Universidade Estadual de Londrina

ALESSANDRO GIURIZATTO MELANDA

ANÁLISE TRIDIMENSIONAL DA MARCHA DE CRIANÇAS COM PARALISIA CEREBRAL:

EFETIVIDADE DO USO DE ÓRTESES SUROPODÁLICAS, CONFIABILIDADE E VALIDADE DE CLASSIFICAÇÕES PREEXISTENTES E CRIAÇÃO E AVALIAÇÃO DE PROPRIEDADES PSICOMÉTRICAS DE UMA NOVA CLASSIFICAÇÃO DA MARCHA.

Londrina
2020

ALESSANDRO GIURIZATTO MELANDA

ANÁLISE TRIDIMENSIONAL DA MARCHA DE CRIANÇAS COM PARALISIA CEREBRAL:

EFETIVIDADE DO USO DE ÓRTESES SUROPODÁLICAS, CONFIABILIDADE E VALIDADE DE CLASSIFICAÇÕES PREEXISTENTES E CRIAÇÃO E AVALIAÇÃO DE PROPRIEDADES PSICOMÉTRICAS DE UMA NOVA CLASSIFICAÇÃO DA MARCHA.

Tese apresentada à Universidade Estadual de Londrina, como requisito parcial para obtenção do título de Doutor em Ciências da Reabilitação (Programa Associado entre a Universidade Estadual de Londrina [UEL] e Universidade Pitágoras - UNOPAR.

Orientadora Profa Dra Suhaila Mahmoud Smaili Santos Coorientadora Profa Dra Dirce Shizuko Fujisawa

Londrina
2020

Ficha de identificagâo da obra elaborada pelo autor, através do Programa de Geração Automâtica do Sistema de Bibliotecas da UEL

M517 Melanda, Alessandro.
AN ISE TRIDIMENSIONAL DA MARCHA DE CRIA AS COM PARALISIA CEREBRAL: EFETIVIDADE DO USO DE ORTESES SUROPOD ICAS, CONFIABILIDADE E VALIDADE DE CLASSIFICA/OES PREEXISTENTES E CRIA/AO E AVALIA AO DE PROPRIEDADES PSICOMETRICAS DE UMA NOVA CLASSIFICA/AO DA MARCHA. / Alessandro Melanda. - Lrndrina, 2020.
254 f. : il.

Orientador: Suhaila Mahmoud Smaili Santos.
Coouentalor: Dirce ShiztAo Fujisawa.
Tese (Doutorado em Câncias da Reabilita âo) - Universidade Estadual de Loudrina, Centro de Ciéncias da Sadde, Programa de Pés-Gradua§âo em Cie-ncias da Reabilita$éo, 2020.
inclui bibliografia.

1. Paralisia Cerebral infantil - Tese. 2. Apâlise tridimensional da marcha - Tese. 3. Classificatées em saude - Tese. 4. Orteses - Tese. I. Mahmoud Smaili Santos, Suñaila II. Shizuto Fujisawa, Dirce . III. Universidade Estadual de Loudrina. Centro de C“iencias da Sadde. Programa de Pés-Gradua§âo em Ciencias da Reabilita§éo. IV. Tftulo.

CDU 61

ALESSANDRO GIURIZATTO MELANDA

ANÁLISE TRIDIMENSIONAL DA MARCHA DE CRIANÇAS COM PARALISIA CEREBRAL:

EFETIVIDADE DO USO DE ÓRTESES SUROPODÁLICAS, CONFIABILIDADE E VALIDADE DE CLASSIFICAÇÕES PREEXISTENTES E CRIAÇÃO E AVALIAÇÃO DE PROPRIEDADES PSICOMÉTRICAS DE UMA NOVA CLASSIFICAÇÃO DA MARCHA.

Tese apresentada à Universidade Estadual de Londrina, no Doutorado em Ciências da Reabilitação, área de concentração em Ciências da Saúde, como requisito parcial para a obtenção do título de Doutor.

BANCA EXAMINADORA

____
Profa. Dra. Suhaila Mahmoud Smaili Santos
Universidade Estadual de Londrina - UEL

____
Prof. Dr. Edson Lopes Lavado
Universidade Estadual de Londrina - UEL

____
Prof. Dr. Felipe Arruda Moura
Universidade Estadual de Londrina - UEL

____
Prof. Dr. Epitácio Leite Rolim Filho
Universidade Federal de Pernambuco

____
Prof. Dr. Paulo Roberto Garcia Lucareli
Universidade Nove de Julho-SP - UNINOVE

Londrina, 18 de novembro de 2020.

Dedico esta tese a minha esposa Alessandra, aos meus filhos Felipe e Gabriel e ao Renatinho (Renato Costa Marques de Nobrega) nossa estrela que tanto brilhou enquanto esteve entre nós e que agora nos une da eternidade.

AGRADECIMENTOS

Essa tese começou a ser construída em 2010 quando o Prof. Dr. Luiz Antonio Munhoz da Cunha, Professor Titular e Chefe do Serviço de Ortopedia e Traumatologia da Universidade Federal do Paraná e do Hospital Pequeno Príncipe, convidou-me para instalar e coordenar o Laboratório de Marcha do Centro Hospitalar de Reabilitação (CHR) Ana Carolina de Moura Xavier em Curitiba. Entre os anos de 2010 e 2017 tive a oportunidade de conviver com uma equipe altamente capacitada e estimulada em tornar realidade o primeiro Laboratório de Marcha com objetivos clínicos do sul do país. Neste período centenas de exames tridimensionais da marcha foram realizados e possibilitaram o desenvolvimento de um extenso banco de dados. Desta forma, meu profundo agradecimento ao Dr. Cunha e aos fantásticos companheiros do Laboratório de Marcha do CHR de Curitiba: Dra. Ana Carolina Pauleto, Rodrigo Faucz Munhoz da Cunha, Luiz Alberto Knaut, Alana EK Ferreira, Dielise Debona Iucksch, Rauce Marçal Silva e Cristina Aparecida Arantes Cararo.

Agradeço a Profa Dra Suhaila Mahmoud Smaili Santos que acreditou no projeto e com habilidade ímpar lapidou cada detalhe da tese, mostrando grande conhecimento, paciência e sabedoria. Poucas pessoas conseguem ter a força e a delicadeza que a Profa Suhaila mostra diariamente ao guiar seus orientandos. Agradeço a Profa Dra. Dirce Shizuko Fujisawa, por doar seu tempo para elaboração da tese.

Aos membros da banca muito obrigado pela pronta disponibilidade em participar dos eventos de qualificação e defesa e pelas significativas colaborações apresentadas.

Agradeço aos meus pais, Delvo e Angela e aos meus irmãos, Daniela, Rafael e Giovana que sempre fizeram parte das minhas conquistas.

Agradeço aos meus filhos, Felipe e Gabriel, que entenderam os períodos de ausência do pai. À minha esposa Alessandra, agradeço o constante estímulo, compreensão e a sua capacidade de com bons princípios e carinho manter nossa família unida.

MELANDA, Alessandro Giurizatto. **Análise tridimensional da marcha de crianças com paralisia cerebral:** efetividade do uso de órteses suropodálicas, confiabilidade e validade de classificações preexistentes e criação e avaliação de propriedades psicométricas de uma nova classificação da marcha. 2020. 255 f. Tese (Doutorado em Ciências da Reabilitação) – Universidade Estadual de Londrina, Londrina, 2020.

RESUMO

Introdução: Paralisia Cerebral (PC) é a causa mais comum de distúrbio físico na infância. As crianças com PC, como efeito da lesão neurológica, comumente apresentam fraqueza, espasticidade, falta de coordenação muscular e controle postural inadequado, que juntos dificultam a mobilidade e limitam as atividades físicas. Entretanto, mais da metade das crianças identificadas com PC andam de forma independente. A avaliação criteriosa dos indivíduos auxilia na indicação, frequência, tempo ou momento no processo de tratamento que cada modalidade deve ser utilizada. A análise tridimensional da marcha (A3DM) é considerada o padrão-ouro na avaliação do andar de indivíduos com PC e foi utilizada nesta tese como principal instrumento de medida. **Objetivos:** avaliar a efetividade do uso de órteses suropodálicas (OSP) em crianças com PC, identificar a aplicabilidade de classificações preexistentes da marcha em crianças com PC espástica e construir uma nova classificação da marcha para crianças com PC para suprir deficiências das classificações atuais. **Métodos:** Quatro estudos originais retrospectivos foram desenvolvidos e contaram com a utilização do banco de dados do Laboratório de Marcha do Centro Hospitalar de Reabilitação de Curitiba – Paraná, coletados entre os anos de 2010 e 2017. O primeiro (1) estudo avaliou 24 crianças com PC espástica que foram submetidas a A3DM com e sem OSP. Foram utilizados para análise o *“Gait Profile Score”* (GPS) e dados de tempo e espaço da marcha das crianças com e sem as órteses. O segundo (2) estudo determinou utilidade da classificação publicada por Papageorgiou et al., em 2019, em avaliar uma amostra de 130 crianças com PC espástica. Também foi determinada a reprodutibilidade inter e intraobservador da referida classificação. O terceiro (3) estudo determinou a utilidade clínica e a reprodutibilidade inter e intraobservadores a partir da classificação da marcha proposta e publicada por Davids e Bagley, em 2014, em uma amostra de 131 crianças. O quarto (4) estudo propôs uma nova classificação baseada em níveis de comprometimento para a marcha de crianças com PC espástica. Foram utilizados dados da A3DM de 101 crianças para construção desta classificação. De forma inovadora, também foi considerado o uso de equipamentos auxiliares da marcha (bengalas, muletas e andadores) nesta construção. Foi determinada a reprodutibilidade inter e intraobservadores, assim como a reprodutibilidade dos observadores com o resultado do consenso da avaliação dos autores e a reprodutibilidade entre os diferentes profissionais (fisioterapeutas e cirurgiões ortopédicos). **Resultados:** O estudo (1) mostrou que o índice GPS, dos lados direito e esquerdo, não apresentaram variações estatisticamente significantes ao comparar os mesmos indivíduos deambulando com e sem órteses. Foi observado aumento das variáveis espaço-temporais (velocidade da marcha, comprimento do passo e da passada), quando os participantes estavam em uso de órtese. O estudo (2) mostrou que todos os grupos da classificação foram representados na amostra avaliada, com 95,4% dos participantes classificados. A classificação mostrou sobreposição das características cinemáticas entre os grupos. A reprodutibilidade foi quase perfeita interobservador, com reprodutibilidade intraobservador substancial e moderada para os avaliadores um e dois, respectivamente. O terceiro estudo (3) determinou que a classificação de Davids e Bagley apresenta utilidade clínica com reprodutibilidade interobservadores e intraobservadores, moderada e moderada a substancial, respectivamente. No quarto estudo (4) foi construída uma classificação de níveis da marcha de crianças com PC, após avaliação do padrão de uma amostra de 101 participantes. A classificação proposta mostrou validade de face, critério e concorrente. A reprodutibilidade interobservadores foi substancial, tanto utilizando dados da A3DM, quanto utilizando apenas a análise observacional da marcha (AOM), por meio de vídeo bidimensional. A reprodutibilidade intraobservador foi substancial ou quase perfeita, a partir dos dados da A3DM ou somente AOM. A reprodutibilidade entre os observadores e o consenso da classificação realizado pelos autores foi substancial ou quase perfeita, assim como a reprodutibilidade entre os tipos de profissionais avaliadores mencionados. **Conclusões:** os quatro estudos científicos utilizaram a A3DM na avaliação de crianças com PC espástica e adicionaram informações relevantes na avaliação da marcha desta população. A presente tese mostrou por meio do primeiro estudo (1) que OSP prescritas por profissional sem utilização da A3DM não produzem alterações significativas no padrão global da marcha (GPS), apesar de apresentarem benefícios funcionais (parâmetros de tempo e espaço). A classificação da marcha dessa população, auxilia na comunicação e no planejamento de tratamentos. O segundo (2) e terceiro (3) estudos determinaram que as classificações estudadas são instrumentos capazes de classificar a marcha de crianças com PC, apesar de limitações terem sido observadas em ambas. O quarto estudo (4) construiu uma nova classificação que objetiva agregar benefícios às classificações existentes com validade e excelente reprodutibilidade em classificar crianças com PC.

Palavras-chave: Paralisia cerebral. Criança. Marcha. Análise da marcha. Classificações em saúde. Órteses.

MELANDA, Alessandro Giurizatto. **Three-dimensional gait analysis of children with cerebral palsy:** effectiveness of the use of ankle foot orthoses, reliability and validity of pre- existing classifications as well as the creation and assessment of psychometric properties of a new classification of gait. 2020. 255 p. Tese (Doutorado em Ciências da Reabilitação) – Universidade Estadual de Londrina, Londrina, 2020.

ABSTRACT

Introduction: Cerebral Palsy (CP) is the most common cause of physical disorders in childhood. Children with CP, as an effect of neurological injury, commonly present weakness, spasticity, lack of muscle coordination and inadequate postural control, which together hinder mobility and limit physical activities. However, more than half of the children identified with CP walk independently. The careful assessment of individuals helps in indicating, frequency, time or moment in the treatment process that each modality should be used. Three-dimensional gait analysis (3DGA) is considered the gold standard in assessing the gait of individuals with CP and was used in this thesis as a measuring instrument. **Aims**: to evaluate the effectiveness of the use of ankle foot orthoses (AFO) in children with CP, to identify the applicability of pre-existing gait classifications in children with spastic CP and to construct a new classification of gait for children with CP to supply deficiencies of the current classifications. **Methods:** Four original retrospective studies were developed and used the database of the Gait Analysis Laboratory of the Hospital Rehabilitation Center of Curitiba - Paraná, between the years 2010 and 2017. The first (1) study evaluated 24 children with spastic CP who underwent 3DGA with and without AFO. The Gait Profile Score (GPS) and spatio-temporal gait parameters of children with and without orthoses were used for analysis. The second (2) study determined the utility of the classification published by Papageorgiou et al., In 2019, in evaluating a sample of 130 children with spastic CP. The inter and intraobserver reliability of that classification was also determined. The third (3) study determined the clinical utility and inter and intrarater reliability from the classification of gait proposed and published by Davids and Bagley, in 2014, in a sample of 131 children. The fourth (4) study proposed a classification of impairment levels for the gait of children with spastic CP. 3DGA data from 101 children were used to construct the classification. In an innovative way, the use of walking aids (canes, crutches and walkers) was also considered in this construction. Inter and intrarater reliability was determined, as well as the reliability of the raters with the result of the consensus of the authors' evaluation and the reliability among the different professionals (physiotherapists and orthopedic surgeons). **Results:** The study (1) showed that the GPS index, on the right and left sides, did not show statistically significant variations when comparing the same individuals walking with and without orthoses. An increase in spatiotemporal variables (gait velocity, stride and stride length) was observed when participants were wearing orthoses. The study (2), showed that all the groups of the classification were represented in the evaluated sample, being that 95.4% of the participants were classified. The classification showed an overlap of the kinematic characteristics between the groups. The reliability interrater was almost perfect with intrarater reliability substantial and moderate for the rater one and two, respectively. The study (3) determined that the Davids and Bagley classification present clinical utility with moderate interrater reliability and moderate to substantial intrarater. In the study (4) a classification of gait levels of children with CP was constructed, after assessing the pattern of a sample of 101 participants. The proposed classification showed face, criterion and concurrent validity. The interrater reliability was substantial both using data from the 3DGA and observational gait analysis (OGA), using 2D video. The intrarater reliability was substantial or almost perfect, using 3DGA data or only OGA. The reliability among the raters and the classification consensus made by the authors was substantial or almost perfect, as well as the reliability between the types of professional evaluators mentioned. **Conclusions:** the four scientific studies used the 3DGA in the evaluation of children with spastic CP and added relevant information to the evaluation of the gait of this population. This thesis showed through the first study (1) that AFO prescribed by a professional without using the 3DGA do not produce significant changes in the global gait pattern (GPS), despite presenting some functional benefits (spatio-temporal gait parameters). Classifying the gait of this population helps in communication and treatment planning. The second (2) and third (3) studies determined that the classifications studied are instruments capable of classifying the gait of children with CP, although limitations have been observed in both. The fourth (4) study constructed a new classification that aims to add benefits to existing classifications with validity and excellent reliability in classifying children with CP

Keywords: Cerebral palsy. Child. Gait. Gait analysis. Health classifications. Orthotic devices.

LISTA DE FIGURAS

CONTEXTUALIZAÇÃO

ARTIGO 3

ARTIGO 4

LISTA DE TABELAS

ARTIGO 4

LISTA DE ABREVIATURAS E SIGLAS

2D	Two-dimensional (bidimensional)
3DGA	Three-dimensional Gait Analysis
A3DM	Análise tridimensional da marcha
Ab-ad	Abdução - adução
ACM	Análise Computadorizada da Marcha
AD	Andar Descalço
AFO	Ankle-Foot Orthoses
Ant/post	Ântero-posterior
App. Equinus	Apparent equinus
Asym.	Asymmetrical
BF	Barefoot
CDC	Center for Disease Control and Prevention
CI	Confidence Interval
CIF	Classificação Internacional de Função
Cm	Centimeters
Cm/sec	Centimeters per second
CP	Cerebral Palsy
Df/Pf	Dorsiflexion/Plantarflexion
EIAS	Espinha Ilíaca Antero Superior
EMG	Eletromiografia
Ext-flx	Extensão – flexão
EUA	Estados Unidos da América
FMS	Functional Mobility Scale
Fx/Ext	Flexion/Extension
GCS	Gait Classification System
GDCS-CP	Gait Disruption Classification System – Cerebral Palsy
GDI	Gait Deviation Index
GMFCS	Gross Motor Function Classification System
GPS	Gait Profile Score
Genu recurv	Genu recurvatum
GVS	Gait Variable Score
Hyperext	Hyperextension

JAAOS	Journal of American Academy of Orthopaedic Surgeons
K	Kappa estatistics
Kg	Kilograms
MCID	Minimal Clinically Important Difference
M	Meters
Neut/Ext/Int	Neutral/External/Internal
Not class.	Not classified
OGA	Observational Gait Analysis
OSP	Órtese Suropodálica
PC	Paralisia Cerebral
Pla-dor	Flexão plantar – flexão dorsal
POS	Pediatric Orthopedic Surgeon
Post-ant	Póstero-anterior
PT	Physiotherapist
SD	Standard Deviation
Up/Dn	Up/Down
Var-val	Varo – valgo
Without abnorm	Without abnormalities

1 INTRODUÇÃO

1.1 JUSTIFICATIVA

A Paralisia Cerebral (PC), é uma condição neurológica que afeta o desenvolvimento motor das crianças e persiste por toda a vida[1], constituindo a mais prevalente causa de deficiência física na infância[2].

A etiologia da PC é diversa e multifatorial, geralmente causada por lesão no cérebro antes, durante ou após o nascimento, até os cinco anos de idade[3,4]. Em torno de 10% de todos os casos de PC são causados por eventos após o nascimento[4]. Entretanto, o nascimento prematuro é o fator de risco mais importante para o desenvolvimento da PC[5].

As tendências temporais na prevalência geral da PC são mais notáveis por sua estabilidade, mas um aumento modesto ocorreu nas últimas décadas do século XX. Esse aumento na prevalência pode ser atribuído à sobrevida de recém nascidos prematuros e de muito baixo peso (< 1000 g), resultante dos cuidados da terapia intensiva neonatal[6]. Winter *et al*. constataram que a prevalência de PC foi de 6,2 por 1.000 nascidos vivos em crianças nascidas com peso entre 1.500 a 2.499 gramas e 59,5 por 1.000 nascidos vivos em crianças nascidas com peso inferior a 1.500 gramas, em comparação com 2 por 1.000 em nascidos com peso 2.500 gramas ou mais[7].

Segundo Gage *et al*., as crianças nascidas prematuras, apresentam melhor potencial de reabilitação[8]. Portanto, apesar da prevalência da PC ter permanecido quase estável, número maior de casos pode ser beneficiado com programas de reabilitação.

Os indivíduos com diagnóstico de PC podem deambular de forma independente de acordo com seu nível de comprometimento neurológico. A probabilidade de crianças com PC andar aos 5 anos de idade sem auxilio é de 54% e de 16% com algum dispositivo auxiliar, segundo estudo realizado por Beckung *et al*.[9]. Um importante objetivo no tratamento dessas crianças é a melhora na habilidade motora e de marcha, devido ao impacto na autonomia e na participação social.

O Centro de Controle e Prevenção de Doenças (CDC) dos Estados Unidos da América (EUA) estimou em um milhão de dólares o custo dos cuidados durante a vida de um indivíduo com PC[10]. Isso porque a condição requer uma variedade de modalidades de tratamentos, que envolvem serviços e profissionais de reabilitação (física, psicológica, comportamental, educacional), serviços médicos (pediatria, cirurgia ortopédica, neurocirurgia, psiquiatria), órteses e tutores externos, constituindo uma abordagem multidisciplinar[11]. A avaliação criteriosa dos indivíduos auxilia na indicação, frequência e momento no processo de tratamento que cada modalidade deve ser utilizada.

Durante a reabilitação das crianças com PC, o uso de órteses é um dos recursos mais utilizados. As órteses suropodálicas (OSP) são dispositivos usados durante o dia por 21,8% das crianças com PC, segundo Sacaze *et al*.[12]. As OSP são frequentemente prescritas para corrigir anormalidades na marcha e facilitar o treino de atividades funcionais[13].

A primeira parte da tese avaliou o impacto global da utilização de órteses na marcha de indivíduos da faixa etária pediátrica com diagnóstico de PC. Para determinar o resultado funcional do uso das órteses utilizou-se a análise tridimensional da marcha (A3DM).

A A3DM é considerada o método padrão-ouro na avaliação do andar em indivíduos com PC[14,15]. Há um aumento evidente da importância da A3DM nas decisões clínicas, repercutindo em melhores desfechos obtidos em indivíduos que tiveram seu tratamento planejado de acordo com esses resultados, quando comparados àqueles submetidos a tratamentos baseados somente na avaliação clínica[16,17,18].

