral palsy is the one which defines walking according to knee movement throughout the walk cycle. In other populations with neurological sequelae, gait is also one of the greatest—if not the greatest—problems during rehabilitation. Craik and Oatis⁹ note that approximately 70% of the patients surviving a brain stroke regain their walking capacity. This ability needs to be understood for better treatment and rehabilitation of these patients.

The challenge is that so far there is not a consensus among the several experts on the kinematic joint variables during hemiparetic gait. The most discussed joint is the knee regarding how the most important changes behave during the walk cycle¹⁰⁻¹⁴ and whether the walking speed changes the mobility patterns of this joint.^{15,16} The load-response mechanism is fundamental for walking, since it

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Received for publication on October 14, 2005.

Accepted for publication on April 19, 2006

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aims to reduce the impact on the lower limb and smoothen the mass center displacement, thus reducing energy expenditure.

The aim of this study was to describe and evaluate the angular kinematic variables of the knee joint during load response in hemiparetic gait from brain stroke.

MATERIALS AND METHODS

Sixty-six adult patients (33 women and 33 men) were involved in this study. Their ages were 45.4 ± 8.5 years (mean \pm SD; range, 31-60). Their weight averaged 67.6 ± 16 kg (range, 44-110), and their height averaged 161.3 ± 9.7 cm (range, 136-189).

The inclusion criteria were diagnosis of ischemic brain stroke sequela with right or left hemiparesis, being at least 12 months post injury; being a community walker; not needing walking aids; being able to walk on bare feet, and not having undergone previous orthopedic surgery.

All study subjects had a clinical indication for tridimensional gait evaluation and were referred to the laboratory by medical request. Having met the above inclusion criteria, the patients were asked to consent to the use of the final report of their test in this study and sign an informed consent form.

The data were collected at the Gait Laboratory of the Associação de Assistência à Criança Deficiente – AACD, in the city of São Paulo.

After anamnesis and evaluation regarding inclusion criteria, the subjects underwent the tridimensional computerized gait analysis protocol. Six infra-red VICON/PEAK® 370 movement analysis cameras and the kinematic markers (Helen Hayes marker system) for the pelvis, hip, knee, and ankle joints were used.^{17,18}

For each cycle in the exam track, a single walking cycle was selected. Using the Vicon Clinical Manager software, the tridimensional kinematic data of the pelvis, hip, knee, and ankle joints were expressed in graphs of the angle positioning of the joint versus time, thus generating 12 graphs for each subject. From the total of 12 cycles, only 1 was chosen for analysis. This selection was based on the protocols of the Gait Analysis Laboratory of AACD, taking as a parameter the mean value of angular kinematics and the mean walking speed. The same cycle was used for angular kinematics analysis of the knee in the sagittal plane.

Three variables were defined based on the knee joint in sagittal plane graph: knee angular position at initial contact, knee first peak flexion in the stance phase (degrees), time of peak knee flexion in the stance (% of the stance).

The comparison groups were formed from the walking speed parameter, taking into consideration the median

(nonparametric distribution) of all speeds measured, making up 2 large groups: one with a speed slower or equal to the median and the other with a speed higher than the median. Each of these groups was divided into 2 subgroups, right and left, according to the hemiparesis-affected side.

Four groups were therefore formed: Group 1 – speed slower than the median, and left hemiparesis (LSLH), with 23 subjects; Group 2 – speed slower than the median, and right hemiparesis (LSRH), with 10 subjects; Group 3 – speed higher than the median, and left hemiparesis (HSLH) with 7 subjects; and Group 4 – speed higher than the median and right hemiparesis (HSRH), 26 subjects.

The possible differences among the groups, according to predefined variables were evaluated by the Kruskal-Wallis nonparametric test for independent samples, completed, as necessary, by the multiple comparisons test. The means were calculated and presented for information purposes. Standard deviation was not calculated, because of the use of a nonparametric test. The evaluated variables do not have a normal distribution; thus, there would have been no meaning to its calculation.

The rejection level for the null hypothesis was established as equal to or less than 0.05 (5%).

RESULTS

The results of angular kinematics for each studied subject were distributed into 4 groups according to the evaluation parameters of walking speed median and affected side.

No significant difference was noted among the groups for the angular position variables at knee initial contact and peak knee flexion at loading response phase (Table 1).

