

LUÍS ABÍLIO DE SOUSA FONSECA MACHADO E CUNHA
BSc in Biomedical Engineering

**USING MUSCULOSKELETAL MODELING TO
ASSESS MUSCLE FUNCTION AND GAIT
SYMMETRY AFTER A STRAYER PROCEDURE
APPLIED TO A CHILD WITH CEREBRAL
PALSY**

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Using musculoskeletal modelling to assess muscle function and gait symmetry after a Strayer procedure applied to a child with cerebral palsy

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Abstract

Cerebral palsy is a common group of neuromotor disorders with symptoms appearing during childhood. Children with cerebral palsy are often submitted to orthopedic surgeries and treatment plans depending on the gait pattern and its severity. Jump gait is a gait pattern present in bilateral spastic cerebral palsy and is characterized by equinus, the most frequent gait deviation, hip and knee accentuated flexion, among others. The modified Strayer procedure is a standard intervention to treat equinus in ambulatory children.

with cerebral palsy and is often accompanied by botulinum toxin injections to aid in spasticity reduction. Musculoskeletal modelling is a promising approach to indirectly estimate muscle function, including muscle force, and muscle induced accelerations. Symmetry in gait is often studied as it is associated with healthier and improved gait. The present work aimed to study gait symmetry and estimate muscle forces, as well as muscle contributions to the mass center acceleration in the vertical and fore-aft directions during three sessions: one before and the other two one and two years after surgery in a child with jump gait. Furthermore, comparison with typically developed children was also performed. Data processing was done through the Mokka, BOPS and MOTONMS soft-

ware while the musculoskeletal simulations were done through OpenSim. After surgery, gait symmetry improved to levels similar to or higher than unimpaired gait. Kinematics improved, although the increase in dorsiflexion was not enough to achieve heel strike at first contact. Muscle estimates show a higher reliance on proximal muscles, mainly the vasti and hamstrings, before and after surgery. The soleus increased its muscle force and vertical contribution, becoming the primary plantarflexor of the triceps surae for support. Suggestions were made for treatment plans and for maintaining surgical improvements, such as strengthening of weakened muscles.

Keywords: Jump gait, Cerebral palsy, Strayer procedure, Botulinum toxin, Musculoskeletal modeling, Global Gait Asymmetry Index, Computed Muscle Control, Induced Acceleration Analysis

Resumo

Paralisia cerebral é um grupo de perturbações neuromotoras cujos sintomas aparecem durante a infância. Crianças com paralisia cerebral são muitas vezes submetidas a cirurgias ortopédicas e planos de tratamento de acordo com o padrão de marcha e grau de severidade. Marcha em “salto” é um padrão de marcha presente em paralisia cerebral espástica bilateral caracterizada por equino, flexão acentuada do joelho e anca, entre outras. O procedimento modificado de *Strayer* é uma intervenção comum para tratar pé ??equino em crianças ambulatórias com paralisia cerebral e normalmente o tratamento é

acompanhado por injeções de toxina botulínica. Modelação musculoesquelética é uma abordagem que permite estimar, indiretamente, as forças e acelerações induzidas musculares. A presença de simetria está associada a uma marcha saudável. Este trabalho tem como objetivo estudar a simetria da marcha, estimar forças musculares e contribuições musculares para a aceleração do centro de massa na direção vertical e ântero-posterior durante três sessões: uma antes, e as outras duas um e dois anos após a cirurgia numa criança com marcha em “salto. Além disso, foi feita a comparação com marcha de crianças com desenvolvimento típico. O processamento dos dados foi feito através dos software Mokka, BOPS e MOTONMS enquanto as simulações musculoesqueléticas foram desenvolvidas no OpenSim. Após cirurgia, a simetria melhorou para níveis semelhantes ou superiores aos da marcha em crianças com desenvolvimento típico. A cinemática também melhorou, porém, apesar da capacidade de dorsiflexão ter aumentado, o primeiro contacto continua sem ser com o calcanhar. Resultados mostram uma dependência em músculos mais proximais, principalmente o vasto e os isquiotibiais, tanto antes como após a cirurgia. O solear aumentou a sua produção de força e contribuição vertical, tornando-se o principal plantarflexor a contribuir para o suporte. Sugestões foram feitas para planos de tratamento e para preservar as melhorias obtidas pela cirurgia, como por exemplo, fortalecimento dos músculos mais debilitados.

Palavras-chave: Marcha em salto, Paralisia cerebral, Procedimento de Strayer, Toxina botulínica, Modelação musculoesquelética, Índice global de marcha assimétrica, Otimização dinâmica, Análise de acelerações induzidas

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Glossary

agonist	Main muscle that contracts to promote movement. 10
antagonist	Muscles that produce an opposing movement to the agonist muscle. 10
athetosis	Movement dysfunction. It's characterized by involuntary writhing movements. 10
clonus	Involuntary and rhythmic muscle contractions. 9
dysarthria	
dystonia	Muscles used for speech are weak and control over them becomes difficult. 10 Movement disorder in which muscles contract involuntarily, causing twisting or repetitive movements. 10 , 12
hyperreflexia	Overactive or overresponsive reflexes. 9
osteotomy	Surgical procedure involving the cutting and re-positioning of a bone 12
spasticity	Abnormal muscle tightness due to prolonged muscle contraction. 9

Acronyms

AFO	Ankle Foot Orthosis 16
BOPS	Batch OpenSim Processing Scripts 35
BTX	Botulinum toxin type A 2 , 3 , 11 , 16 , 66 , 68 , 70–72
CMC	Computed Muscle Control ix , xi–xiii , 35 , 42–45 , 57 , 60 , 67 , 73 , 96–103
COM	Center of mass x , xi , 3 , 5 , 7 , 13 , 19 , 38 , 60–66 , 70–72
CP	Cerebral Palsy ix–xi , 1–7 , 9–12 , 14–19 , 32 , 47–51 , 57 , 58 , 60 , 61 , 66–74 , 104
DBS	Deep brain stimulation 12
DOF	Degree of freedom x , 8 , 36 , 41 , 46–49 , 51–53 , 56 , 57 , 69
EMG	Electromyography xi , 4 , 6 , 33–35 , 44 , 58 , 67 , 73 , 102 , 103
GGA	Global Gait Asymmetry x , 8 , 46 , 47 , 51 , 52 , 69 , 72

GMFCS	Gross Motor Functioning Classification System 10 , 12 , 32
GRF	Ground Reaction Forces xi , 4 , 33–35 , 40 , 45 , 53 , 60 , 70 , 73 , 103
IAA	Induced Acceleration Analysis ix , xi , 5 , 35 , 45 , 46 , 60 , 103
ID	Inverse Dynamics xii , 40 , 42 , 48 , 54–56
IK	Inverse Kinematics 39–41 , 48
MOToNMS	matlab MOTion data elaboration TOolbox for NeuroMusculoSkeletal applications 35
MRI	Magnetic Resonance Imaging 7 , 38
RRA	Residual Reduction Algorithm ix , xii , 35 , 41 , 42 , 44 , 52 , 54–57 , 90–95
SDR	Selective dorsal rhizotomy 11 , 12 , 16
SEMLS	Single-event Multilevel Surgery 12 , 16