Entretanto, devido ao grande número de informações produzidas pelos laboratórios de movimento com a A3DM, classificações da marcha foram elaboradas para doenças específicas, o que simplifica e norteia a interpretação e, ainda, facilita as decisões clínicas[19].O termo "classificação de marcha" refere-se a um sistema que permite a alocação de padrões de marcha em grupos que podem ser diferenciados uns dos outros com base em um conjunto de variáveis definidas[20]. Porém, as atuais classificações da marcha para a PC, apresentam limitações, seja na capacidade em apontar os desvios em todos os planos de movimento ou na sua reprodutibilidade[20].

Sendo assim, com o objetivo de determinar a aplicabilidade de classificações existentes e produzir alternativas, a segunda parte da tese avaliou a confiabilidade e a validade de duas classificações da marcha para crianças com PC e, finalmente, elaborou e propôs uma nova classificação para essa população.

2 OBJETIVOS

2.1 OBJETIVO GERAL

- Avaliar as características da marcha de crianças com PC por meio da A3DM, determinar a aplicabilidade de classificações preexistentes e elaborar nova classificação da marcha para essa população.

2.2 OBJETIVOS ESPECÍFICOS

- Avaliar a efetividade das OSPs na marcha de crianças com diagnóstico de PC bilateral, utilizando os índices *“Gait Profile Score*” (GPS) e *“Gait Variable Score*” (GVS) da A3DM, além de dados de tempo e espaço (artigo 1);

- Classificar a marcha de uma amostra de crianças com PC espástica por meio da classificação proposta por Papageorgiou *et al*., validar e avaliar a sua reprodutibilidade (artigo 2);

- Validar e determinar a reprodutibilidade da Classificação das Alterações da Marcha em Crianças com PC, proposta por Davids e Bagley (artigo 3);

- Construir uma nova classificação que apresente características de continuidade entre os níveis de comprometimento da marcha de crianças com PC espástica e avaliar as propriedades psicométricas desse instrumento (artigo 4).

3 REVISÃO DE LITERATURA - CONTEXTUALIZAÇÃO

3.1 PARALISIA CEREBRAL

Paralisia cerebral (PC) é um termo genérico utilizado para um grupo de distúrbios de deficiência motora causados por uma lesão não progressiva no cérebro da criança em desenvolvimento durante o período intrauterino ou nos primeiros anos de vida[21].

3.1.1 Conceitos Gerais

Os primeiros relatos sobre PC são creditados ao cirurgião inglês William Little, realizados em uma série de aulas entre os anos 1843 e 1844, e contidos no artigo para a Sociedade Obstétrica de Londres de 1861[22]. Dr. Little descreveu a condição como um problema obstétrico decorrente de asfixia neonatal ou lesão mecânica no feto imediatamente antes ou durante o parto. Sigmund Freud no início da sua carreira como neurologista propôs ser a PC infantil um termo "guarda-chuva" para o conceito geral de doenças infantis causadas por eventos ocorridos no período fetal ou após o nascimento[23]. O limite usado para a definição de PC pós-neonatal é arbitrário, mas na maioria dos estudos é considerado até cerca de cinco anos[4].

Rosenbaum e colaboradores, em 2007, definiram PC como "um grupo de desordens permanentes do desenvolvimento motor e da postura, causando limitação na atividade, que são atribuídas a distúrbios que ocorrem no desenvolvimento cerebral do feto ou da criança. As desordens motoras da PC são frequentemente acompanhadas por distúrbios de sensações, percepções, cognição, comunicação, comportamento, epilepsia e por problemas musculoesqueléticos"[1].

Segundo Blair e Paneth, a PC é determinada por um diagnóstico clínico, pois não há exames laboratoriais, histológicos, genéticos ou qualquer outro que demonstrem a existência ou a ausência da doença[6,24].

Apesar do diagnóstico de PC ocorrer principalmente com base no reconhecimento de características clínicas, como atraso nos marcos motores, alterações no tônus muscular e nos reflexos miotendíneos[25], a Academia Americana de Neurologia recomenda que, sempre que possível, o diagnóstico clínico de PC seja confirmado por exames de imagem[3]. A avaliação com neuroimagem apresenta achados em mais de 80% das crianças com PC, enquanto que em 17% delas, os exames de imagem não detectam anormalidades[26,27]. Estudos de neuroimagem são normais em até 50% das crianças com PC discinética[28].

A PC é a causa mais comum de distúrbio físico em crianças nos países desenvolvidos, com prevalência de aproximadamente 1 em cada 500 nascidos vivos, com 17 milhões de pessoas afetadas em todo o mundo[5]. A prevalência de PC na Turquia foi determinada pelo estudo de Serdaroglu *et al*.[29] como sendo de 4.4 por 1000 nascidos vivos com inclusão de PC adquirida pós natal. No Brasil não existem dados consistentes, mas estima-se que a incidência da PC nos países em desenvolvimento alcance valores de 7 por 1.000 nascidos vivos[30,31].

O tratamento de indivíduos com PC requer uma abordagem multidisciplinar[11], com encargos aos serviços de saúde 10 a 26 vezes maiores em relação a crianças sem PC[32–34]. Com isso, a PC e suas condições associadas representam um custo econômico significativo para as famílias, o sistema de saúde e a economia em geral, com relação diretamente proporcional entre a gravidade e os gastos da criança com PC[35].

3.1.2 Etiologia

Os fatores de risco mais significativos para o desenvolvimento da PC são prematuridade, baixo peso ao nascer, gemelaridade ou nascimentos múltiplos e infecção perinatal. Esses fatores de risco operam de forma independente ou em conjunto[36].

O dano cerebral típico da PC relacionada à prematuridade é frequentemente uma combinação de leucomalácia periventricular induzida por citocinas e dano isquêmico provocado por eventos pós-natais, como hemorragia intraventricular e hidrocefalia[28].

A prevalência da PC está inversamente associada ao peso ao nascer e à idade gestacional, variando de 90 casos por 1.000 nascido vivos com peso inferior a 1000 gramas e entre 1 e 5 casos por 1.000 para nascidos com peso igual ou superior a 2500 gramas[2,21,37]. O risco para bebês nascidos antes das 28 semanas de gestação é aproximadamente 50 vezes maior que os nascidos a termo[37].

As malformações cerebrais são outro fator etiológico, presente em aproximadamente 10 a 15% das crianças com PC, e requerem avaliação com neuroimagem para serem detectadas[38]. É provável, ainda, que mutações genéticas sejam responsáveis por uma proporção substancial de casos de PC, da mesma maneira que são importantes na etiologia de outros distúrbios complexos do desenvolvimento neurológico, como autismo e dificuldades de aprendizado[39].

3.1.3 Fisiopatologia da PC

A PC é a causa mais frequente da síndrome do neurônio motor superior na infância, com características positivas, como espasticidade, hiper-reflexia e cocontração muscular, e características negativas, incluindo fraqueza muscular, perda do controle motor seletivo sobre o movimento, além de déficits sensoriais e de equilíbrio[28].

As características positivas da síndrome do neurônio motor superior em particular a espasticidade, têm recebido maior atenção dos profissionais de saúde, porque são passíveis de tratamento. Entretanto, as características negativas são as responsáveis pelo prognóstico locomotor[28,40]. A fraqueza e a perda do controle motor seletivo determinam quando ou se uma criança caminhará, enquanto que os déficits de equilíbrio ditarão a dependência de dispositivos auxiliares para a marcha[41].

Crianças com PC espástica têm músculos menores[42] e mais fracos do que crianças saudáveis[43]. A força muscular observada nos membros inferiores de crianças com PC é 43 a 90% menor que os valores dos controles saudáveis[40]. Essas alterações funcionais são decorrentes da diminuição do volume muscular, da área de secção transversal e do comprimento do ventre muscular[44]. As alterações musculares estão presentes no nível estrutural, com fibras musculares de menor diâmetro, sarcômeros alongados, alterações na matriz extracelular e no tecido conjuntivo (menor complacência). O número de células-tronco musculares (células satélites) encontra-se diminuído e com expressão gênica alterada, determinando menor capacidade de regeneração tecidual[45].

Grahan e Selber enfatizaram que apesar da PC ser, do ponto de vista neurológico, uma doença não progressiva, as alterações musculoesqueléticas podem progredir e levar ao aparecimento de deformidades nos membros e tronco, principalmente durante o crescimento[41].

A lesão cerebral da PC, portanto, interfere com o andar de diversas maneiras. Inicialmente, por meio dos efeitos primários da lesão cerebral, pela perda do controle seletivo do movimento, distúrbios de equilíbrio, alterações no tônus muscular e espasticidade e, de forma adicional, pela imposição de forças anormais ao esqueleto, produzindo mudanças no crescimento musculoesquelético secundárias à lesão cerebral[8].

3.1.4 Classificações da PC

A PC é classificada de acordo com o tipo motor, distribuição topográfica do envolvimento dos segmentos corporais e funcionalidade.

A classificação do tipo motor ou anormalidade neuromotora é realizada de acordo com o tipo predominante, visto que muitos casos são mistos (apresentam mais de um tipo motor). Três são os grupos dessa classificação: espásticos, discinéticos (distônicos e coreoatetóticos) e atáxicos[1,25,46].

A classificação topográfica do acometimento motor é composta por hemiparesia, diparesia e tetraparesia[47]. Uma abordagem alternativa promissora foi recomendada por Cans e diferencia comprometimento unilateral de bilateral com relação ao envolvimento topográfico motor[48]**.**

A classificação funcional mais utilizada na PC é realizada pelo Sistema de Classificação da Função Motora Grossa (*Gross Motor Function Classification System* – GMFCS), por ser uma classificação estável e por possibilitar a definição de objetivos para os diferentes tratamentos[49,50]. O GMFCS consiste em cinco níveis de função motora relacionadas à capacidade de locomoção do indivíduo (Figura 1).

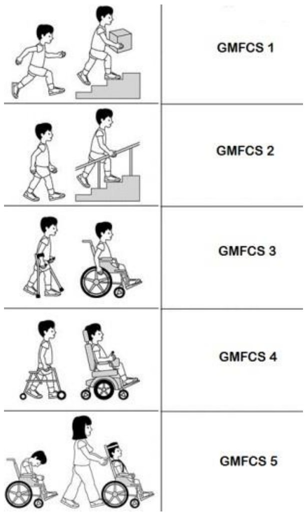


Figura 1. Sistema de Classificação da Função Motora Grossa (GMFCS) da faixa etária de 6 a 12 anos (Palisano *et al*. 1997, Graham, 2005)[49,51].

Em 2001, a Organização Mundial de Saúde publicou a Classificação Internacional de Funcionalidade, Incapacidade e Saúde (CIF)[52], que descreve as disfunções em três níveis: 1) distúrbios da estrutura corporal (órgãos ou membros) ou funções (fisiológica ou psicológica), 2) limitações em atividades (execução de tarefas ou ações individuais) e 3) restrição na participação em situações da vida diária[53,54]. Apesar da recente publicação de um instrumento com aspectos essenciais da CIF aplicáveis a crianças e jovens com PC, a classificação continua com pouca utilização na prática clínica[55].

Na mesma linha e com objetivo de caracterizar a mobilidade individual em várias distâncias, Grahan *et al*. elaboraram a Escala de Mobilidade Funcional (*Functional Mobility Scale* – FMS). Nesta classificação, a capacidade habitual de andar da criança é graduada em três distâncias (5, 50 e 500 m), de acordo com a necessidade de dispositivos auxiliares, como bengalas, muletas, andadores ou cadeira de rodas[56].

3.1.5 Prognóstico motor e sobrevida nas crianças com PC

O andar é um dos principais focos da reabilitação na PC, consumindo demasiada quantidade de tempo e recursos para as crianças e seus pais ao longo de muitos anos, com envolvimento de soma significativa das finanças públicas. Apesar desses esforços, está bem estabelecido que muitas crianças com PC não adquirem ou não mantêm a marcha funcional. Dessa forma, é importante buscar parâmetros que estabeleçam o prognóstico de deambulação de forma a não submeter os indivíduos sem capacidade neurológica a tratamentos extenuantes que não atinjam objetivos realísticos.

Alguns parâmetros clínicos são citados na literatura como marcadores prognósticos para aquisição da deambulação em crianças com PC. O controle motor de sentar entre um e dois anos de idade é fator prognóstico favorável à aquisição da marcha independente[57–59]. Outro parâmetro de prognóstico para a marcha é o tipo de comprometimento motor, como exemplo, as crianças hemiparéticas que deambulam independentemente e muitas daquelas com diparesia espástica que também deambulam, mas com auxílio de suportes externos. Por outro lado, aqueles com tetraparesia espástica raramente têm deambulação funcional[41]. Em geral, as crianças que andam independentemente o fazem por volta dos três anos de idade; quem anda com apoio pode fazê-lo até os nove anos. Já uma criança que não anda até os nove anos de idade, dificilmente andará, mesmo com apoio[57].

Durante a adolescência e na idade adulta ocorre diminuição na função e no padrão da marcha, traduzidos por diminuição na velocidade da marcha, comprimento da passada e movimentos articulares no plano sagital[60,61].

A maioria das crianças com PC sobrevivem até a idade adulta. Mesmo os indivíduos mais gravemente afetados, 50% deles sobreviverão até a metade da terceira década de vida. Isso é resultado de melhor nutrição e da prevenção de complicações respiratórias[36,62].

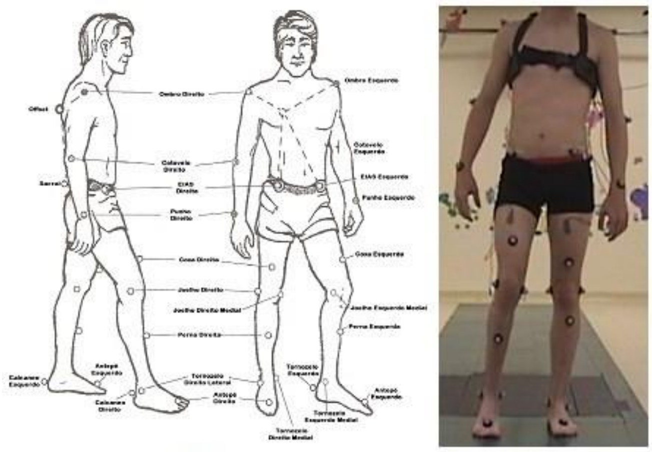
3.2 Análise Tridimensional Da Marcha (A3DM)

Desde a década de 1970, a A3DM tem sido utilizada na avaliação de crianças com PC. A análise da marcha foi inicialmente aplicada para fins de pesquisa, mas progressivamente passou a ser utilizada para apoiar a tomada de decisão clínica e avaliar resultados de tratamentos nessa população[63]. O desenvolvimento da tecnologia de câmeras e computadores proporcionou maior disponibilidade de sistemas de análise da marcha com *hardwares e softwares* complexos necessários para realizar esta tarefa com precisão e confiabilidade (Figura 2). Estes componentes da A3DM provaram ser muito desafiadores e felizmente o processo evolutivo continua até hoje[64].

(a) (b) (c)

Figura 2. Equipamentos utilizados para captura do exame computadorizado da marcha : (a) Plataformas de força (*Advanced Mechanical Technology, Inc. Watertow*, MA, USA); (b) câmera com espectro de resposta sensível ao infravermelho – modelo *Hawk* (*Motion Analysis Corporation*, Santa Rosa, CA) e (c) eletromiógrafo wireless (*Delsys Incorporated, Natick*, MA, USA).

A medição acurada do movimento é central em qualquer método científico de análise da marcha[65]. Atualmente, a rotina dos exames realizados nos laboratórios especializados de biomecânica são compostos pela avaliação clínica, filmagem em dois planos (sagital e coronal), coleta dos dados de cinemática e cinética tridimensional (Figura 3) e eletromiografia (EMG)[66].



(a) (b)

Figura 3. (a) Desenho do corpo humano nas posições lateral direita e anterior com demonstração dos pontos anatômicos segundo o modelo biomecânico Hellen Hayes (*Reference Manual OrthoTrak 6.5 Motion Analysis Corporation*, Santa Rosa, CA, USA), (b) fotografia de uma criança com marcadores reflexivos fixados aos pontos anatômicos do modelo biomecânico Hellen Hayes (arquivo do autor).
EIAS: espinha ilíaca ântero- superior.

Os dados da cinemática tridimensional (Figura 4) podem ser obtidos por dispositivos capazes de registrar o deslocamento realizado pelo corpo durante um intervalo de tempo. Neste sentido, câmeras de vídeo, sistemas acústicos, sistemas eletromagnéticos, dispositivos eletromecânicos e sistemas ópticos eletrônicos podem ser utilizados. Nesta tese os dados cinemáticos tridimensionais foram obtidos por meio de um sistema óptico eletrônico com câmeras infravermelhas sincronizadas que capturam o movimento de marcadores reflexivos colocados em pontos anatômicos do sujeito em estudo[67]. O futuro da captura do movimento 3D deve ser a eliminação do uso de marcadores passivos ou ativos colados ao corpo do indivíduo em estudo e a diminuição no número de câmeras[64]. A força de reação ao solo e, consequentemente as forças atuantes no esqueleto, são capturadas por meio de plataformas de força. O padrão de atividade muscular é capturado por um sistema múltiplo de EMG[68]. A EMG produz informações a respeito do recrutamento muscular promovido pela ação do sistema nervoso central. O registro dessas informações durante a marcha pode ser usado para quantificar, inclusive, o controle seletivo motor dos pacientes [69].

Apesar da aplicabilidade em várias doenças, a A3DM tem como maiores beneficiados as crianças com PC e mielomeningocele[70]. Nesta população, a A3DM é utilizada para ajudar na indicação de cirurgias, de terapias físicas, nos bloqueios periféricos e na prescrição de órteses e próteses[8].

Há um aumento crescente acerca das evidências sobre a importância da análise da marcha nas decisões clínicas. Pacientes que tem seu tratamento planejado de acordo com os resultados da A3DM apresentam resultados superiores em relação àqueles baseados somente na avaliação clínica.[16,17] [18] DeLuca *et al*. compararam as recomendações cirúrgicas feitas para sujeitos com PC oriundas da avaliação clínica e da análise de vídeo com a A3DM, e observaram mudança nas indicações em 52% dos casos[71]. Segundo Gough e Shortland, a análise da marcha ajudou a distinguir as crianças com PC espástica que se beneficiariam da cirurgia daquelas para as quais o manejo não-operatório era mais apropriado[72].

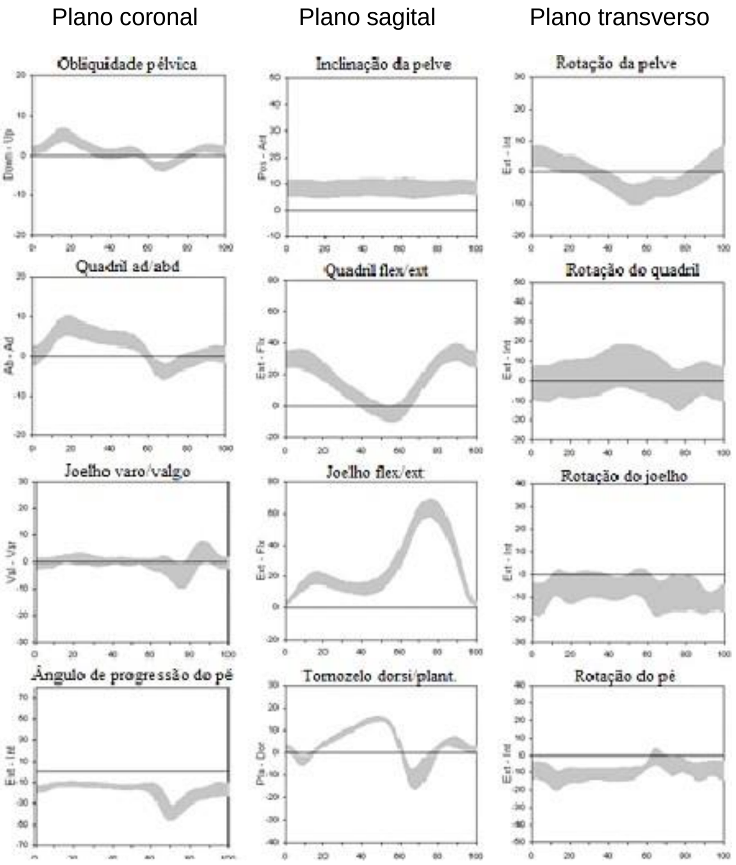


Figura 4. Gráficos de cinemática da pelve, quadril, joelho, tornozelo e pé durante o ciclo de marcha nos planos coronal, sagital e transverso. Cada quadro apresenta na vertical graus de movimento da articulação e na horizontal porcentagem do ciclo da marcha. A faixa horizontal presente em cada quadro é a marca da posição neutra. O traçado cinza representa um desvio da normalidade do movimento da articulação durante o ciclo da marcha (arquivo do Laboratório de Marcha do Centro Hospitalar de Reabilitação Ana Carolina de Moura Xavier – Curitiba – Pr.). Dow-Up: rebaixado e elevado; ab-ad: abdução e adução; var-val: varo e valgo; ext-flx: extensão e flexão; post-ant: posterior e anterior; pla-dor: plantarflexão e dorsiflexão.

Como a A3DM fornece grande quantidade de dados, que são complexos e interdependentes, foram desenvolvidos índices para descrever a qualidade do padrão da marcha de acordo com uma pontuação. Os índices pontuam o andar e podem auxiliar no entendimento de quão distante o sujeito em análise está do comportamento típico esperado[73,74].

As medidas de resumo mais comumente usadas são o *Gait Deviation Index* (GDI)[75] e o GPS[76], que fornecem uma única pontuação da qualidade da cinemática do paciente durante a marcha. O GDI é baseado no cálculo da distância entre os dados do paciente e a média do conjunto de dados de referência. Para esse cálculo são utilizadas 15 variáveis cinemáticas da marcha que incluem dados da pelve, quadril, joelho e tornozelo[75]. O GPS é obtido através das mesmas variáveis cinemáticas utilizadas para o cálculo do GDI. Entretanto, o GPS é calculado por meio da diferença da raiz quadrada média entre os dados do paciente e a média do conjunto de dados de referência[77]. O GPS tem como vantagem poder ser decomposto nas GVS que são as variáveis cinemáticas que compõem o GPS e são representadas em um quadro chamado de *“Motion Analysis Profile”* (MAP)[78]. Com isso é possível determinar quais as variáveis (que compõem o cálculo do índice) encontram-se mais distantes da normalidade.