The time-point of peak knee flexion in stance was significantly different in the 4 groups studied. After application of the complementary test of the absolute values of the differences between means, it was possible to note a similarity between group 1 (LSLH) and group 4 (HSRH): the slower gait velocity changed the time-point in which the peak flexion occurred (Table 2).

DISCUSSION

Gait analysis is a complex procedure requiring the understanding of several biomechanical factors. Among them are kinematics, which evaluates the movement but is not concerned with the causes of the movement, and kinetics, concerned with the understanding of the causes generating movement and muscle activity, and understanding when and how muscle contractions take place during the walk cycle.

Table 1 - Speed median value and mean value of the kinematic variables of knee joint of patients with ischemic brain stroke sequela

	Goup 1 (VMEE)	Group 2 (VMED)	Group 3 (VMAE)	Group 4 (VMAD)
Speed median (cm/s)	≤ 64.8	≤ 64.8	> 64.8	> 64.8
Knee angular position in the initial contact (°) N.S.	9.5	7.0	16.6	8.7
Knee first flexion peak in the stance phase (°) N.S.	10.50	11.17	17.06	10.24
Time of knee flexion peak in the stance(% of the stance) *	4.7	11.3	9.1	10.3

Group 1 (VMEE) - speed lower than the median, and left hemiparesis;
 Group 2 (VMED) - speed lower than the median and right hemiparesis,
 Group 3 (VMAD) - speed higher than the median and left hemiparesis
 Group 4 (VMAD) - speed higher than the median and right hemiparesis

N.S - Non significant; * p<0,05.

Table 2 - Absolute value of the difference between the mean values of patients with ischemic brain stroke and hemiparesis of the four groups and least significant difference

	Group 1, VADMP	Group 2 DMS	Group 1, VADMP	Group 3 DMS	Group 1, VADMP	Group 4 DMS
Time to knee flexion peak in load response (% of load response)	14.52	19.18	12.14	21.86	12.90 §	14.50
Time to knee flexion peak in load response (% of load response)	2.38	24.96	1.62	18.85	0.76	21.57

VADM - absolute value of the means difference; DMS - least significant difference; § Groups values approximation

Evaluation of joint and segment kinematics is a valuable resource for clinical practice, since it can precisely measure the angular variation between the segments, clarifying and quantifying what the human eye, even with great clinical experience, is unable to do.

When a patient is affected by a brain stroke, alterations in motor control make understanding the walking mechanics more complex. In most cases, such alterations affect the entire lower limb, and, all too frequently they are superficially evaluated. It is not uncommon that clinicians make a wrong, or a partially wrong diagnosis, turning their attention to secondary changes, which are frequently more evident; consequently, the primary cause of the disability goes undetected. In these cases, the patient is submitted to interventions that do not actually treat the problem, causing the gait patterns to return. Eventually, new patterns may appear.

The most effective alternative is to evaluate each joint individually and later understand the influence they have on each other; for instance, excessive knee flexion may affect the hip joint or even lead to postural changes of the body.

This work describes the angular kinematic changes of the knee joint during hemiparetic gait, in search for similarities among the evaluated variables, and trying to define a pattern for the knee joint.

Initially, the result of knee angular movement during the walk cycle was subdivided into 11 variables containing values of angular positioning during the cycle, speed values of angular movement, and values representing the cycle period when these events occurred.

The first characteristic found in the evaluated groups was the knee positioning at the start of the cycle, that is, at initial contact. The values found in our samples corresponded to those in the literature for normal gait¹⁹ independently of walking speed changes. Burdett et al¹⁰ described an increase in knee joint flexion during the initial contact, when subjects walked at "normal" speed. Olney,¹⁶ however, notes that speed variation affects the knee flexion: with increased flexion at faster walking speeds. Knutsson,^{11,12} Lehmann,¹³ Cozean,¹⁴ and Intiso,¹⁵ report that the values found for the knee position at initial contact are different from the previous ones, with less knee flexion at initial contact. Thus, the literature data⁹⁻¹⁶ show discrepancies, and this subject has not yet been completely clarified. However, it is known that changes in knee positioning may interfere with step length, compromising the walking cycle at its beginning, and may be reflected later in the walking cycle.