3.3 MARCHA NORMAL

A marcha bípede de humanos é única, contrastando com os padrões de quadrúpedes e de primatas não humanos, nos quais a atividade temporal dos músculos difere significativamente[79,80]. As pegadas deixadas nas cinzas vulcânicas de Laetoli, na África, pelos hominídeos de 3 milhões de anos atrás, indicam que eles já andavam com padrão semelhante ao homem moderno[81].

O termo marcha descreve um padrão cíclico de movimentos corporais que são repetidos a cada passada[82]. A marcha humana utiliza movimentos repetitivos dos membros para avançar o corpo, mantendo simultaneamente a estabilidade no apoio[70]. Isso é alcançado por padrões rigorosamente regulados de ativações musculares e geração de momentos e potências das articulações. Parte do trabalho muscular é feito para aceleração e parte é usado para controlar momentos externos resultantes da força de gravidade e da inércia do segmento em movimento[83].

Segundo Sutherland *et al*., cinco determinantes são importantes indicadores de uma marcha madura: tempo de apoio simples, velocidade da marcha, cadência (número de passos dados por minuto durante a marcha), comprimento do passo e base de suporte. À medida que a maturidade avança, a cadência diminui enquanto a velocidade do andar e o comprimento do passo aumentam. Importantes fatores no desenvolvimento de um padrão maduro são o aumento do comprimento do membro e a maior estabilidade do membro, demonstrada pela duração crescente do apoio simples. Um padrão de marcha maduro, conforme determinado por esses critérios, está bem estabelecido aos três anos de idade[84].

Na marcha normal, mecanismos biomecânicos são utilizados com a finalidade de minimizar o consumo de energia pelo organismo, com mínima excursão do centro de massa do corpo[63,65,82]. A energia típica gasta na marcha normal (2,5 quilos de calorias por minuto) é menos que o dobro do gasto quando o indivíduo está na posição sentada ou em pé (1,5 quilos de calorias por minuto). Desvios da marcha normal aumentam muito esse custo energético[85].

A marcha humana segue um padrão constante no próprio indivíduo e muda pouco entre as pessoas, tornando possível identificar o desenvolvimento e as características maduras da marcha normal[84].

O ciclo da marcha normal (Figura 5) inicia-se pelo contato do calcâneo com o solo e termina com um novo toque do mesmo pé no solo. O ciclo da marcha é dividido em dois grandes períodos chamados de apoio e balanço. Durante o período de apoio, que corresponde a 62% do ciclo da marcha, o pé mantém contato com o solo. No balanço, responsável por 38% do ciclo, o membro inferior avança de um ponto a outro no espaço, sem contato com o solo[86].

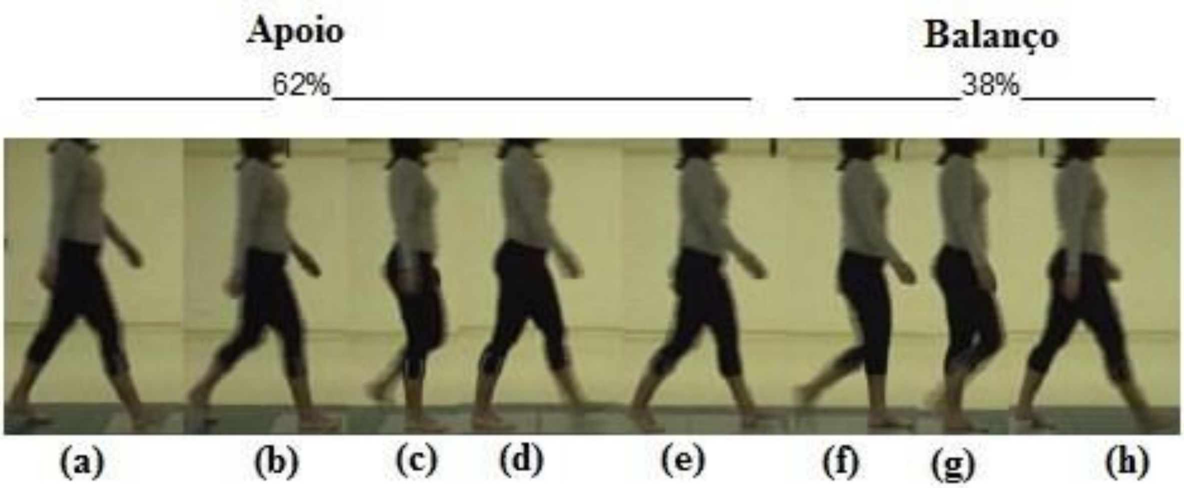


Figura 5. Ciclo da marcha (membro inferior direito) com períodos de apoio (62%) e balanço (38%). Fases do ciclo da marcha: (a) contato inicial, (b) resposta à carga, (c) médio apoio, (d) apoio terminal, (e) pré-balanço, (f) balanço inicial, (g) balanço médio, (h) balanço terminal (arquivo do autor).

Cada passada ou ciclo da marcha apresenta oito fases que correspondem aos padrões críticos do movimento sinérgico e seletivo presente no andar[86]. O contato inicial e a resposta à carga são as duas primeiras fases do apoio e responsáveis pela recepção da carga pelo membro. O médio apoio e o apoio terminal representam o apoio simples, onde apenas um membro está em contato com o solo. O pré-balanço, balanço inicial, balanço médio e balanço terminal são as fases finais do ciclo da marcha normal e têm o objetivo de avançar o membro de um local a outro[87].

Parâmetros de tempo e espaço, como a velocidade e a cadência, auxiliam no entendimento da capacidade funcional da marcha do indivíduo[87].

A ação muscular produz a força necessária para promover ou restringir as articulações, podendo ser concêntrica, isométrica ou excêntrica[70]. A atividade elétrica medida pela EMG determina que o músculo está ativo, mas não diferencia qual tipo de contração[88]. A atividade muscular durante a deambulação é complexamente coordenada e os grupos musculares iniciam e cessam sua ação em curtos espaços de tempo. Na PC a perda da coordenação entre os grupos musculares é uma das principais causas das alterações da marcha[86].

A cinemática tridimensional, fornece uma descrição precisa dos movimentos que estão ocorrendo em uma articulação específica em todos os três planos durante o ciclo da marcha, mas as medidas são essencialmente descritivas e não fornecem a causa do movimento[85]. A cinética, por outro lado, lida com as forças que produzem o movimento. Essas medidas incluem momentos e potências articulares. Momento é similar à força, exceto pelo fato de produzir um movimento de rotação[68]. Momento é gerado quando uma força é exercida a alguma distância da articulação e a unidade de medida é Newton-metro por quilograma.

Por não existir uma forma direta para medir a força muscular gerada durante o andar, utiliza-se uma maneira indireta, através da força que o pé imprime durante a fase de apoio da marcha, medida por plataformas de força posicionadas no caminho a ser percorrido[89]. A potência articular é medida em watts por quilograma e é o produto da multiplicação do momento articular pela velocidade angular da articulação[90].

Valores positivos para potência articular indicam que o músculo está diminuindo de tamanho (contração concêntrica) e produzindo uma aceleração. Um valor negativo indica que o músculo está alongando (contração excêntrica) e produzindo uma desaceleração[90]. A potência articular é a variável que melhor descreve as fases concêntricas e excêntricas da energia mecânica que os músculos geram para realizar o movimento[85].

3.4 ASPECTOS GERAIS DA MARCHA NA PARALISIA CEREBRAL

Na PC, a lesão dos neurônios motores superiores resulta em dois tipos de efeitos. O efeito predominante e mais importante resulta da perda das conexões do trato corticoespinhal com os neurônios motores inferiores e, portanto, com os músculos esqueléticos. Isso causa paresia ou plegia, que geralmente é mais pronunciada nos músculos distais do que nos músculos proximais. Como outro efeito, supõe-se que a hipertonia e hiperreflexia sejam causadas pela perda da ação inibitória descendente aos neurônios motores inferiores, o que torna hiperativo o reflexo de estiramento no sistema neuromuscular periférico[28].

A alteração do controle neural dos movimentos, somado à fraqueza muscular e a uma variedade de comprometimentos osteomusculares secundários[91], fazem com que indivíduos com PC usem uma estratégia de controle simplificada durante a marcha em comparação aos indivíduos não comprometidos[92].

Segundo Perry, a marcha típica apresenta quatro pré-requisitos que são frequentemente perdidos na marcha dos indivíduos com PC. São eles: estabilidade no apoio, adequada liberação do pé para a fase de balanço, apropriado pré-posicionamento do pé no balanço e adequado comprimento do passo[86]. Gage incorporou um quinto pré-requisito: a conservação de energia[93].

A prevalência de anormalidades específicas da marcha em crianças com PC varia com a função motora (GMFCS) e muda com a idade e com os tratamentos realizados. Após avaliar 492 indivíduos com PC, Wren *et al*. observaram como problemas mais comuns a presença de joelho rígido durante o período de balanço (80%), seguido por marcha em agachamento, caracterizada pela flexão do joelho maior que um desvio padrão da normalidade durante significante parte do período de apoio (69%), flexão excessiva o quadril, determinada pela flexão maior que 0° no apoio terminal (65%), ângulo de progressão do pé em rotação interna (64%) e pé equino no apoio (61%)[94]. A Figura 6 ilustra esses padrões de deambulação.

Figura 6. Padrões comuns de deambulação de crianças com PC espástica: (a) joelho rígido (flexão diminuída do joelho na fase de balanço), (b) agachamento, (c) flexão excessiva do quadril, (d) pé em rotação interna, (e) pé equino (arquivo do autor).

Note que, como os sintomas motores da PC incluem alterações relacionadas à lesão do sistema nervoso central e adaptações músculo esqueléticas, uma das características da PC é a variabilidade na apresentação clínica[95].

3.5 Órteses Na Marcha De Indivíduos Com Pc

Órtese é definida pela Organização Internacional de Padrões (ISO) como “um dispositivo aplicado externamente para modificar as características estruturais e funcionais do sistema esquelético e neuromuscular”[96].

As crianças deambuladoras com PC utilizam órteses abaixo da articulação do joelho, chamadas órteses suropodálicas (OSPs) que abrangem a articulação do tornozelo e a totalidade ou parte do pé[8,97].

Na marcha normal o pé e o tornozelo realizam uma série de movimentos na fase de apoio chamados rolamentos, que auxiliam a absorção do impacto do membro com o solo, promovem estabilidade no apoio e produção de potência para a marcha. Na fase de balanço, o pé e o tornozelo contribuem com dorsiflexão, para facilitar a liberação do pé do solo e auxiliar o posicionamento para a fase de apoio subsequente[98].

As crianças com PC apresentam, frequentemente, os movimentos dos pés e tornozelos alterados, devido ao desequilíbrio dinâmico entre os músculos extrínsecos da panturrilha que controlam o alinhamento desse segmento. Esse desequilíbrio pode ser consequência da espasticidade e do controle motor ou equilíbrio diminuídos[98].

Anormalidades da marcha comumente tratadas com OSPs incluem fraqueza dos flexores plantares ou dos músculos dorsiflexores, déficit no controle motor, espasticidade ou hiperatividade dos flexores plantares, instabilidade no apoio e ou problemas de equilíbrio (Figura 9). As duas categorias principais de OSPs são as fixas (rígidas) e articuladas[99].

A utilização de aparelhos ortopédicos durante o processo de reabilitação de doenças musculoesqueléticas faz parte do arsenal terapêutico. A marcha patológica de crianças com PC pode ser melhorada com o uso de órteses e a indicação do uso de OSPs deve ser feita prioritariamente após determinação da ausência de deformidades estruturadas nos tornozelos e joelhos, pois, caso contrário, a melhora funcional desejada não será alcançada.

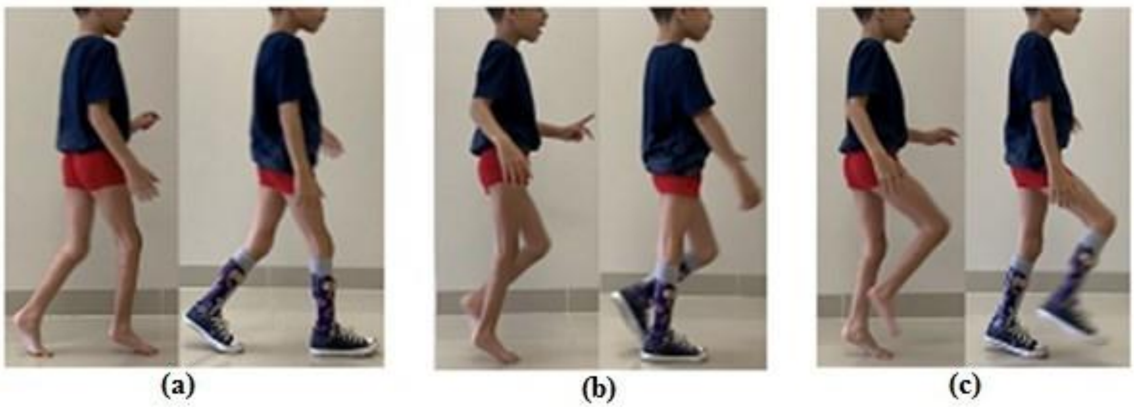


Figura 7. Indivíduo com diagnóstico de PC espástica sem e com OSP. (a) No contato inicial, (b) no médio apoio, e (c) no balanço da marcha (arquivo do autor).

As OSPs rígidas limitam a dorsiflexão do tornozelo no apoio, bloqueando o segundo mecanismo de rolamento[86], com maior extensão do joelho nesta fase como consequência. As OSPs rígidas ou articuladas são capazes de impedir a flexão plantar inapropriada no apoio, evitando um terceiro mecanismo de rolamento precoce, e ainda controlam o posicionamento do tornozelo e pé durante a fase de balanço da marcha. As OSPs articuladas não deveriam ser prescritas para crianças que apresentem dorsiflexão excessiva do tornozelo no apoio, com o potencial prejuízo de produzir flexão aumentada do joelho nesta fase da marcha[98]. As deformidades flexíveis que resultam em desvio no plano coronal do pé (deformidade em valgo, varo, inversão ou eversão) podem ser modificadas pelas OSPs, enquanto os desvios rotacionais não são influenciados com uso das OSPs.

Há fortes evidências de que as OSPs induzem pequenas melhoras na velocidade da marcha em crianças com PC espástica e moderada evidência de que as OSPs têm pequeno a moderado efeito na função motora geral[100], com aumento do GDI apenas em 37% dos casos[101]**.** Apesar de algumas incertezas, as OSP são dispositivos usados durante o dia por 21,8% das crianças com PC, segundo Sacaze *et al*.[12].

Devido a necessidade de aumentar as evidências científicas do uso de OSPs no processo de reabilitação, o primeiro estudo desta tese, avaliou o impacto global da utilização de órteses na marcha de indivíduos da faixa etária pediátrica com diagnóstico de PC, utilizando as avaliações por meio da A3DM.

3.6 Classificações Dos Desvios Da Marcha Na Pc

O termo classificação da marcha refere-se a um sistema que permite a alocação do padrão de marcha do indivíduo em grupos que podem ser diferenciados uns dos outros com base em variáveis definidas previamente[20].

A A3DM é considerada o padrão-ouro na avaliação do andar de indivíduos com PC[14,15]. Entretanto, a grande quantidade de dados biomecânicos multidimensionais produzidos pela A3DM, dificulta a interpretação clínica[102]. Resumir esses dados, usando uma classificação da marcha, pode facilitar a tomada de decisões clínicas. Consequentemente, vários Sistemas de Classificações da Marcha (SCM) têm sido desenvolvidos baseados nos dados adquiridos por intermédio da A3DM[19,20,103–107] [108,109 110].

As principais desvantagens dos atuais SCM são: considerar apenas (ou principalmente) parâmetros cinemáticos; considerar somente um plano de movimento e elaborar as classificações para tipos clínicos específicos, dificultando o uso para a população geral de indivíduos deambuladores com PC[110].

Os SCM são construídos de forma qualitativa ou quantitativa, com base na elaboração a partir da experiência clínica ou de dados medidos de forma objetiva, respectivamente[107]. Por exemplo, os SCM elaborados a partir de premissas qualitativas apresentaram limitações na sua construção, com avaliação de apenas uma articulação[111,112], um único tipo clínico, como hemiparéticos[113] ou diparéticos[114], e apenas um plano de movimento, o sagital[111,113,114]. A maioria das classificações qualitativas tiveram como origem as classificações de Winters *et al*., para hemiparéticos e as de Sutherland e Davids[111] e Rodda *et al*.[114] para diparéticos espásticos.

A construção quantitativa utiliza cálculos matemáticos complexos, como rede Bayesiana e regressão logística, e podem usar meios automáticos para extração dos dados da ATM[19,102]. Entretanto, o aumento no desempenho é limitado e não supera o custo computacional adicional, gerando maior risco de perda da capacidade de interpretação clínica, o que ameaça a sua aceitação e aplicabilidade[20,102].

Segundo o estudo de Rethlefsen *et al*., que avaliaram 1005 crianças com PC, as alterações mais comuns na marcha deste grupo de indivíduos foram: rotação interna, flexão e adução dos quadris, flexão excessiva dos joelhos, joelhos rígidos, pé equino e em rotação interna[103]. Nieuwenhuys *et al*. identificaram 49 padrões articulares, que englobavam alterações nos planos sagital, coronal e transverso, durante as fases de apoio e balanço da marcha das diversas articulações dos membros inferiores[108]. Portanto, é possível entender que alterações da marcha na PC não estão limitadas a um único plano de movimento ou nível articular.

Um SCM para indivíduos com PC apresentaria utilidade clínica caso: a classificação fosse aplicada à marcha de hemiparéticos e diparéticos; incorporasse desvios em múltiplos níveis e planos de movimento; incluísse, quando apropriado, dados cinéticos e eletromiográficos; e levasse em consideração o uso de dispositivos auxiliares em pessoas com maior comprometimento funcional e distúrbios mais complexos do movimento.

Em 2019, Papageorgiou *et al*. realizaram uma revisão sistemática da literatura, e determinaram um consenso de padrões da marcha de crianças com PC[110]. Os seis padrões de consenso foram: genu recurvato, pé caído, equino verdadeiro, marcha em salto, equino aparente e marcha agachada.

Apesar dos padrões estarem relacionados a múltiplos níveis articulares (pelve, quadril, joelho e tornozelo), apenas o plano sagital e a cinemática foram utilizados na classificação.

Sendo assim, o segundo estudo desta tese avaliou o consenso de padrões do andar de crianças com PC, estabelecido por meio da revisão sistemática da literatura conduzida por Papageorgiou *et al*.[110]. Para tal, uma amostra de indivíduos da faixa etária pediátrica foi classificada utilizando os padrões relatados e, assim, determinada a capacidade deste instrumento classificar esta amostra e sua reprodutibilidade.

A revisão sistemática da literatura conduzida por Papageorgiou *et al*., determinou que para avaliar as classificações eram necessárias informações relacionadas à validade, reprodutibilidade e aplicabilidade clínica[110]. Entre os SCM avaliados por Papageorgiou *et al*., o sistema proposto por Davids e Bagley apresentou características positivas em sua construção e significativa aplicabilidade clínica. Entretanto, não havia sido testado em uma amostra de sujeitos com PC[107].

O “Sistema de Classificação das Alterações da Marcha de Crianças com PC” de Davids e Bagley, incorpora aspectos úteis clinicamente e baseia-se em processos biomecânicos da PC. A classificação determina alterações do período de apoio e balanço do plano sagital (Figura 8), assim como alterações no plano transverso de movimento (Figura 9).

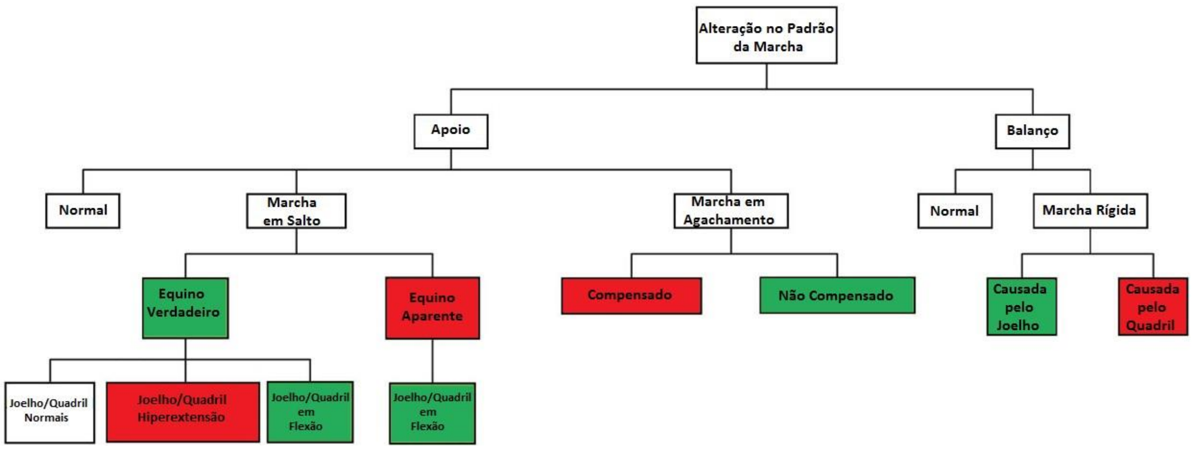


Figura 8. Classificação de Davids e Bagley do plano sagital de movimento durante o ciclo da marcha de crianças com PC[107]. Retângulos em verde representam alterações da marcha que deveriam receber tratamento cirúrgico ortopédico e em vermelho alterações que não deveriam receber tratamento cirúrgico (reprodução com permissão do autor).

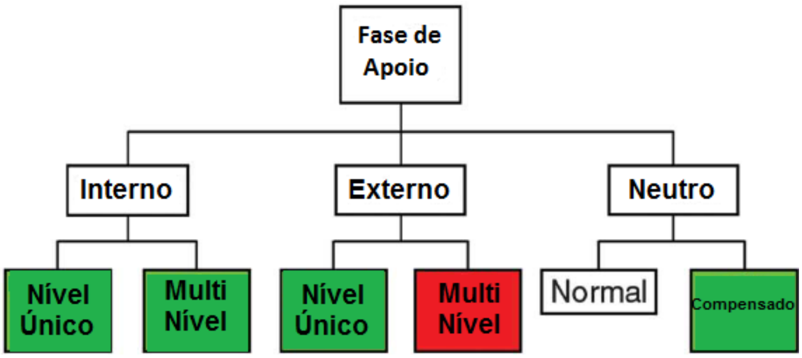


Figura 9. Classificação de Davids e Bagley do plano transverso de movimento durante o ciclo da marcha de crianças com PC[107]. Retângulos em verde representam alterações da marcha que deveriam receber tratamento cirúrgico ortopédico e em vermelho alterações que não deveriam receber tratamento cirúrgico (reprodução com permissão do autor).

Esta classificação, apesar de ser categórica, é verticalmente integrada e considera os padrões da marcha em mais de um plano de movimento. Por conta da necessidade de SCM com boa aplicabilidade clínica, o terceiro estudo desta tese avaliou a validade e reprodutibilidade da classificação desenvolvida por Davids e Bagley[107] (autorizado pelo autor), uma vez que ainda não tinha sido testada em uma amostra de crianças com PC.

Por fim, um quarto estudo foi desenvolvido com objetivo de construir uma nova classificação da marcha de crianças com PC para agregar benefícios às classificações anteriormente citadas. Durante o processo de construção, os autores levaram em consideração conceitos de classificações prévias e adicionaram a importante característica de continuidade das alterações da marcha na PC. Para determinar o aspecto progressivo da classificação incluíram o conceito básico descrito por Winter (1980) de que a função primordial dos membros inferiores durante a marcha é resistir ao colapso em flexão e apresentar extensão eficiente para a produção de potência no final do apoio[115]. Dessa forma, um dos elementos da progressão utilizados nesta nova classificação é o aumento da flexão dos tornozelos e joelhos. A nova classificação incluiu, ainda, a avaliação de mais de um plano de movimento e a utilização de tutores externos durante a marcha (bengalas/muletas/andadores), por estar, esta última, relacionada a menor funcionalidade na deambulação.

4 ARTIGO 1

Artigo original publicado no periódico Acta Ortopédica Brasileira.

Fator de Impacto: 0,570 Qualis: A2 (ISSN 1413-7852)

Acta Ortop Bras. 2020;28(3):137-41

Title:

Results of orthoses used on ambulatory patients with bilateral cerebral palsy.

Authors

Alessandro Giurizatto Melanda[1, 3], Ana Carolina Pauleto[3,4], Dielise Debona Iucksch[2,3], Rodrigo Faucz Munhoz da Cunha[3], Suhaila Mahmoud Smaili[1].

[1]Program of Master and Doctoral degree in Rehabilitation Sciences, State University of Londrina (UEL), Londrina - Londrina – Brazil.
[2]Universidade Federal do Paraná, Curitiba – Paraná State - Brazil.
[3]Centro Hospitalar de Reabilitação Ana Carolina Moura Xavier, Curitiba – Paraná State - Brazil.
[4]Hospital Pequeno Príncipe, Curitiba - Paraná State – Brazil.

Corresponding Author:
Alessandro G. Melanda
State University of Londrina – Brazil.
Instituto Pro-Kids.
Av. Adhemar Pereira de Barros, 1199.
Bela Suiça, Londrina – Paraná – Brazil.
ZipCode: 86047-250.
melanda@uel.br

DOI: http://dx.doi.org/10.1590/1413-785220202803228922

ORIGINAL ARTICLE

RESULTS OF ORTHOSES USED ON AMBULATORY PATIENTS WITH BILATERAL CEREBRAL PALSY

RESULTADOS DO USO DE ÓRTESES EM PACIENTES DEAMBULADORES COM PARALISIA CEREBRAL

ALESSANDRO GIURIZATTO MELANDA[1,3], ANA CAROLINA PAULETO[3,4], DIELISE DEBONA IUCKSCH[2,3], RODRIGO FAUCZ MUNHOZ DA CUNHA[3], SUHAILA MAHMOUD SMAILI[1]

1. Program of Masters and Doctoral degree in Rehabilitation Sciences, Londrina State University (UEL).
2. Universidade Federal do Paraná, Curitiba, PR, Brazil.
3. Centro Hospitalar de Reabilitação Ana Carolina Moura Xavier, Curitiba, PR, Brazil.
4. Hospital Pequeno Príncipe, Curitiba, Pr, Brazil

ABSTRACT

Objective: To investigate the impact of ankle-foot orthoses (AFO) on subjects diagnosed with bilateral cerebral palsy (CP) using the gait index and temporal data parameters. Methods: Twenty-four subjects, 14 male and 10 female, with a mean age of 11 (5-17 years old), underwent a comprehensive gait analysis under both barefoot (BF) and braced walking conditions. All children had been wearing the orthoses for at least 2 months before the gait analysis. Results: The overall values for the left and right Gait Profile Scores (GPS) did not show statistically significant variations when comparing the same individuals with and without orthoses. Gait velocity increased by 19.5% ($p < 0.001$), while the cadence decreased by 4% with use of orthosis, although it was not statistically significant ($p > 0.05$). The stride and the step lengths on both the right and left sides, however, resulted in statistically significant increases, when wearing AFO. Conclusion: AFO, prescribed for assistance by professionals without using gait data, did not significantly affect the gait index (GPS), but improved temporal data. The determination of quantitative clinical parameters for the prescription of orthotics in patients with bilateral CP, as well as orthotics that meet the specific requirements are points to be addressed in the future to obtain more significant effects. ***Level of evidence III, Case control study.***

Keywords: Cerebral Palsy. Foot Orthoses. Gait.

RESUMO

Objetivo: Investigar o impacto das órteses suropodálicas (AFOs) utilizando índices da análise computadorizada da marcha (ACM) e dados de tempo e espaço, em indivíduos com diagnóstico de paralisia cerebral (PC) bilateral. Métodos: 24 indivíduos, 14 do sexo masculino e 10 do sexo feminino, com média de idade de 11 anos (5-17 anos), foram submetidos a uma análise da marcha, tanto na condição de andar descalço (AD) quanto com uso das órteses. Todas as crianças usavam as órteses há no mínimo 2 meses antes da ACM. Resultados: Os valores do perfil global da marcha (GPS) dos lados direito e esquerdo não apresentaram variações estatisticamente significativas quando os mesmos indivíduos foram comparados, com e sem órteses. Com o uso de órtese a velocidade da marcha aumentou 19,5% ($p < 0,001$), enquanto a cadência diminuiu 4%, embora não tenha sido estatisticamente significativa ($p > 0,05$). No entanto, com o uso da órtese, a passada e o comprimento do passo dos lados direito e esquerdo tiveram aumentos estatisticamente significativos. Conclusão: As AFOs, quando prescritas por profissionais sem o uso de dados da ACM, não alteraram significativamente o índice da marcha (GPS), mas melhoraram os dados de tempo e espaço. A determinação de parâmetros clínicos quantitativos para a prescrição de órteses em pacientes com PC bilateral, bem como órteses que atendam a requisitos específicos, são pontos a serem abordados no futuro, a fim de obter efeitos mais significativos. ***Nível de evidência III, Estudo de caso e controle.***

Descritores: *Paralisia Cerebral. Órteses do Pé. Marcha.*

Citation: Melanda AG, Pauleto AC, Iucksch DD, Cunha RFM, Smaili S. Results of orthoses used on ambulatory patients with bilateral cerebral palsy. Acta Ortop Bras. [online]. 2020;24(1):137-41. Available from URL: http://www.scielo.br/aob.

INTRODUCTION

Cerebral Palsy (CP) is the most common cause of physical disability affecting children in developed countries, with an incidence rate between 2.0 and 3.5 per every 1,000 live births,[1-3] while in developing countries this index may reach 7 for every 1,000.[4] The explanation for the difference between these two groups of countries is attributed to poor conditions of antenatal care and primary care for pregnant women. Functionally, approximately 60% of patients with CP can walk independently, approximately 10% use a mobility device, and approximately 30% have limited or no walking ability.[5]

Efficient walking is an important treatment goal for children with CP.[6] Orthotic management is a significant and useful treatment

All authors declare no potential conflict of interest related to this article.

The study was carried out at Universidade Estadual de Londrina in the Graduate Program in Rehabilitation Sciences at the Universidade Estadual de Londrina-Paraná-Brazil and at the Ana Carolina de Moura Xavier Rehabilitation Center - Curitiba-Paraná-Brazil.

Correspondence: Alessandro Giurizatto Melanda. Av. Adhemar Pereira de Barros, 1199. Londrina, Brazil, 86047250. melanda@uel.br

Article received on 09/18/2019, approved on 11/07/2019.

option for a number of conditions that affect gait and posture, and usually forms part of an overall rehabilitation program established for patients with CP.[6]

Orthoses are commonly prescribed to address both structural and functional deficiencies.[7] Eighty-five percent of children with CP have had at least one orthotic device.[8] The most commonly used lower-limb orthoses in CP are AFO that provide direct control of the ankle and foot to improve gait.[9] Orthoses influence the ankle and foot by providing a control moment opposing ankle motion, and also stabilize the motions of the mid and forefoot joints.[10]

In children with CP, the aim of orthotic management in the form of ankle-foot orthoses (AFO) is to produce a more natural gait pattern. AFO may be used to protect the outcome of a surgical procedure during the healing and rehabilitation phases, to prevent the development or worsening of musculoskeletal deformities with growth and to improve gait.[11]

The prescription of rehabilitation treatments and recommendation of orthoses is generally performed after a clinical evaluation. The use of three-dimensional gait analysis (3DGA) contributes to defining strategies for the treatment of patients with cerebral palsy.[12-14] However, even with the assistance of gait analysis, the degree to which a patient's gait improves after an intervention remains difficult to assess. Considering not only how each feature of the gait pattern has changed, but also how the relationship between the features changed is important to accurately assess the changes in gait resulting from a specific treatment.[15] For such, the gait profile score (GPS) will be used, in order to produce an overview of the gait.[16] The gait index summarizes the kinematic data, helping the clinician to understand the general changes in gait pathology after a specific treatment.[17]

Our study seeks to verify the outcome of the use of orthoses by patients with cerebral palsy that were prescribed through clinical criteria due to the unavailability of gait laboratories in most cities around the world. We must question if we are really improving the gait of patients with cerebral palsy by prescribing orthoses without using 3DGA. It was hypothesized that gait index and spatial-temporal data parameters could improve with the use of orthoses.

METHODS

This retrospective cross-sectional study was conducted using the database of the gait laboratory at the Rehabilitation Center of Paraná in Curitiba, Paraná, Brazil. All participants and parents/guardians signed an informed consent form before the study. The approval of the local research ethics committee (number: 2.447.001) to conduct the study had been previously obtained. A search was conducted for all children with spastic CP who had underwent 3DGA, both barefoot (BF) and for those who were using orthoses during a single visit to the gait analysis laboratory between 2011 and 2017.

Participants

The inclusion criteria were: children with a clinical diagnosis of spastic CP, with bilateral involvement of the lower limbs, using rigid or articulated AFO (the same design worn bilaterally), who had undergone 3DGA with and without orthoses.

Previous treatments such as single event multilevel surgery or botulinum toxin type A injections were allowed, as well as the use of walkers and crutches. All children had been wearing the orthoses for at least 2 months before the gait analysis. The walking motion trials were conducted on those wearing orthoses during the same visit as the barefoot trials.

Measurements

The Gross Motor Classification System (GMFCS) and Functional Mobility Scale (FMS) were assigned by a senior clinical physical therapist and a pediatric orthopedist in appointment with the child and their parents.[18,19]

The kinematic data was collected using reflective markers strategically placed on specific anatomical points on the participants, as described by Kadaba et al.,[20] and recommended by the software user's manual (Cortex Version 1.1.4.368 – User's Manual; Motion Analysis Corporation, Santa Rosa, CA, USA). Three-dimensional kinematic gait data was collected bilaterally using 6 infrared cameras and a motion capture system (infrared digital Hawk; Motion Analysis Corporation, Santa Rosa, CA) sampling at 60 Hz.

Three-dimensional gait kinematics data was used to estimate the GPS and temporal data was used to quantify the overall deviation of an individual's gait from normal gait.

GPS represents the root mean square (RMS) difference between particular gait trials and averaged data from people with no gait pathology. The overall GPS is based upon 15 clinically important kinematic variables including, gait variable score (GVS): Pelvic Tilt (Ant/Post), Pelvic Obliquity (Up/Dn) and the rotation of the left side and hip flexion, abduction, internal rotation, knee flexion, ankle dorsiflexion and foot progression for the left and right sides, as shown in Table 2. In this analysis, a GPS score for each side was used based on all nine GVS for each side. As the GPS uses all the gait features representing the root mean square difference between the patient's data and the average from the reference dataset obtained from all of the relevant kinematic variables for the entire gait cycle, the higher the GPS value the less physiological the gait pattern.[21]

Temporal data, GPS and GVS were used to quantify the changes of the gait with and without orthoses.

Three different analyses were conducted. First, all 24 participants were analyzed while walking barefoot using orthoses. Second, the participants were divided according to the use of rigid or articulate orthoses. Third, they were divided by functional status (GMFCS), classified into levels I, II, III and IV.

Statistical analysis

Data was presented as median and interquartile range, according to the Shapiro-Wilk test for normality. For intragroup analyses (with or without orthoses) the paired t-test or Wilcoxon test was performed, and for the analyses between groups (GMFCS classification and type of orthosis), the t-test for independent samples or Mann-Whitney test was used, according to the normality distribution of the data. Statistical analyses were conducted using SPSS 22 for Windows (SPSS Inc., Chicago, IL), adopting a 5% significance level.

RESULTS

The sample consisted of 24 subjects, 14 male and 10 female, with a median age of 11 [5-17 years old] and with GMFCS as follow: 1 participant at level I, 13 at level II, 9 at level III and 1 at level IV. Regarding orthosis characteristics, 10 patients used rigid AFO and 14 articulated AFO.

No significant differences were found for outcomes considering GPS overall, GPS right and GPS left side when comparing the walking tests with the individuals using or not using the orthoses (Table 1).

Table 1. Median [quartile range] of gait profile scores overall, left and right sides for bilateral cerebral palsy group when walking barefoot and with ankle-foot orthoses.

Variable	Barefoot	AFO	P
GPS overall	14.96 [13.11-18.18]	15.54 [14.05-16.40]	0.25
GPS right	13.06 [11.50-16.13]	14.15 [11.77-15.62]	0.73
GPS left	14.80 [13.00-16.85]	14.62 [12.70-16.30]	0.87

Considering GVS variables such as pelvic tilt, pelvic rotation, pelvis obliquity, hip flexion, hip rotation, hip abduction, knee flexion, ankle dorsiflexion, and foot angle of advancement, no statistically significant differences were observed between BF and with use of orthoses, except for one parameter: GVS Hip Abduction-Adduction left- barefoot = 5.76 [4.42-8.85] and with AFO = 6.44 [5.31-8.97] – $p = 0.01$. All results are shown in Table 2.

Table 2. Median [quartile range] of gait variable scores for the bilateral cerebral palsy group when walking barefoot and with ankle-foot orthoses.

Parameter	Barefoot	AFO	P
GVS Pelvic Tilt (°)	5.76 [4.24-8.77]	6.77 [4.49-9.79]	0.19
GVS Pelvic Rotation (°)	10.16 [8.52-12.84]	9.87 [7.11-13.60]	0.19
GVS Pelvic Obliquity (°)	4.45 [3.07-5.53]	4.66 [3.24-5.67]	0.39
GVS Hip Flex-Extension right (°)	11.96 [8.24-19.91]	12.06 [10.02-17.61]	0.64
GVS Hip Flex-Extension left (°)	13.26 [6.65-20.16]	12.41 [7.41-15.25]	0.08
GVS Hip Ab-Adduction right (°)	6.60 [5.26-7.45]	6.14 [5.13-8.53]	0.84
GVS Hip Ab-Adduction left (°)	5.76 [4.42-8.85]	6.44 [5.31-8.97]	0.01
GVS Hip Rotation right (°)	9.52 [7.92-14.73]	10.52 [7.92-15.16]	0.27
GVS Hip Rotation left (°)	13.84 [8.12-20.51]	11.67 [8.00-15.83]	0.66
GVS Knee Flex-Extension right (°)	21.48 [15.28-27.93]	20.87 [18.51-27.94]	0.62
GVS Knee Flex-Extension left (°)	22.53 [19.17-29.34]	22.12 [19.72-29.72]	0.58
GVS Ankle Dorsi-Plantarflexion right (°)	10.83 [7.80-14.80]	10.98 [8.74-14.34]	0.97
GVS Ankle Dorsi-Plantarflexion left (°)	11.31 [7.88-15.82]	9.42 [7.07-12.89]	0.24
GVS Foot Progression right (°)	11.88 [9.19-20.71]	15.98 [9.59-24.47]	0.06
GVS Foot Progression left (°)	15.05 [8.28-26.05]	12.85 [8.13-26.98]	0.36

When considering the spatio-temporal parameters of gait, there was a 19.5% increase in Gait velocity with the use of orthosis ($p < 0.001$). The Stride length and the step length of the right and left sides showed a statistically significant increase. No difference were observed in cadence. The values are shown in Table 3.

Table 3. Median [quartile range] of velocity and cadence. Mean (standard deviation) of stride length and step length of right and left sides for the bilateral cerebral palsy group when walking barefoot and with ankle-foot orthoses.

Parameters	Barefoot	AFO	P
Velocity (cm/sec)	68.85 [25.95-80.50]	82.31 [36.70-89.25]	0.01
Cadence (steps/min)	112.25 [68.15-123.15]	107.50 [61.42-118.87]	0.46
Stride Length (cm)	68.62 (4.15)	77.65 (4.58)	< 0.01
Right Step Length (cm)	35.15 (2.16)	40.28 (2.28)	< 0.01
Left Step Length (cm)	33.42 (2.20)	37.82 (2.49)	< 0.01

When performing the detailed gait analysis with and without orthoses according to the functional classification – GMFCS 1-2 and GMFCS 3-4, as well as between subjects using rigid and articulated orthoses, we found the same results reported for the general sample. That is, no significant difference was found between the groups related to overall, right, left GPS and GVS. However, the significant increase in velocity and stride length was maintained.

DISCUSSION

The most typical use of an AFO is to optimize the normal dynamics of walking by applying a mechanical constraint (control moment) to the ankle to control motion and, at the same time, to produce a more efficient gait.[22]

Different types of orthoses may be prescribed for children with CP, such as AFO, which can help with alignment and in improving gait quality. AFO in fact, reduce, plantarflexion of the ankle, leading to greater stability in the support phase of gait.[22]

The values for general, left and right GPS did not present statistically significant differences when comparing the same individuals with and without the use of orthoses. These results are in concordance with a previous study by Danino et al.,[23] that did not find any changes in GPS in subjects with cerebral palsy when walking BF and using AFO. The explanation for the non-improvement in GPS was postulated because the index mainly examined the general kinematics of gait as measured from normal, and despite some changes in distal parameters, the overall gait pattern did not change significantly.

Our study analyzed GVS variables and significant changes were not found when analyzing the subjects walking BF or with orthoses, except for, hip adduction/abduction at the left side, the only parameter that changed. However, this had no clinical significance.

In contrast with our results, Galli et al.[22] reported improvement in GVS of the ankle and pelvic tilt with a small sample of 10 subjects diagnosed with bilateral cerebral palsy, walking barefoot and with AFO. It is important to remember that the GVS evaluates the area of the kinematic curve as a whole. However, the orthosis positions the ankle in such a way that it avoids extreme positions of plantar flexion and/or dorsiflexion, without necessarily making the ankle movements look close to normal.

On the other hand, the temporal parameters showed changes that included gait velocity increasing by 19.5% with the use of the orthoses, while the cadence decreased by 4%, although the latter is not statistically significant. The lengths of the stride and step of the right and left sides had a statistically significant increase.

With the concept of minimal clinically important difference (MCID), which means a limit to determine when significant changes occur, there is an increasing emphasis in clinical research into establishing whether outcomes are clinically meaningful, as well as statistically significant.[24,25] Oeffinger et al.,[26] reported that changes in gait velocity, cadence and stride length, respectively 9.1%, 8.1% and 5.8% from normal were MCID. The mean subject's velocity, cadence and stride length in our study changed 19.5%, – 4.2% and 13%, respectively. When comparing these changes with normal values, we noted that the velocity and the stride lengths were MCID. The reported changes that reach statistical significance were also clinically meaningful (gait velocity and stride length). As walking velocity is often used as a surrogate measure for overall gait quality, we can say that orthoses in our sample produced functional benefits, agreeing with a systematic review and meta-analysis published by Lintanf et al.,[27] despite avoiding the appearance of musculoskeletal deformities. Furthermore, we can observe the results above point to an improvement in function, since the increase in velocity relates to an increase in the stride length, rather than an increase in cadence, as shown in Table 3.

The authors also performed the subdivision of the sample considering greater and lesser motor impairment (GMFCS 1-2 and GMFCS 3-4), and by the type of orthosis used (articulated or rigid). The results reported for the general sample were the same when the sample was divided using the level of motor impairment and type of orthosis. Therefore, the heterogeneity in the sample was not responsible for the changes.

For children with CP, Davids et al.,[11] argued that analogous with multilevel surgery decision making, optimal orthotic management requires the physician to clearly identify the gait deviation and functional deficits to be addressed using the orthosis.