The first peak knee flexion takes place in the bearing phase and is called *load response*. We found values agreeing with the findings of Burdett et al,¹⁰ Olney,¹⁶ and Kerrigan.²⁰ These authors also described for patients with hemiplegia a movement amplitude below that anticipated in this phase of the walking cycle when compared subjects with no neurological afflictions. Olney²¹ however, disagreed, stating that there is difference in the angular position of the knee in load response when the walking speed is increased or reduced.

The load response contributes to a smoothening of the sudden changes in the intersections of the track arcs of the

mass center. More specifically, the weight load response flattens the arc that the mass center displaces throughout the movement. The change produced by this mechanism reduces the quality and quantity of ground shock absorption.

Changes in this walk phase can be due to several causes: (i) weakness of the quadriceps muscle resulting in excessive knee flexion; (ii) spasticity of the quadriceps muscle leading to stretching the quadriceps when starting flexion, in turn leading to a hypertonic response and consequent premature knee extension; (iii) excessive plantar flexion (plantar flexion contracture and spasticity of the soleus muscle); (iv) failure to make the initial contact with the rear foot, causing inhibition or blocking of the rolling mechanism of the tibia over the foot during load bearing.²¹⁻²⁴

The time-point of the peak knee flexion during load bearing, that is, an event which occurred while the knee was in flexion, was significantly different among the 4 stud-

ied groups. Although the evaluated groups presented a significant difference in the duration of the flexion, their average values all ranged from 4.7% to 10.3% of the walking cycle. These values are below the normal gait pattern described in literature,^{19,22} where the reference values for duration of flexion are 15% of the gait cycle. The loss of selective control, the absence of efficacious contraction of knee extensor muscles, or even the spasticity of plantar flexors, could be pulling the tibia backwards.

Therefore, an important alteration in the load response caused to the angular kinematics of the knee joint of the knee during hemiparetic gait following cerebral vascular accident modifies in an important way one of the prerequisites for the normal gait and increases the energy consumption during deambulation. Further studies are needed to detect the possible causes of this alteration to direct surgical treatment and therapeutic choices for these patients.

RESUMO

Lucarelli PRG, Greve JMA. Alteração do mecanismo de resposta à carga da articulação do joelho durante a marcha hemiparética oriunda de AVC, analisada por cinemática tridimensional. Clinics. 2006;61(4):295-300.

OBJETIVO: O objetivo deste estudo foi avaliar as variáveis resultantes da alteração do mecanismo de resposta à carga por análise tridimensional da cinemática angular da articulação do joelho durante a marcha hemiparética oriunda de acidente vascular cerebral.

MÉTODO: Estudo retrospectivo com 66 pacientes adultos de ambos os sexos (33 masculino e 33 feminino), com idade $45,4 \pm 8,5$ anos, com diagnóstico de acidente vascular cerebral isquêmico com hemiparesia em lado direito ou esquerdo. Todos os pacientes foram submetidos ao protocolo de realização do exame tridimensional computadorizado de marcha por meio de VICON/PEAK® 370. Os valores da cinemática angular do joelho foram selecionados para análise.

RESULTADOS: Não foram encontradas diferenças

estatisticamente significantes (teste de Kruskal Wallis) entre os sujeitos para as variáveis: posição angular e pico de flexão do joelho ($p < 0,05$). As características clínicas relevantes encontradas foram: aumento da flexão do joelho no contato inicial e amplitude de movimento abaixo do esperado nesta fase do ciclo de marcha, estas são as que devem ser levadas em conta na seleção do melhor tratamento, pois são as que apresentam alterações importantes no mecanismo de resposta à carga na totalidade dos pacientes.

DISCUSSÃO: O mecanismo de resposta à carga é funda-

mental para o andar porque tem como objetivo reduzir o impacto no membro inferior e suavizar o deslocamento do centro de massa no espaço reduzindo assim o consumo energético. Esta capacidade necessita ser compreendida para ser então melhor tratada e reabilitada. A dificuldade é que ainda não há consenso entre os diversos estudiosos do tema sobre as variáveis cinemáticas das articulações durante a marcha hemiparética.

UNITERMOS: Hemiplegia, Joelho, Biomecânica, Marcha, Distúrbios Neurológicos da Marcha.

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