Recommendations for orthoses must meet specific requirements in physical exams and in gait performance. Adequate range of motion for typical alignment while walking is necessary to properly fit the orthosis and to expect good functionality. This requires at least a neutral ankle dorsiflexion with the knee extended and no knee flexion contractures. Femoral anteversion and tibial torsion decrease the effectiveness of a well-made orthosis and should be identified and corrected to maximize effectiveness.[7] Rodda and Graham,[28] proposed the use of articulated AFO in true equinus gait and jump gait as well as the use of rigid AFO for apparent equinus and crouch gait. This recommendation reveals the concern with keeping the ankle in a more neutral position during the stance phase of gait.

Careful clinical evaluation of the patient by the professional is essential to avoid prescribing an orthosis under suboptimal conditions for use. Clinical gait analysis may aid in orthosis recommendations. In our study, the fact that prescriptions for orthoses were issued without the aid of quantitative data (gait analysis), may have been a contributing factor for non-significant changes in some parameters such as ankle GVS.

The lack of evidence is also observed due to the scarcity of prescription guidelines.[29] In clinical practice, this lack of consensus observed due to differences in treatment paradigms regarding both the recommendations and the mechanical construction of AFO.[9] A systematic review on the quality of AFO studies in children with CP concluded that substantial variability in the quality or reporting was present in currently published studies.[30]

The prevention of the occurrence of skeletal muscle dysfunction is one of the reasons to prescribe orthoses in this population. Studies such as these do not evaluate this important effect of the use of orthoses in patients diagnosed with CP.

The limitations of our study relate to the small study cohort sample, collected out of convenience and for the efficacy of orthoses, who were evaluated in a laboratory, and not in an environment where children participated in normal daily activities.

Clinical implications

The attending professional needs to carefully assess the recommendations and effects of orthoses on ambulatory patients with CP. This is because some predicted effects of orthoses recommendations may not be achieved, as occurred in the sample studied in which no changes were observed in the overall gait characteristics.

The determination of quantitative parameters for the prescription of orthotics in patients with bilateral CP, as well as orthotics that meet specific requirements are points to be addressed in the future to obtain more significant effects.

CONCLUSION

In this study, the AFO, prescribed for assistance by professionals without using gait data, did not significantly affect the gait index (GPS), but improved temporal data. Answering the question: are we improving the gait of patients with cerebral palsy by prescribing orthoses without using 3DGA? In the evaluated sample the patients using orthoses became more functional with increased velocity, step and stride length. However, the movements of the lower limbs were no closer to normality.

AUTHORS' CONTRIBUTIONS: Each author contributed individually and significantly to the development of this article: AGM: article design, project design and writing; ACP: data collection and review; DDI: data collection and review; RFMC: data collection and review; SS: statistical analysis, writing and review.

REFERENCES

1. Kerr Graham H, Selber P. Musculoskeletal aspects of cerebral palsy. J Bone Joint Surg Br. 2003;85(2):157-66. doi: 10.1302/0301-620X.85B2.14066
2. Colver A, Fairhurst C, Pharoah PO. Cerebral palsy. Lancet. 2014;383(9924):1240-49.
3. Yeargin-Allsopp M, Van Naarden Braun K, Doernberg NS, Benedict RE, Kirby RS, Durkin MS. Prevalence of cerebral palsy in 8-year-old children in three areas of the United States in 2002: a multisite collaboration. Pediatrics. 2008;121(3):547-54. doi: 10.1542/peds.2007-1270
4. Zanini G, Cemin NF, Peralles SN. Paralisia cerebral: causas e prevalências. Fisioter Mov. 2009;22(3):375-81.
5. Christensen D, Van Naarden Braun K, Doernberg NS, Maenner MJ, Arneson CL, Durkin MS, et al. Prevalence of cerebral palsy, co-occurring autism spectrum disorders, and motor functioning: autism and developmental disabilities monitoring network, USA, 2008. Dev Med Child Neurol. 2014;56(1):59-65.
6. **Aboutorabi A, Arazpour M, Ahmadi Bani M, Saeedi H, Head JS. Efficacy of ankle foot orthoses types on walking in children with cerebral palsy: a systematic review. Ann Phys Rehabil Med. 2017;60(6):393-402.**
7. Gage JR, Schwartz MH, Koop SE, Novacheck TF. The identification and treatment of gait problems in cerebral palsy. 2nd ed. London: Mc Keith Press; 2009.
8. Sacaze E, Garlantezec R, Rémy-néris O, Peudenier S, Rauscent H, le Tallec H, et al. A survey of medical and paramedical involvement in children with cerebral palsy in Britanny: preliminary results. Ann Phys Rehabil Med. 2013;56(4):253-67.
9. Morris C, Bowers R, Ross K, Stevens P, Phillips D. Orthotic management of cerebral palsy: recommendations from a consensus conference. NeuroRehabilitation. 2011;28(1):37-46.
10. Ries AJ, Novacheck TF, Schwartz MH. A data driven model for optimal orthosis selection in children with cerebral palsy. Gait Posture. 2014;40(4):539-44.
11. Davids JR, Rowan F, Davis RB. Indications for orthoses to improve gait in children with cerebral palsy. J Am Acad Orthop Surg. 2007;15(3):178-88.
12. Gage JR, Deluca PA, Renshaw TS. Gait Analysis : Principles and Applications. J Bone Jt Surg. 1995;77(10):1607-23.
13. Wren TAL, Gorton GE, Õunpuu S, Tucker CA. Efficacy of clinical gait analysis: a systematic review. Gait Posture. 2011;34(2):149-53.
14. Wren TAL, Otsuka NY, Bowen RE, Scaduto AA, Chan LS, Sheng M, et al. Influence of gait analysis on decision-making for lower extremity orthopaedic surgery: baseline data from a randomized controlled trial. Gait Posture. 2011;34(3):364-9.
15. Schutte LM, Narayanan U, Stout JL, Selber P, Gage JR, Schwartz MH. An index for quantifying deviations from normal gait. Gait Posture. 2000;11(1):25-31.
16. Baker R, McGinley JL, Schwartz MH, Beynon S, Rozumalski A, Graham HK, et al. The gait profile score and movement analysis profile. Gait Posture. 2009;30(3):265-9.
17. **Rasmussen HM, Nielsen DB, Pedersen NW, Overgaard S, Holsgaard-Larsen A. Gait deviation index, gait profile score and gait variable score in children with spastic cerebral palsy: intra-rater reliability and agreement across two repeated sessions. Gait Posture. 2015;42(2):133-7.**
18. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol. 1997;39(4):214-23.
19. Graham HK, Harvey A, Rodda J, Nattrass GR, Pirpiris M. The functional mobility scale (FMS). J Pediatr Orthop. 2004;24(5):514-20.
20. Kadaba MP, Ramakrishan HK, Wootten ME. Measurement of lower extremity kinematics during level walking. J Orthop Res. 1990;8(3):383-92.
21. Cimolin V, Galli M. Summary measures for clinical gait analysis: a literature review. Gait Posture. 2014;39(4):1005-10.
22. **Galli M, Cimolin V, Rigoldi C, Albertini G. Quantitative evaluation of the effects of ankle foot orthosis on gait in children with cerebral palsy using the gait profile score and gait variable scores. J Dev Phys Disabil. 2016;28(3):367-79.**
23. **Danino B, Erel S, Kfir M, Khamis S, Batt R, Hemo Y, et al. Are gait indices sensitive enough to reflect the effect of ankle foot orthosis on gait impairment in cerebral palsy diplegic patients? J Pediatr Orthop. 2016;36(3):294-8.**
24. Crosby RD, Kolotkin RL, Williams GR. Defining clinically meaningful change in health-related quality of life. J Clin Epidemiol. 2003;56(5):395-407.
25. **Devetak GF, Martello SK, de Almeida JC, Correa KP, Iucksch DD, Manffra EF. Reliability and minimum detectable change of the gait profile score for post-stroke patients. Gait Posture. 2016;49:382-7.**
26. Oeffinger D, Bagley A, Rogers S, Gorton G, Kryscio R, Abel M, et al. Outcome tools used for ambulatory children with cerebral palsy: responsiveness and minimum clinically important differences. Dev Med Child Neurol. 2008;50(12):918-25.

27. **Lintanf M, Bourseul JS, Houx L, Lempereur M, Brochard S, Pons C. Effect of ankle-foot orthoses on gait, balance and gross motor function in children with cerebral palsy: a systematic review and meta-analysis. Clin Rehabil. 2018;32(9):1175-88.**
28. Rodda J, Graham HK. Classification of gait patterns in spastic hemiplegia and spastic diplegia: a basis for a management algorithm. Eur J Neurol. 2001;8 Suppl 5:98-108.
29. Harlaar J, Brehm M, Becher JG, Bregman DJ, Buurke J, Holtkamp F, et al. Studies examining the efficacy of ankle foot orthoses should report activity level and mechanical evidence. Prosthet Orthot Int. 2010;34(3):327-35.
30. Ridgewell E, Dobson F, Bach T, Baker R. A systematic review to determine best practice reporting guidelines for AFO interventions in studies involving children with cerebral palsy. Prosthet Orthot Int. 2010;34(2):129-45.

5 ARTIGO 2

Artigo original formatado de acordo com as normas do periódico Developmental Neurorehabilitation Journal.

Fator de Impacto: 1,707 Qualis: A1.

Title:

The reliability and validity of the multiple joint pattern consensus of gait classifications in children with cerebral palsy.

Authors

Alessandro G. Melanda[ab], Ana C. Pauleto [b], Alexandre R M Pelegrinelli[c], Alana EK Ferreira[b], Dirce Shizuko Fujisawa[a], Suhaila Mahmoud Smaili[a]

[a]Program of Master and Doctoral degree in Rehabilitation Sciences, Londrina State University (UEL) – Health Sciences Center - Av. Robert Koch, 60 – Operária - 86038-440, Londrina - Paraná State – Brazil.
[b]Gait Analysis Laboratory - Hospital Rehabilitation Center- Ana Carolina Moura Xavier. Rua Quintino Bocaiuva, 329 – Cabral – 80.350-090 – Curitiba – Parana State – Brazil.
[c]State University of Londrina – Physical Education and Sports Center - Applied Biomechanics Laboratory – LBA. Rodovia Celso Garcia Cid, PR-445, Km 380 - Campus Universitário, 86044-766. Londrina - Paraná State – Brazil.

Corresponding Author:
Alessandro G. Melanda
State University of Londrina – Brazil.
Instituto Pro-Kids.
Av. Adhemar Pereira de Barros, 1199.
Bela Suiça, Londrina – Paraná – Brazil.
Zip Code: 86047-250.
melanda@uel.br

Abstract

Purpose: Evaluate the reliability and validity of a gait classification of multiple joint patterns consensus from systematic literature review multiple performed by Papageorgiou et. al. in 2019.

Methods: One hundred and thirty children with CP (61 girls; 69 boys); median age was 12 [10-15] years. Participants were classified using the classification of Papageorgiou et al. through three-dimensional gait analysis. The GMFCS, velocity, cadence, stride length and GPS were determined to characterize the groups of the gait classification. The comparison between the groups was performed using Kruskal-Wallis test, according to the normality of the data. The significance level adopted was 5%. The reliability of the classification was determined using weighted Kappa for inter and intrarater, with 95% confidence interval (CI).

Results: All classification groups were represented in the evaluated sample. 95.4% of the participants in the sample were classified. The six children (4.61%) not classified all had a homogeneous pattern. The classification showed superposition of the kinematic characteristics between close groups. Interrater reliability was 0.803 (0.652-0.953) and intrarater was 0.795 (0.583-1.007) and 0.531 (0.327-0.735).

Conclusions: The present study aims to provide a first insight of the aforementioned consensus-based GCS in children with CP. The proposed classification system is possible to be used in patients with unilateral and bilateral involvement and classified 95.4% of the participants in the sample. The reliability was almost perfect interrater with moderate and substantial intrarater. Consequently, the proposed classification has validity and important clinical utility to classify the sagittal plane of children with CP.

Keywords: Cerebral palsy, Gait, Classifications, Children.

1. Introduction

Accurate gait classification of Cerebral Palsy (CP) can be challenging because of its heterogeneous presentations[1]. The motor symptoms associated with CP including spasticity, weakness, impaired balance, and loss of selective motor control affect the child's ability to walk. Because of these different motor symptoms, the variability with which CP affects gait is considerable[2].

Functionally, approximately 60% of patients with CP are able to walk independently, 10% use a mobility device, and 30% have limited or no walking ability[3].

Gait Classification System (GCSs) have been reported to aid in clinical decision making, in improving communication among healthcare providers and in comparing gait between or within specific patients. The GCSs may include the description of deviations occurring in a single or multiple joint pattern simultaneously, the latter category being preferable for the known interrelation of the joints of the lower limbs during ambulation[4].

The method in which one classification is constructed was coded as either qualitative or quantitative. Qualitative construction methods included those where decisions to group members relied on the judgment and experience of those making the decisions[5-7]. A potential advantage of qualitative methods is to be more meaningful in terms of clinical diagnosis and treatment planning. When quantitative methods for classification construction were used, the majority of the studies used a variation of cluster analysis[8]. The limitations of cluster analysis include that the process may uncover groups that have no clinical relevance or meaning[9].

However, both classification processes did not produce a classification capable to cluster the universe of gait possibilities of CP patients as well as being clinically useful. This statement is confirmed by observing the studies of Dobson et al. [10] and McDowell et al.[11] They found 12% and 42% of children with hemiplegia as not classifiable according to the Winters[5] criteria, respectively. In diplegia patients Walsh et al.[12] who applied the GCS of Rodda et al.[7] where 3 patients in 20 could not be classified and de Morais-Filho, who could not classify 13% of their patients (n=228)[13] when using the GCS of Sutherland and Davids[6]. More recently, in a reliability study of a GCS where 4.7% of all gait trials could not be classified according to the rules suggested by Nieuwenhuys et al.[14]. An additional challenge for gait classification in children with CP is that often the observed joint motions do not match perfectly with a set of predefined joint motion patterns, and some kind of accommodation ends up being accepted to set a pattern.

Using a literature review, Papageorgiou et al. in 2019, revealed that six multiple joint patterns displayed a relevant consensus [4]. The six multiple joint patterns were derived from classifications built using qualitative methods[5-7]. Another important factor of the new classification is the fact that it presents existing patterns in patients with unilateral and bilateral neurological involvement. Thus, the clinical applicability of this classification needs to be tested to determine whether the described elements produce a greater ability to classify children with CP.

According to the authors knowledge, the present study is the first to classify a sample of CP patients using the six multiple joint patterns consensus published by Papageorgiou, 2019[4]. Thus, the purpose of this study was to test the consensus[4] to classify a sample of CP patients. The study focused on exploring whether these six commonly used multiple joint patterns cover all potential patterns in children with spastic CP and the reliability of this classification. The secondary objective was to characterize each pattern based on age, Gross Motor Function Classification System (GMFCS)[15], Gait Profile Score (GPS)[16] and spatiotemporal data parameters (velocity, cadence and stride length).

2. Methods

2.1 Design

A retrospective cross-sectional and reliability study was conducted using the database from Gait Analysis Laboratory of the Ana Carolina de Moura Xavier Rehabilitation Hospital Center in Curitiba, Paraná, Brazil. The project was approved for a local research ethics committee under opinion 2.447.001 The study was developed by an estimated sample of 115 individuals considering the prevalence of 0.3% [3] and maximum standard error of 1%. The search conducted to the database between 2010 and 2017, provided a sample of 130 children who had undergone gait analysis with a diagnosis of spastic cerebral palsy.

The study was performed in two stages. The first was a utility study classifying gait patterns in children with CP using the consensus of the gait classifications for children with CP proposed by Papageorgiou et al. [4]. The second stage was to investigate the intra and inter-observer reliability of the classification.

2.2 Participants

Eligible participants were between 5 years old and 18 years old, classified in GMFCS levels I to IV, predominantly spastic CP. Previous treatments such as single event multilevel surgery or botulinum toxin type A injections were allowed.

All participants underwent a three-dimensional gait analysis under barefoot (BF) walking conditions with self-select speed, during a single visit to the gait analysis laboratory. They have received no benefits.

2.3 Cross-sectional study

The sample group comprised of 130 patients who fulfilled the study criteria, and were classified according to the Papageorgiou et al**.**, by one rater with wide clinical experience in gait analysis. After classifying the sample, the groups formed were compared in terms of age, gait velocity, cadence, stride length and GPS.

2.4 Reliability study

A learning phase was proposed, in which all raters attended and participated in an online presentation, to discuss the classification of, and to present examples that illustrated how to classify cases using Papageorgiou et al**.** classification. The raters were provided with written definitions and illustrations of the posture of the ankle, knee, hip and pelvis for each gait pattern in relation to the planes of motion ((supplementary material).

To determine interrater reliability, 25 participants (50 lower limbs), from the total sample, were selected to create a sample that included variation in age and levels of neurological involvement (GMFCS). Two raters, with more than 3 years of experience in gait analysis, classified the sample. To determine intrarater reliability one rater evaluated the 25 participants (50 lower limbs) a second time, one month after the initial assessment. The order of the 25 participants was randomly changed between the 2 viewing sessions.

2.5 Measurements

The GMFCS was assigned by a senior clinical physiotherapist and a pediatric orthopedist in consultation with the child and his or her parents.

Each participant's gait was recorded on video, using sagittal and coronal views. Instrumented 3DGA was performed using the conventional gait model (Helen-Hayes model)[17], with reflective markers (n =26), to obtain spatiotemporal parameters (step and stride lengths, cadence, walking velocity) and lower extremity kinematics at the pelvis, hip, knee, and ankle. The trajectory of the markers within the lab space was captured through an electronic optical system consisting of six digital motion analysis cameras (Motion Analysis Corporation in Santa Rosa, CA) sampling at 60 Hz. Joint kinematics were calculated by the Cortex software (Motion Analysis Corp., Santa Rosa, CA). The data was processed using OrthoTrack software (OrthoTrack 6.5.1 software, Reference Manual 2007. Motion Analysis Corporation, Santa Rosa, CA). The data were smoothed using a Butterworth filter with a cut-off frequency of 6 Hz. The motion analysis system was calibrated before each analysis. All kinematic data were time-normalized to 100 % of one gait cycle.

3DGA kinematics were used to calculate the GPS, which quantifies the overall deviation of an individual's gait from normal gait[18].

The kinematic data were collected from a minimum of 7 gait cycles for each assessed leg and the most representative trial was reported, alongside the corresponding video clips, and classified according to the six multiple joint patterns consensus[4] (Table 1).

Children who presented an asymmetrical pattern, that is to say, classification on one lower limb side which differed from the other, were classified as asymmetrical group. Children with kinematics of the lower limbs close to normal, were classified as without abnormalities group. Children that presented abnormal kinematic of the lower limbs but did not fit in any classification group, were classified as being in the, not classified group.

2.6 Statistical Analysis

Descriptive data were presented as medians and interquartile ranges, according to the non-normality distribution, analyzed using the Shapiro-Wilk test. Levene test was used to verify the homogeneity of variances. For the comparison between groups was used the Kruskal-Wallis test using Mann-Whitney´s post hoc test. The statistical significance was $P < 0.05$.

The reliability of the classification was determined by weighted Kappa (k) statistics for inter and intrarater, with 95% confidence interval (CI). The strength of k was interpreted as: equal to zero, "without agreement"; between zero and 0.19, "poor agreement"; from 0.20 to 0.39, "weak agreement"; from 0.40 to 0.59, "moderate agreement”; from 0.60 to 0.79, "substantial agreement"; from 0.80 to 1.00, “almost perfect agreement” [19].

The analyses were performed in IBM SPSS Statistics for Mac, version 27.0 (IBM Corp., Armonk, N.Y., USA).

3. Results

The sample consisted of 130 children with spastic CP, 69 (53.1%) being male and 61 (46.9%) female, of which 114 had been diagnosed with bilateral and 16 with unilateral CP, whose median age was 12 [10-15] years.

The classification of the participants according Papageorgiou et al. resulted in the following distribution among groups: genu recurvatum 10 (7.7%); drop foot 18 (13.9%); true equinus 4 (3.1%); jump gait 18 (13.9%); apparent equinus 9 (6.9%); crouch gait 27 (20.8%); 7 without abnormalities by classification (5.4%); 6 not classified (4.6%); 31 asymmetrical (23.9%). Thus, 95.4% of the sample was classified with 4.6% presenting abnormalities in gait that cannot be classified in one of the classification groups. Considering the distribution of participants according to the GMFCS classification, most participants were included in the GMFCS II (82), followed by the GMFCS III (24), GMFCS I (20) and GMFCS IV (4).

Note that the most common gait pattern seen in participants classified in GMFCS I was drop foot (40,0%). In GMFCS II, the most frequent group was asymmetrical (29.3%). The group most observable in GMFCS III was crouch gait (37.5%). In GMFCS IV, three patients had crouch pattern (75%), and one patient who was classified as asymmetrical, also had one lower limb in crouch, as well.

The summarized sagittal plane kinematic data for the study population is shown in the Figure 1. Across the gait patterns, from genu recurvatum to crouch gait, there were changes between the anatomical levels. At the ankle, there was a change from normal dorsiflexion to equinus and then to excessive dorsiflexion. At the knee, there was hyper extension, which was followed by increasing flexion. The hip and the pelvis, there are no visual changes between the patterns.

The groups showed no statistically significant difference in relation to age and cadence. Differences between groups were observed regarding speed, cadence, stride length and GPS as recorded in Table 2. Taking into account time-distance parameters, the groups without abnormalities, drop foot, true equinus and jump gait had faster and longer velocity and stride length than the crouch gait pattern participants.

The GPS of the participants in the jump gait, apparent equinus and crouch gait groups presented statistically significant differences in relation to the group without abnormalities ($p<0.001$). The GPS for the group without abnormalities by the classification had a median of 9.50 [8.39-11.70] (Table 2).

With regard to patients in the not classified group, a total of six children, all of them had the same pattern detected by 2D video and kinematics of the sagittal plane. As shown in Figure 2, the individuals presented trend to knee extension at some point during the stance phase, peak knee flexion delayed in swing phase and dorsiflexion close to normal or increased.

Concerning reliability study, the reliability interrater had almost perfect agreement and the reliability intrarater had moderate and substantial agreement, for rater one and two, respectively (Table 3).

4. Discussion

In recent systematic literature review of gait classifications in CP, Papageorgiou et al.[4], pointed six multiple joint patterns that reached a consensus in literature. Papageorgiou's classification[4] added the Rodda classification[7] into two sub types: "drop foot" and "genu recurvatum". The drop foot pattern was present in Winter's classification[5] for hemiplegics, while the genu recurvatum pattern was one of the sub types of Sutherland's classification[6] for diplegics. Thus, the Papageorgiou classification[4] has as its premise to classify patients with unilateral and bilateral involvement.

Pioneering the classification mentioned above in a patient sample of 130 children diagnosed with spastic CP with unilateral and bilateral involvement, it was found that six participants (4.61%), were not classified and seven (5.38%), showed no detectable abnormalities by classification. These values, although relevant, are lower than when other qualitative classifications were used in children with CP[10–13]. This is because the GCS categories fail to cover all possible gait deviations in children with CP. On the other hand, it has been argued that the gait of children with CP lies along a continuum[20]. Categorization in fixed patterns leads the evaluator to include within the categories, participants who do not fulfill all the requirements for this. This continuum of gait abnormalities can be seen in figure 1 by the overlap of the kinematic characteristics of the lower limb joints in some parts within the gait cycle.

Despite the difficulty in establishing a single classification for the varied gait changes in CP, 95.38% of the participants within the sample were classified. Another important contribution of the Papageorgiou's classification[4] system was the inclusion of this sample of patients with both unilateral and bilateral involvement. This is because the construction of the classification was elaborated using as a basis the gait classifications for both hemiplegic[5] and diplegic[7] children.

The gait patterns, from genu recurvatum to crouch gait, presented kinematics changes between the anatomical levels. At the ankle, there was a change from normal dorsiflexion to equinus and then to excessive dorsiflexion. At the knee, there was hyper extension, which was followed by increasing flexion. The results of this paper are similar to Rodda et al[7]. in relation to ankle and knee. Thus, the full biomechanical assessment is essential to evaluate and plan the individual treatment of the patients [21,22].

The statistical evaluation of the outcome variables (age, velocity, cadence, stride length and GPS), did not point to differences between the classification groups that could be considered clinically significant (Table 2). Although the comparison between the groups showed some statistically significant differences, it was not possible to determine an evolutionary trend of greater or lesser functional impairment with the classification under study and the groups formed.

It should be reported that patients classified as without abnormalities by the classification had a median GPS of 9.50 [8.39-11.70], and the value for children without disabilities is 5.3°[23]. This may be related to the fact that the Papageorgiou's classification[4] does not consider some data used to calculate the GPS index, as changes in the swing phase of the gait and in other motion planes. As described by Davids and Bagley[20], new classifications must take into account the coronal and transverse planes of movement, in addition to the sagittal.

Ounpuu et al.[24], mention an overlap of gait problems among patients in the various GMFCS levels, what was also observed in the present study (table 2). On the other hand, the present study in agreement with Rethlefsen et. al.[25] found an increase number of equinus posture in lower GMFCS levels and calcaneus posture with crouch gait in higher GMFCS levels. According to Rethlefsen et. al.[25] and studies of natural progression of gait in children with CP[24,26], there is a deterioration of gait function over time with great number of individuals with equinus in early in life and calcaneus gait with increasing age. The previous descriptions corroborate the idea of walking in CP children is a continuity, both due to the variability in presentation and the possibility of progression of musculoskeletal deformities. So fixed categorizations, while important, do not include these transition phases. Proof of this is that the present study detected a pattern in participants not classified by the consensus published by Papageorgiou et. al[4]. These individuals had dorsiflexion of the ankle close to normal or increased, knee extension at some point of the stance and peak knee flexion delayed in swing phase. The participants not classified have a different pattern from that observed in jump gait participants due to the lack of equinus during stance phase. They can also be differentiated from apparent equinus gait and crouch gait due to the knee extension that occurs at some point in the stance phase. Researchers should pay attention to this reported movement pattern, as it is possible that this is a transition between pattern or a new one.

The separation of children who walk in equinus during stance phase in two different patterns, true equinus an genu recurvatum, according to Papageorgiou et al. it is still debatable. This is because the prevalence of these groups may not be sufficient to consider different groups. In the present study, only four children were classified as being of the true equinus pattern, which keeps the debate open. The reliability of the gait classification was established using the weighted kappa statistic for both interrater and intrarater, which showed almost perfect and substantial to moderate agreement, respectively. The validity of this classification has been established by the ability to classify a patient sample and confidence on the technique of choice, sagittal kinematics.

In the future, classifications should assess changes in the coronal and transverse planes as contributing to the inability to maintain proper sagittal plane alignment. Initiatives that evaluate the swing phase of the gait and other movement plans remain desirable. The overlap in the kinematic characteristics within the groups revealed that the future classifications could be considered as a continuity rather than categorizing in a static way.

The current study had some limitations. Most participants evaluated were seeking orthopedic intervention to improve their ambulatory function, their gait problems may not reflect those of the general CP population. Some patients used walking aids during gait analysis testing, which could have impacted kinematic data and, therefore, prevalence of gait deviations such as excessive hip flexion. The influence of previous treatments was not considered in this analysis, since the main objective of the study was to evaluate the instrument's ability to classify the gait of a subject with CP.

5. Conclusion

The present study aims to provide a first insight of the aforementioned consensus-based GCS in children with CP. The proposed classification system is possible to be used in patients with unilateral and bilateral involvement and classified 95.4% of the participants in the sample. The reliability was almost perfect interrater and moderate to substantial intrarater. Consequently, the proposed classification has validity and important clinical utility to classify the sagittal plane of children with CP.

Author contribution statement

Alessandro G. Melanda (Conceptualization) (Methodology) (Validation) (Formal Analysis) (Investigation) (Data Curation) (Writing – Original Draft) (Writing – Review & Editing) (Visualization) (Supervision).

Ana C. Pauleto (Writing – Review & Editing) (Visualization).

Alexandre R M Pelegrinelli (Data Curation) ((Writing – Review & Editing) (Visualization).

Alana EK Ferreira (Writing – Review & Editing) (Visualization).

Dirce Shizuko Fujisawa (Conceptualization) (Visualization) (Supervision).

Suhaila Mahmoud Smaili (Conceptualization) (Formal Analysis) (Writing – Review & Editing) (Visualization) (Supervision).

All authors have read and approved the final manuscript.

Declaration of Competing Interest

All authors declare that they have no conflicting interests. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

Not applicable.

Supplementary material

Appendix A. Written description of the gait consensus classification for children with Cerebral Palsy.

Appendix B. Orientation of how to use the Classification System (PowerPoint presentation for the raters).

References

1. Nirav K. Pandya; Scott P. Kaiser. Cerebral Palsy. In: Martus JE, ed. *Orthopaedic: Knowledge Update - Pediatrics (5)*. 5° Edition. Rosemont, Il: AAOS; 2016:4422-4426. doi:2016947581

2. De Laet T, Papageorgiou E, Nieuwenhuys A, Desloovere K. Does expert knowledge improve automatic probabilistic classification of gait joint motion patterns in children with cerebral palsy? *PLoS One*. 2017;12(6):1-18. doi:10.1371/journal.pone.0178378

3. Christensen D, Van Naarden Braun K, Doernberg NS, et al. Prevalence of cerebral palsy, co-occurring autism spectrum disorders, and motor functioning - Autism and Developmental Disabilities Monitoring Network, USA, 2008. *Dev Med Child Neurol*. 2014;56(1):59-65. doi:10.1111/dmcn.12268

4. Papageorgiou E, Nieuwenhuys A, Vandekerckhove I, Campenhout A Van, Ortibus E, Desloovere K. Systematic review on gait classifications in children with cerebral palsy: an update. *Gait Posture*. 2019. doi:10.1016/j.gaitpost.2019.01.038

5. Winters TF, Gage JR, Hicks R. Gait patterns in spastic hemiplegia in children and young adults Patterns in Spastic and Young Hemiplegia Adults. *J Bone Jt Surg*. 1987;69:437-441. doi:10.1302/0301-620X.86B2.13878

6. Sutherland, DH; Davids J. Common Gait Abnormalities of the Knee in Cerebral Palsy. *Clin Orthop Relat Res*. 1993;march(288):139-147.

7. Rodda JM, Graham HK, Carson L, Galea MP, Wolfe R. Sagittal gait patterns in spastic diplegia. *J Bone Jt Surg*. 2004;86(2):251-258. doi:10.1302/0301-620X.86B2.13878

8. Kienast G, Bachmann D, Steinwender G, Zwick E-B, Saraph V. Determination of gait patterns in children with cerebral palsy using cluster analysis. *Gait Posture*. 1999;10(1):57. doi:10.1016/s0966-6362(99)90401-0

9. Dobson F, Morris ME, Baker R, Graham HK. Gait classification in children with cerebral palsy: A systematic review. *Gait Posture*. 2007;25(1):140-152. doi:10.1016/j.gaitpost.2006.01.003

10. Dobson F, Morris ME, Baker R, Wolfe R, Graham HK. Clinician agreement on gait pattern ratings in children with spastic hemiplegia. *Dev Med Child Neurol*. 2006;48(6):429-435.

11. McDowell BC, Kerr C, Kelly C, Salazar J, Cosgrove A. The validity of an existing gait classification system when applied to a representative population of children with hemiplegia. *Gait Posture*. 2008;28(3):442-447. doi:10.1016/j.gaitpost.2008.02.003

12. Walsh SJ, Nicol RO, Mackey AH, Stott NS, Atherton WG, Galley IJ. The Reliability and Validity of Assessment of Sagittal Plane Deviations in Children Who Have Spastic Diplegia. *Arch Phys Med Rehabil*. 2005;86(12):2337-2341.

doi:10.1016/j.apmr.2005.06.021

13. de Morais Filho MC, Kawamura CMC, Fernandes Lopes JA, et al. Most Frequent Gait Patterns in Diplegic Spastic Cerebral Palsy. *Acta Ortop Bras*. 2014;22(4):197-201. doi:10.1590/1413-78522014220400942

14. Nieuwenhuys A, Papageorgiou E, Molenaers G, Monari D, de Laet T, Desloovere K. Inter- and intrarater clinician agreement on joint motion patterns during gait in children with cerebral palsy. *Dev Med Child Neurol*. 2017;59(7):750-755. doi:10.1111/dmcn.13404

15. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol*. 1997;39(2):214-223. doi:10.1111/j.1469-8749.1997.tb07414.x

16. Baker R, Mcginley JL, Schwartz MH, et al. The Gait Profile Score and Movement Analysis Profile. *Gait Posture*. 2009;30:265–269. doi:10.1016/j.gaitpost.2009.05.020

17. Kadaba M, Ramakrishnan H WM. Measurement of lower extremity kinematics during level walking. *J Orthop Res*. 1990;08:383–392.

18. Baker R, McGinley JL, Schwartz MH, et al. The Gait Profile Score and Movement Analysis Profile. *Gait Posture*. 2009;30(3):265-269. doi:10.1016/j.gaitpost.2009.05.020

19. Landis, J R ; Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1):159-174.

20. Davids JR, Bagley AM. Identification of Common Gait Disruption Patterns in Children With Cerebral Palsy. *J Am Acad Orthop Surg*. 2014;22(12):782-790. doi:10.5435/JAAOS-22-12-782

21. Kerr Graham H, Selber P. Musculoskeletal aspects of cerebral palsy. *J Bone Jt Surg*. 2003;85(2):157-166. doi:10.1302/0301-620X.85B2.14066

22. Graham HK, Rosenbaum P, Paneth N, et al. Cerebral palsy. *Nat Rev Dis Prim*. 2016;2. doi:10.1038/nrdp.2015.82

23. Baker R, McGinley JL, Schwartz M, Thomason P, Rodda J, Graham HK. The minimal clinically important difference for the Gait Profile Score. *Gait Posture*. 2012;35(4):612-615. doi:10.1016/j.gaitpost.2011.12.008

24. Õunpuu S, Gorton G, Bagley A, et al. Variation in kinematic and spatiotemporal gait parameters by Gross Motor Function Classification System level in children and adolescents with cerebral palsy. *Dev Med Child Neurol*. 2015;57(10):955-962. doi:10.1111/dmcn.12766

25. Rethlefsen SA, Blumstein G, Kay RM, Dorey F, Wren TAL. Prevalence of specific gait abnormalities in children with cerebral palsy revisited: influence of age, prior surgery, and Gross Motor Function Classification System level. *Dev Med Child*

Neurol. 2017;59(1):79-88. doi:10.1111/dmcn.13205

26. Bell KJ, Ounpuu S, DeLuca PA, Romness MJ. Natural progression of gait in children with cerebral palsy. *J Pediatr Orthop*. 2002;22(5):677-682. doi:10.1097/01.BPO.0000023143.69745.A9

27. Papageorgiou E, Nieuwenhuys A, Vandekerckhove I, Campenhout A Van. Systematic review on gait classifications in children with cerebral palsy : An update. *Gait Posture*. 2019;69(November 2018):209-223. doi:10.1016/j.gaitpost.2019.01.038

Table 1. Definition of gait parameter of the Gait Classification System from the consensus of Papageorgiou et al.[4]

	Sagital Kinematics			
Gait Pattern	Pelvic tilt	Hip fx/Ext	Knee Fx/Ext	Ankle Df/Pf
Genu Recurvatum	Normal Anterior	Normal Flexed	Towards or in Hyperext.	Reduced dorsiflexion or plantarflexion
Drop Foot	Normal or Minor deviations	Normal or Minor deviations	Normal or Minor deviations	Plantarflexion during the swing phase
True Equinus	Normal Anterior	Normal	Normal	Plantarflexion
Jump Gait	Normal Anterior	Normal Flexed	Flexed	Plantarflexion
Apparent Equinus	Normal Anterior	Flexed	Flexed	Normal
Crouch Gait	Anterior Normal Posterior	Flexed	Flexed	Excessive dorsiflexion

Hip fx/Ext: hip flexion and extension; Knee Fx/Ext: knee flexion and extension; Ankle Df/Pf: ankle dorsiflexion and plantarflexion; Hyperext: hyperextension.

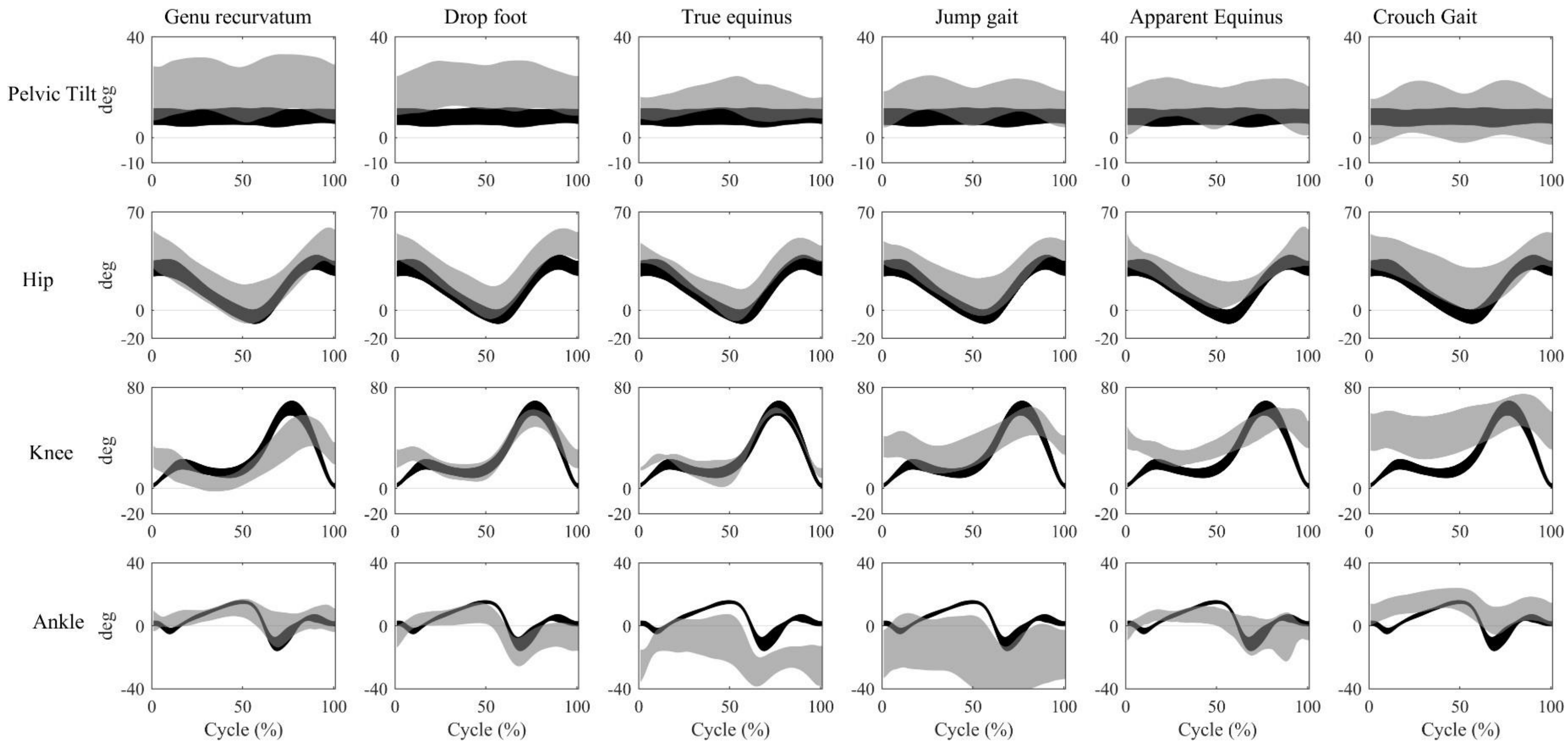


Figure 1. The summarized sagittal plane kinematic data for each gait pattern for the study population. The black band represented the mean ± 1 SD of kinematic data normal database, and the grey band the mean ± 1 SD for each gait pattern. The vertical axis represents joint angular displacement and the horizontal axis, 100% of the gait cycle.

Table 2. Median and interquartile range of the variables age, gait velocity, cadence, stride length and GPS in relation to 130 children according to gait pattern of the groups under investigation.

Gait pattern/ variables	Genu recurv n=10	Drop foot n=18	True equinus n=4	Jump gait n=18	Apparent Equinus n=9	Crouch gait n=27	Not class n=6	Without abnorm n=7	Asym. n=31	P
Age (years)	15.5 [11.5-17.0]	11.0 [8.5-13.0]	11.0 [8.0-12.5]	11.0 [9.0-13.0]	11.5 [7.0-16.0]	14.0 [12.0-16.0]	11.0 [8.2-14.0]	14.0 [11.0-15.0]	12.0 [9.0-15.0]	0.052
Velocity (cm/sec)	73.9 [25.1-110.5] [a]	94.9 [80.5-109.1] [e,f,g]	104.70 [89.9-108.2] [i]	90.0 [72.8-106.1] [l,m,o]	71.1 [18.7-81.7]	64.8 [41.1-81.5] [s]	77.4 [61.4-98.2]	90.0 [75.5-98.4] [u]	70.2 [58.5-88.6]	<0.001
Cadence (step/min)	109.3 [64.1-117.4] [b]	114.2 [105.7-126.0] [f]	118.8 [103.9-127.1]	124.7 [106.3-138.6] [l,m,o]	106.9 [48.2-121.7]	99.6 [80.0-116.1]	120.9 [87.5-131.2]	109.3 [94.1-126.3]	111.7 [99.4-119.0]	0.440
Stride Length (cm)	81.2 [56.9-107.2] [a]	100.4 [90.4-100.4] [e,f,g]	103.7 [99.5-108.0] [i]	89.2 [70.4-102.5] [m]	69.2 [45.0-86.7] [q]	74.0 [58.0-86.2] [s]	88.7 [77.3-95.9]	108.3 [91.0-113.7]	80.0 [65.7-98.1]	<0.001
GPS (°)	13.0 [12.2-14.6] [c]	12.7 [11.2-14.2] [d,f]	9.3 [8.6-11.1] [h,i,j]	18.3 [12.0-19.5] [n]	12.4 [11.5-15.6] [p]	16.4 [14.6-21.2] [r,s,t]	12.2 [11.2-14.9]	9.5 [8.3-11.7] [u]	14.3 [11.2-17.8]	<0.001

Cm: centimeters; cm/sec: centimeter per second; step/min: steps per minutes; genu recurv: genu recurvatum; without abnorm: without abnormalities; asym.: asymmetrical; (°): degrees; not class: not classified; without abnorm: without abnormalities.
a = statistically significant difference between genu recurvatum and drop foot.
b = statistically significant difference between genu recurvatum and jump gait.
c = statistically significant difference between genu recurvatum and crouch gait.
d= statistically significant difference between drop foot and jump gait.
e= statistically significant difference between drop foot and apparent equinus.
f= statistically significant difference between drop foot and crouch gait.
g= statistically significant difference between drop foot and asymmetrical.
h= statistically significant difference between true equinus and jump gait.
i= statistically significant difference between true equinus and crouch gait.
j= statistically significant difference between true equinus and assymetrical gait.

l= statistically significant difference between jump gait and apparent equinus.
m= statistically significant difference between jump gait and crouch gait.
n= statistically significant difference between jump gait and without abnorm.
o= statistically significant difference between jump gait and assymetrical gait
p= statistically significant difference between apparent equinus and crouch gait.
q= statistically significant difference between apparent equinus and without abnorm.
r= statistically significant difference between crouch gait and not class.
s= statistically significant difference between crouch gait and without abnorm.
t= statistically significant difference between crouch gait and assymetrical gait
u= statistically significant difference without abnorm. and assymetrical gait

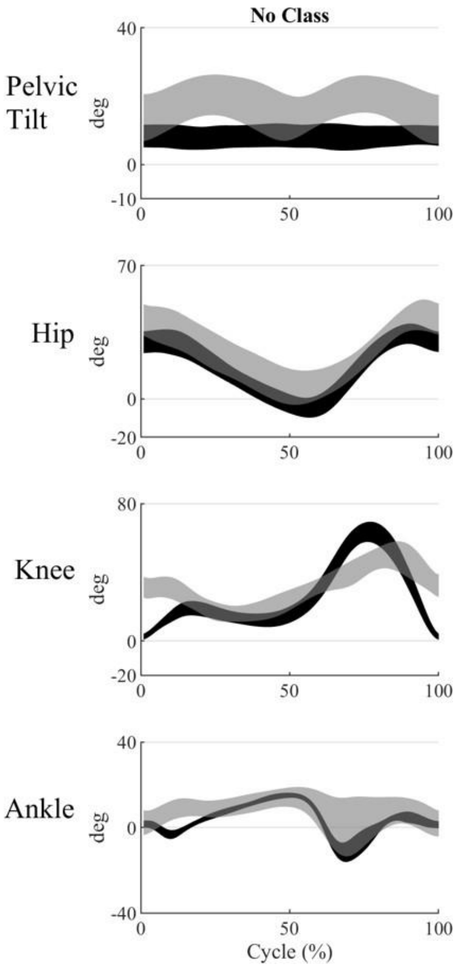


Figure 2. The summarized sagittal plane kinematic data for the limbs of the not classified participants. The black band represented the means ± 1 SD (Standard Deviation) of data normal database, and the grey band the mean ± SD for each =gait pattern. The vertical axis represents joint angular movement and the horizontal axis, 100% of the gait cycle. No class: not classified.

Table 3. Weighted Kappa (k) statistics with 95% CI for interrater and intrarrater reliability of the classification.

Interrater (n=50)	**k**	**SE**	**CI 95%**	**P**
Total	0.803	0.077	(0.652-0.953)	P<0.001
Intrarater (n=50)	**k**	**SE**	**CI 95%**	**P**
Rater 1	0.795	0.108	(0.583-1.007)	P<0.001
Rater 2	0.531	0.104	(0.327-0.735)	P<0.001

SE= Standard Error ; CI= Confidence Interval.

5.1. **Supplementary material** (Training material for raters).

Appendix A. Written description of the gait consensus classification for children with Cerebral Palsy.

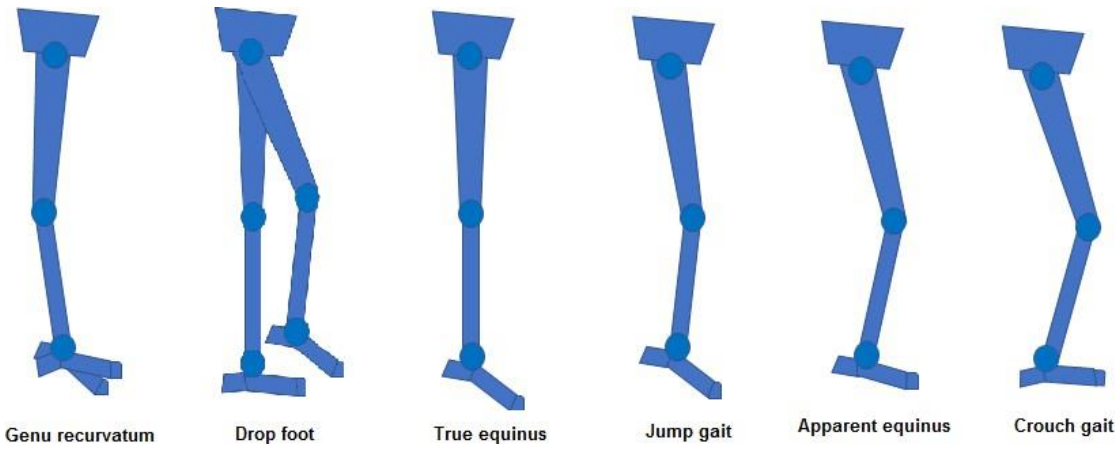


Figure A1. The six multiple joint patterns that displayed a relevant consensus[1].

Multiple joint patterns with consensus

The Gait Classifications Systems (GCS) were initially intended to be applicable to a specific population, either hemiplegic or diplegic CP children.

It was apparent that the multiple joint patterns where agreement was reached have been observed in both populations, further establishing their use in all ambulant children with CP. The literature review revealed that six multiple joint patterns displayed a relevant consensus (Figure A1)[1].

Four out of these six commonly used multiple joint patterns were described in the GCS established by Rodda et al.[2], who introduced the “true equinus” and “apparent equinus” patterns and extended two patterns originally introduced by Sutherland et al.[3].

The patterns “jump gait”, “apparent equinus” and “crouch” can mainly be differentiated from one another based on the position of the ankle joint[2].

Crouch gait is a pattern not just related of increased knee flexion during stance, knee motion on its own is not sufficient to distinguish crouch from other patterns.

Despite the variability in definitions of these 4 multiple joint patterns, the characteristics presented by Rodda et al. were considered as the most exhaustive ones, always including information about the co-occurring deviations across all lower limb joints (Table A1).

Apart from these 4 patterns established by Rodda et al.[2] the literature review also highlighted two additional patterns, namely “drop foot” and “genu recurvatum”.

The “drop foot” appear as a swing phase pattern, there is other gait features in stance (i.e. typical dorsiflexion), as well as minor deviations in other joints (i.e. increased knee flexion at initial contact, during loading response and terminal swing, increased hip flexion during swing and pelvic lordosis throughout the gait cycle).

The patterns “genu recurvatum” describes a knee motion towards or in hyperextension with reduced dorsiflexion and possibly but not necessarily-plantarflexion in the ankle.

Table A1. Definition of gait parameter of the Gait Classification System from the consensus of Papageorgiou et al.[1]

	Sagital Kinematics			
Gait Pattern	**Pelvic tilt**	**Hip fx/Ext**	**Knee Fx/Ext**	**Ankle Df/Pf**
Genu Recurvatum	Normal Anterior	Normal Flexed	Towards or in Hyperext.	Reduced dorsiflexion or plantarflexion
Drop Foot	Normal or Minor deviations	Normal or Minor deviations	Normal or Minor deviations	Plantarflexion during the swing phase
True Equinus	Normal Anterior	Normal	Normal	Plantarflexion
Jump Gait	Normal Anterior	Normal Flexed	Flexed	Plantarflexion
Apparent Equinus	Normal Anterior	Flexed	Flexed	Normal
Crouch Gait	Anterior Normal Posterior	Flexed	Flexed	Excessive dorsiflexion

Hip fx/Ext: hip flexion and extension; Knee Fx/Ext: knee flexion and extension; Ankle Df/Pf: ankle dorsiflexion and plantarflexion; Hyperext: hyperextension.

Genu recurvatum

Full knee Ext or hyperextension (HE) during stance, with almost typical hip motion during stance and impaired ankle motor control, resulting in plantarflexion (PF) or reduced dorsiflexion (DFL) (Figure A2).

Figure A2. Schematic drawing of the genu recurvatum gait pattern.

Drop foot

Drop foot during swing but adequate DFL range of motion (ROM), increased knee flexion (FL) at terminal swing (TSw), initial contac (IC) and loading response, hip hyperflexion (HFL) during swing and increased lordosis throughout the gait cycle (GC) (Figure A3).

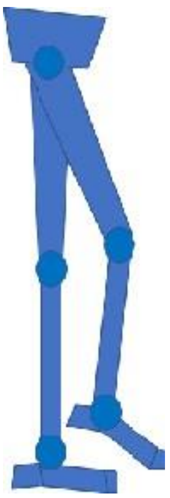


Figure A3. Schematic drawing of the drop foot gait pattern.

True equinus

Ankle in equinus during stance, full knee Ext, full hip Ext, pelvis within typical ROM or anterior tilt (Figure A4).

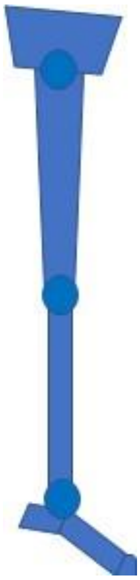


Figure A4. Schematic drawing of the true equinus gait pattern.

Jump gait

Ankle in equinus, particularly in late stance. Knee and hip in HFL in early stance, followed by Ext to a variable degree in late stance, pelvis within typical ROM or anterior tilt (Figure A5).

Figure A5. Schematic drawing of the jump gait pattern.

Apparent equinus

Ankle typical ROM, knee and hip in HFL throughout stance, pelvis within typical ROM or anterior tilt (Figure A6).

Figure A6. Schematic drawing of the apparent equinus gait pattern.

Crouch gait

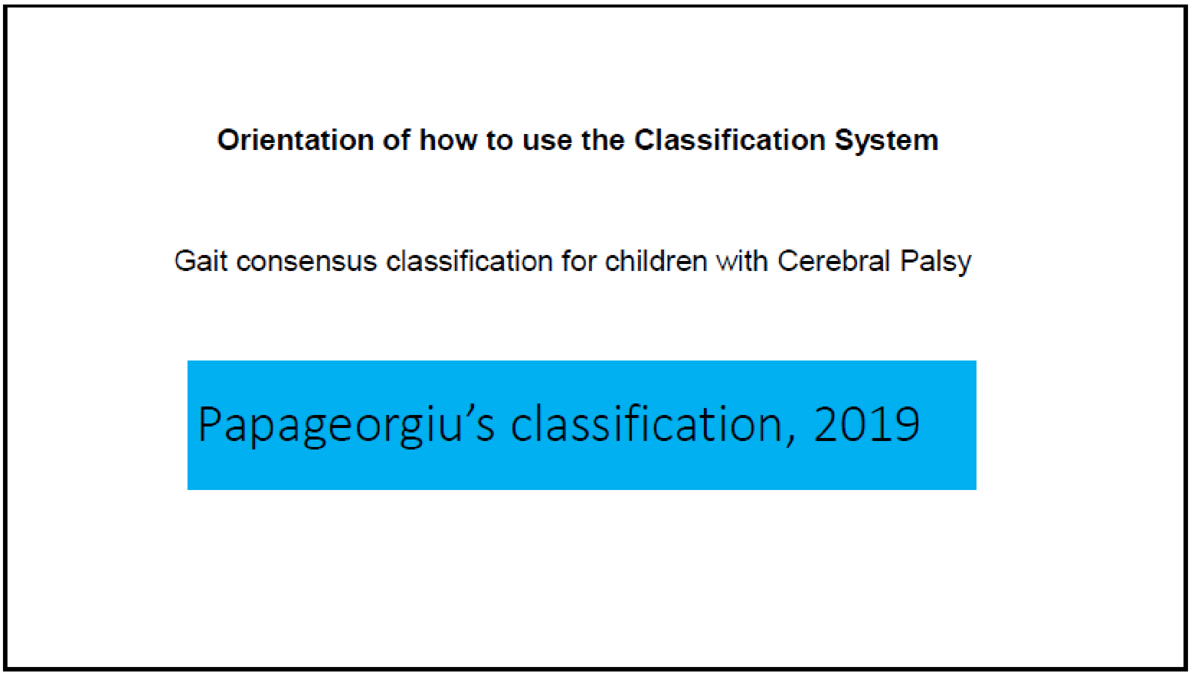
Ankle in excessive DFL throughout stance, knee and hip in HFL, pelvis in normal ROM, anterior or posterior tilt (Figure A7).

Figure A7. Schematic drawing of the crouch gait pattern.

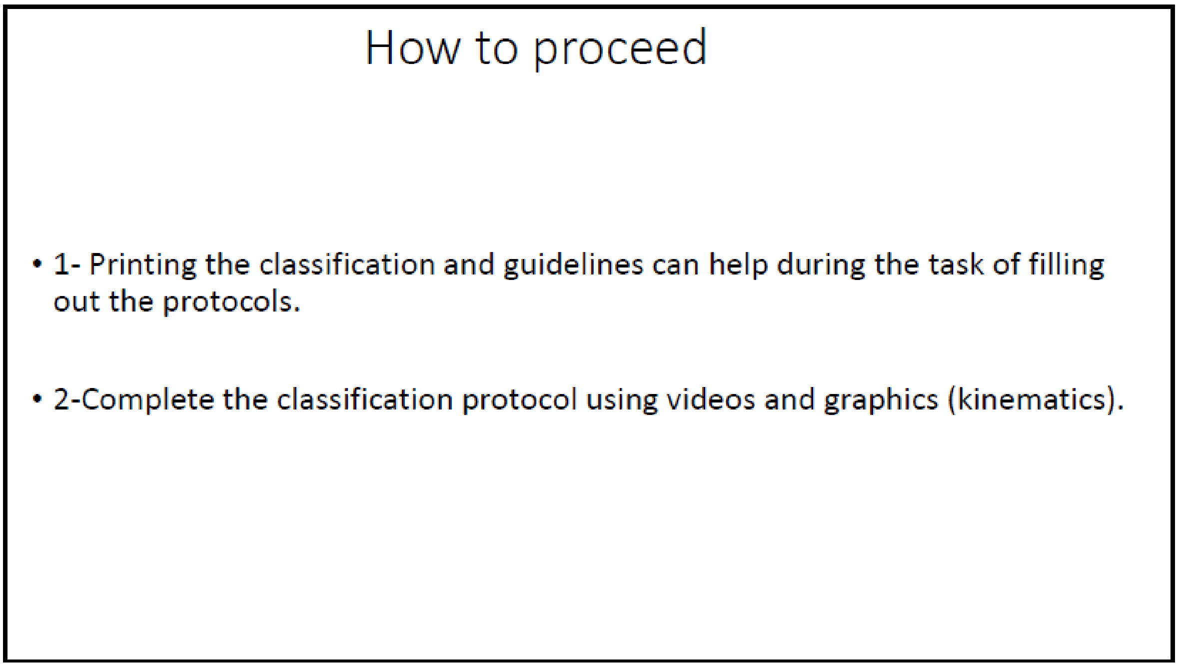
References

1. Papageorgiou E, Nieuwenhuys A, Vandekerckhove I, Campenhout A Van, Ortibus E, Desloovere K. Systematic review on gait classifications in children with cerebral palsy: an update. *Gait Posture*. 2019. doi:10.1016/j.gaitpost.2019.01.038
2. Rodda JM, Graham HK, Carson L, Galea MP, Wolfe R. Sagittal gait patterns in spastic diplegia. *J Bone Jt Surg*. 2004;86(2):251-258. doi:10.1302/0301-620X.86B2.13878
3. Sutherland, DH; Davids J. Common Gait Abnormalities of the Knee in Cerebral Palsy. *Clin Orthop Relat Res*. 1993;march(288):139-147.

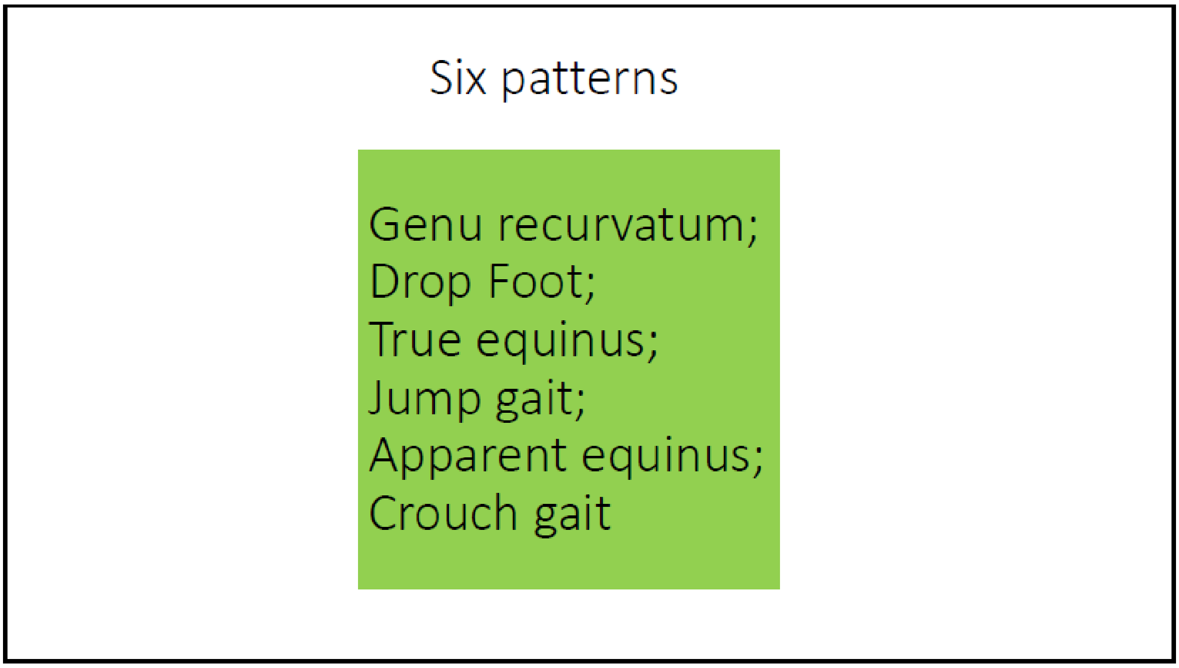
Appendix B. Orientation of how to use the classification system (PowerPoint presentation for the raters).



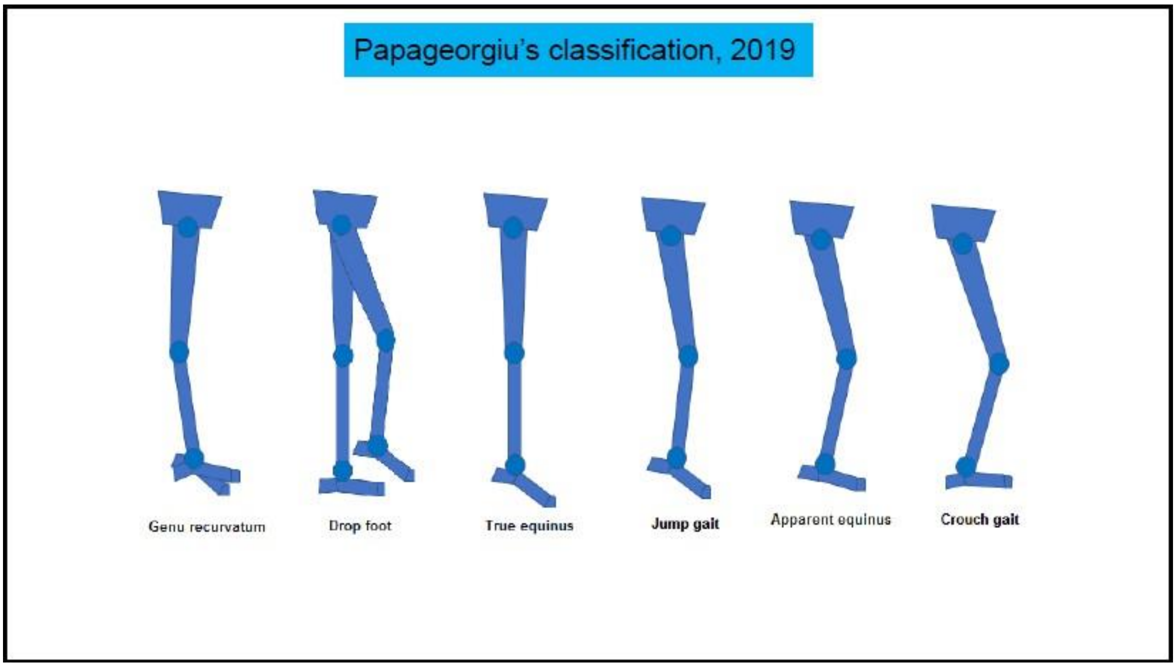
Slide B1. Orientation of how to use the classification system.



Slide B2. How to proceed to classify the sample of children.



Slide B3. Six gait patterns.

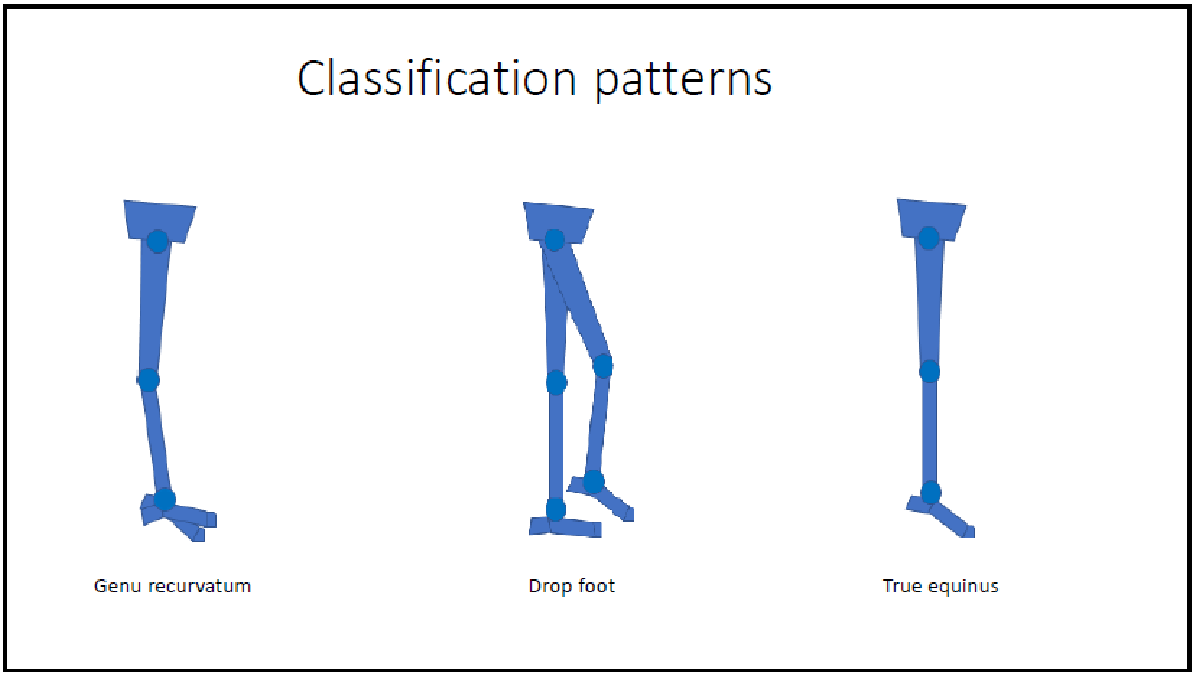


Slide B4. Schematic drawing of the gait patterns of the classification

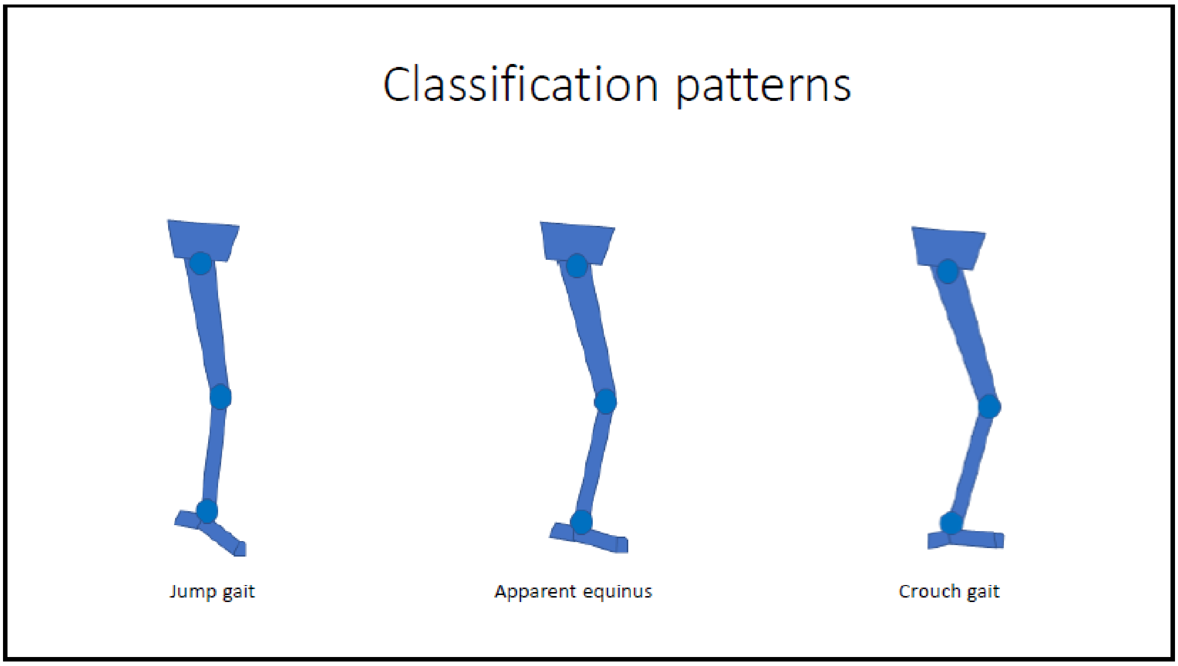
Papageorgiu's classification, 2019

	Sagital Kinematics			
Gait Pattern	Pelvic tilt	Hip fx/Ext	Knee Fx/Ext	Ankle Df/Pf
Genu Recurvatum	Normal Anterior	Normal Flexed	Towards or in Hyperext.	Reduced dorsiflexion or plantarflexion
Drop Foot	Normal or Minor deviations	Normal or Minor deviations	Normal or Minor deviations	Plantarflexion during the swing phase
True Equinus	Normal Anterior	Normal	Normal	Plantarflexion
Jump Gait	Normal Anterior	Normal Flexed	Flexed	Plantarflexion
Apparent Equinus	Normal Anterior	Flexed	Flexed	Normal
Crouch Gait	Anterior Normal Posterior	Flexed	Flexed	Excessive Dorsiflexion

Slide B5. Definitions of the gait patterns.



Slide B6. Schematic drawing of the gait patterns: genu recurvatum, drop foot and true equinus.



Slide B7. Schematic drawing of the gait patterns: jump gait, apparent equinus and crouch gait.

Excel spreadsheet protocol

participant	right side	left side
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		

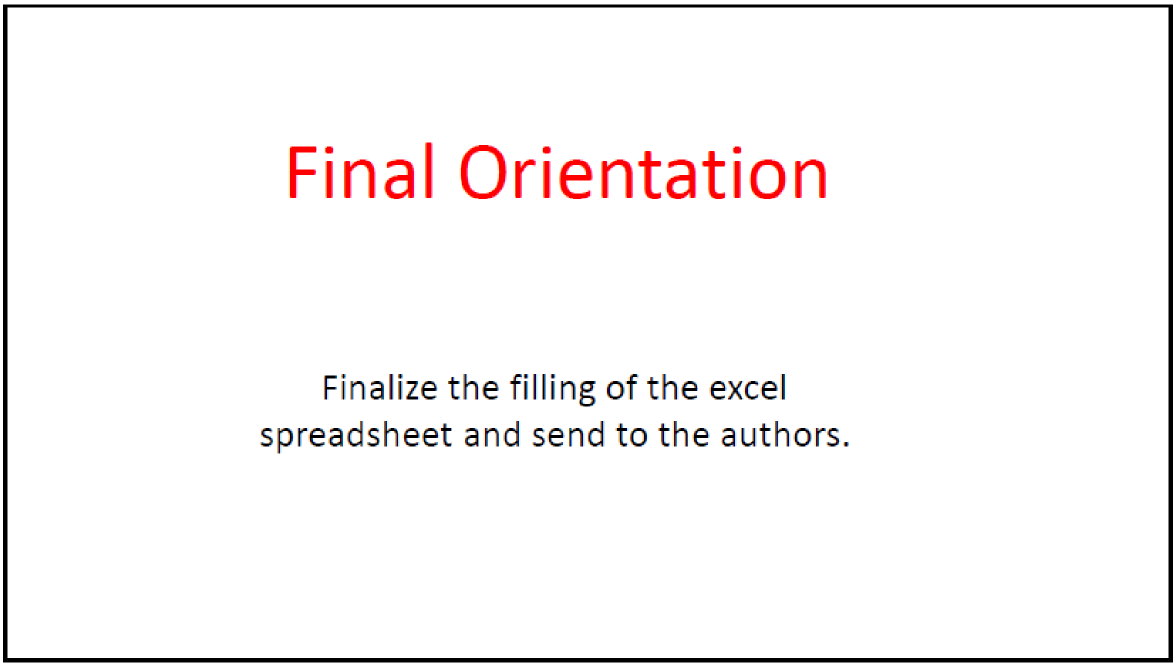
Use one of the options below to fill the protocol, for both the right and left side of each participant of the study.

Genu recurvatum;
Drop Foot;
True equinus;
Jump gait;
Apparent equinus;
Crouch gait.

Not rated;
Without abnormalities.

The authors named the participant as asymmetrical, when the evaluator classified the participant in different pattern the right and left sides.

Slide B8. Example of excel spreadsheet protocol.



Slide B9. Final guidance for evaluators.

6 ARTIGO 3

Artigo original formatado de acordo com as normas do periódico Journal of the American Academy of Orthopaedic Surgeons (JAAOS).

Fator de Impacto: 2.286

Title:

Reliability and validity of the Gait Disruption Classification System in Children with Cerebral Palsy (GDCS-CP).

Authors

Alessandro G. Melanda[ab], Jon R. Davids[c], Ana C. Pauleto[b], Alana EK Ferreira[b], Alexandre RM. Pelegrinelli[d], Luiz Alberto Knaut[b], Suhaila Mahmoud Smaili[a]

[a] Program of Master and Doctoral degree in Rehabilitation Sciences, Londrina State University (UEL) - Health Sciences Center - Av. Robert Koch, 60 – Operária - 86038-440, Londrina - Paraná State – Brazil.
[b] Gait Analysis Laboratory, Ana Carolina Moura Xavier Hospital Rehabilitation Center. Rua Quintino Bocaiuva, 329 – Cabral – 80.350-090 – Curitiba – Pr – Brazil.
[c] Shriners Hospitals for Children — Northern California.
2425 Stockton Blvd. Sacramento, CA 95817
[d] State University of Londrina – Physical Education and Sports Center - Applied Biomechanics Laboratory – LBA. Rodovia Celso Garcia Cid, PR-445, Km 380 - Campus Universitário, 86044-766. Londrina - Paraná State – Brazil.

Corresponding Author:
Alessandro G. Melanda
State University of Londrina – Brazil
Av. Adhemar Pereira de Barros, 1199.
Bela Suiça, Londrina – Paraná – Brazil
Zip Code: 86047-250.
melanda@uel.br

Abstract

Background: Gait classifications systems (GCS) may enable clinicians to differentiate gait patterns into clinically significant categories that assist in clinical decision-making and assessment of outcomes. In 2014, Davids and Bagley described a GCS for children with cerebral palsy (CP); the purpose of our study was to use it for the first time on a sample of patients with CP and to evaluate the reliability and utility of the classification system.

Methods: The gait of 131 children with CP was retrospectively reviewed and classified according to Davids and Bagley's 2014 classification, using 2D video and 3D lower limb kinematics and kinetics. GMFCS levels was determined and the GPS calculated to characterize the sample in relation to gait classification. The comparison between the groups was performed using the Kruskal-Wallis test, in accordance with the non-normal distribution of the data. The intrarater and interrater reliability of the classification was determined using the Kappa index (k) statistics with 95% CI.

Results: All GDCS-CP groups were represented within the evaluated sample. Of the 131 cases evaluated, 127 (96.95%) were able to be classified with respect to sagittal plane stance phase gait deviations. All patients in the sample were able to be classified with respect to sagittal plane swing phase and transverse plane gait deviations. The interrater reliability was 0.596 and 0.485, for the first and second levels of the classification, respectively, according to the Fleiss's Kappa statistics. Intrarater reliability was 0.776 and 0.714 for the raters one and two, respectively, according to the Cohen's Kappa statistics.

Significance: The GDCS-CP exhibited clinical utility, successfully classifying almost all of the subjects with CP, based upon kinematic and kinetic data. The classification is valid and has moderate interrater and moderate to substantial intrarater reliability.

Keywords: cerebral palsy, children, gait, gait analysis, classifications.

Level of Evidence: Level III diagnostic

1. Introduction

Spastic cerebral palsy (CP) is one of the most challenging disorders, because many different clinical variables play a role in the expression of this static brain injury[1]. The primary disorder in the brain is associated with abnormal muscle tone, most often hypertonia, accompanied by loss of selective voluntary motor control, muscle weakness, and impaired balance[2]. Hypertonia and the limited use of muscles due to developmental delay result in dynamic muscle–tendon contractures, which become static joint contractures over time as the tight muscles fail to grow in proportion to the long bones, which they traverse. The growing skeleton remodels in response to typical stresses associated with the motor milestones, which when delayed, or absent, result in retention of infantile morphology and development of secondary bone deformities and joint instability, which contribute to lever-arm dysfunction[3].

There is pronounced individual variety of movement patterns in ambulatory children with CP[1]. The abnormal gait is observed in a wide variety of patterns, depending on the severity of neurologic and motor impairments[4].

Three-dimensional gait analysis (3DGA) serves as a gold standard to objectively evaluate pathological gait in children with CP [5].

To support the clinical understanding of gait data, many attempts have been made to identify and classify gait deviation patterns from kinematic and kinetic data, using both qualitative and quantitative approaches [5].

As reviewed by Dobson et al., qualitative and quantitative strategies for gait classification construction can be distinguished [6]. Qualitative strategies are defined as methods which are experiential and intuitive, distinguish clinically relevant groups, but are frequently limited by their subjective nature and poor reliability [6,7]. Quantitative strategies, which are systematic and analytical, use varying methods of objective data reduction and classification techniques to preprocess 3DGA data, which unfortunately may have limited clinical utility [8],[9].

Using computerized three-dimensional (3D) motion analysis has made it possible to identify the similarities and differences within abnormal gait patterns that manifest in patients with CP[4]. Due to the large amount of information produced by movement laboratories using 3DGA, gait classification systems (GCS) have been developed for specific diseases, which simplifies interpretation and facilitates clinical decisions[9]. However, the current classifications of gait for CP have significant limitations, either in their ability to point out deviations in all planes of movement or in their reproducibility[6].

Utility of GCSs for individuals with CP is based upon: the classifications can be applied to the gait of patients with unilateral and bilateral involvement; they consider deviations in multiple levels and planes of movement; they include, where appropriate, kinetic and electromyography data; and take into account the use of assistive devices used by people with greater functional impairment and more complex movement disorders[10,11]. Thus, as with any clinical classification system, GCSs should be useful by facilitating communication among health professionals, assisting in therapeutic decisions and comparing results, treatments or natural history.

In 2019, Papageorgiou et al. carried out a systematic review of the literature on the subject of GSCs for children with CP, and determined that to assess the classifications, information related to validity, reproducibility and clinical applicability was necessary[12].

Among the GCSs evaluated by Papageorgiou et al., the one proposed by Davids and Bagley presented positive characteristics in its construction and significant clinical applicability[10,12]. However, it had not been tested on a sample of subjects with CP. Therefore, the purpose of this study was to validate the existing "Gait Disruption Classification System in Children with Cerebral Palsy (GDCS-CP)" as described by Davids and Bagley by evaluating its usefulness in a defined population of children with CP[10]. The study focused on exploring whether this classification covered all potential patterns in children with spastic CP, regardless of unilateral and bilateral involvement. The secondary objective was to evaluate the intra and inter-observer reliability of the classification.

2. Methods

2.1. Study design

This study was conducted as a retrospective study after the project was approved by a local research ethics committee under opinion 2.447.001. The study was developed by an estimated sample of 115 individuals considering the prevalence of 0.3% [3] and maximum standard error of 1%. The search conducted from the database of the Gait Analysis Laboratory at the Ana Carolina de Moura Xavier Rehabilitation Hospital Center in Curitiba, Paraná, Brazil, provided a sample of 131 children who had undergone gait analysis with a diagnosis of spastic cerebral palsy. Written informed consent was obtained from all participants.

The study was performed in two stages. The first was a cross-sectional study classifying gait patterns in children with CP using the GDCS-CP. The second stage was to investigate the intra and inter-observer reliability of the classification[10].

2.2. Participants

Eligible participants were between five and nineteen years old, classified as GMFCS levels I to IV, and predominantly had spastic CP. Previous treatments such as single event multilevel surgery or botulinum toxin type A injections were acceptable within the sample.

All participants underwent a 3DGA under barefoot (BF) walking conditions at a self-selected speed, during a single visit to the gait analysis laboratory. They received no remuneration for participation.

2.3. Cross-sectional study

The sample group comprised of 131 patients who fulfilled the study criteria and were classified according to the GDCS-CP [10], by one rater with wide clinical experience in gait analysis. After classifying the sample, the groups formed were compared in terms of age, GPS and gait velocity.

2.4. Reliability study

A training program was developed, in which all raters attended and participated in an online presentation, to discuss the classification's structure, and to present examples that illustrated how to classify cases using the GDCS-CP. The raters were provided with written definitions and illustrations of the posture of the ankle, knee, hip and pelvis for each gait pattern in relation to the planes of motion (supplementary material). Each rater was supplied with a package that included a pen drive, standardized information which included definitions of the classification categories, as well as videos and 3DGA data from the participants included in the study.

To determine interrater reliability, 60 participants diagnosed with ambulatory CP who had had 3DGA were evaluated by four raters, two pediatric orthopedic surgeons and two physiotherapists who all had experience in gait analysis. To determine intrarater reliability two of the evaluators (randomly selected) evaluated 30 participants from the group that would later be assessed a second time, a month after the initial assessment. The cases with their 3DGA and corresponding videos were selected to create a sample that included variation in age and levels of motor impairment (as reflected by the GMFCS).

Intra and interrater reliability were calculated for the first and second levels of the GDCS-CP.

2.5. Measurements

Each participant's gait was recorded on video, using sagittal and coronal views. Instrumented 3DGA was performed using the conventional gait model (Helen-Hayes model)[13], with reflective markers (n =26), to obtain spatiotemporal parameters (step and stride lengths, cadence, walking velocity) and lower extremity kinematics and kinetics at the pelvis, hip, knee, and ankle. 3D kinematic and kinetic gait data were collected bilaterally using 6 digital motion analysis cameras (Motion Analysis Corporation in Santa Rosa, CA) sampling at 60 Hz, alongside two force plates (AMTI Biomechanics Force Plate OR6-7 2000 - Watertown, MA, USA) sampling at 1000 Hz. Joint kinematics and external movements were calculated by the Cortex software (Motion Analysis Corp., Santa Rosa, CA). The data was processed using OrthoTrack software (OrthoTrack 6.5.1 software, Reference Manual 2007. Motion Analysis Corporation, Santa Rosa, CA). The data were smoothed using a Butterworth filter with a cut-off frequency of 6 Hz. The motion analysis system was calibrated before each analysis. All kinematic and kinetic data were time-normalized to 100 % of one gait cycle.

3DGA kinematics were used to calculate the GPS, which quantifies the overall deviation of an individual's gait from normal gait[14]

The kinematic and kinetic data were collected from a minimum of 7 gait cycles for each assessed leg and the most representative trial was reported, alongside the corresponding video clips, and classified according to the GDCS-CP[10]. Kinetic data was not collected for participants who used walking aids, typically GMFCS III and IV. Children who presented an asymmetrical gait pattern, which resulted in classification on one lower limb side which differed from the other, were excluded from the analysis of GPS.

The GMFCS was assigned by a senior clinical physiotherapist and a pediatric orthopedist in consultation with the child and his or her parents.

2.5.1 Description of the gait classification categories.

The gait parameters of the GDCS-CP, for the sagittal plane in stance and swing phases, and the transverse plane, are summarized in Table 1. For the sagittal plane stance phase, the first level of distinction is between normal, jump, and crouch gait (based upon kinematic data). Jump gait is then subdivided into the second level as either true equinus or apparent equinus (based upon kinematic data). Crouch gait is subdivided into compensated and uncompensated patterns; in the former, the internal knee extensor moment is normal, while in the latter there is increased internal knee extensor moment throughout the stance phase (based upon the kinetic data). For the sagittal plane swing phase, the first level of distinction is between normal gait and stiff gait (based upon kinematic data). The stiff gait is subdivided into knee source and hip source. Stiff gait-knee source had a fast flexion of the hip during the transition from stance to swing phase, unlike hip source that had a slow slope of the hip flexion during the transition phases. The transverse plane is classified in a hierarchical manner, with the first level of distinction including internal, external, and neutral foot progression patterns (based upon the kinematic data). Both internal and external progression patterns are subdivided into single-level and multilevel patterns. The neutral progression pattern is characterized by a neutral foot-progression angle (i.e., orientation of the long axis of the foot that is comparable to the line of progression of gait) and subdivided into normal and offset patterns, with the latter due to internal rotation of the hip compensated for by increased external tibial torsion[10].

2.6. Statistical Analysis

Descriptive data was presented as means and standard deviations or as medians and interquartile ranges, according to normal distribution, and analyzed using the Shapiro-Wilk test. The Levene test was used to verify the homogeneity of variances. The comparison between the groups was performed using the Kruskal-Wallis test and Mann-Whitney´s post hoc test, in accordance with the non-normal distribution of the data. The level of significance was set at $p < 0.05$.

The reliability of the classification was determined using Kappa index statistics with 95% CI, used to describe intra and inter-observer agreement with the following reference values: equal to zero, “without agreement”; between zero and 0.19, “poor agreement”; from 0.20 to 0.39, “weak agreement”; from 0.40 to 0.59, “moderate agreement”; from 0.60 to 0.79, "substantial agreement"; from 0.80 to 1.00, “almost perfect agreement”[15]. Fleiss’s Kappa was used for interrater reliability and Cohen’s Kappa for intrarater.

The analyses were performed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, N.Y., USA).

3. Results

3.1 Cross-sectional study study

The sample consisted of 131 subjects with spastic CP, 70 being male (53.43%) and 61 being female (45.56%); 116 with bilateral and 15 with unilateral CP. The median age was 12 [10-15] years. Considering the distribution of participants according to the GMFCS classification,, most participants were included in the GMFCS II - 83, followed by the GMFCS III - 24, GMFCS I - 20 and GMFCS IV - 4. Participants at GMFCS III, 12 used walkers, 9 used crutches and 2 used canes.

There were no statistically significant age differences between the classification groups (Table 2). The GPS showed differences between the normal group and the other groups in the sagittal stance phase. The GPS in the transverse plane was different between neutral normal and neutral off-settings, as well as between neutral normal and external multilevel. The normal group exhibited the lowest GPS values in both situations, 10.8° [9.09 - 12.15], and 11.8° [10.04-13.88].

All the groups within the classification were represented in the evaluated sample. Of the 131 cases evaluated, 127 (96.95%) were able to be classified according to the GDCS-CP proposed for the stance phase of the sagittal plane. All patients in the sample were able to be classified according to the GDCS-CP proposed for both the swing phase of the sagittal plane and the transverse plane.

Across the gait patterns, from the true equinus to crouch gait, there were changes between the anatomical levels from equinus to excessive dorsiflexion of the ankle and increase of knee flexion from apparent equinus to crouch gait (Figure 1). In the non-compensated crouch pattern, there was an increase in the knee extensor moment in the stance phase.

The stiff gait presented a delayed and diminished peak knee flexion in the swing phase (Figure 1). The stiff gait hip source group manifested slower overall gait velocity than the normal and stiff gait/knee source (p=0.015) (Table 2).

The internal, external and neutral positions are clearly illustrated by the angle of progression of the foot as observed in Figure 2. On the other hand, there was an overlap between the subdivisions single and multi-level of the internal and external, as well as neutral normal and offset positions (Figure 2).

3.2 Reliability

The overall interrater reliability of the four raters for the first level of the GDCS-CP was 0.596 (0.562-0.631) and 0.485 (0.461-0.509) for the second level of the classification according to the Fleiss's Kappa statistics. The interrater reliability for each plane of the first and second levels of the classification are presented in Table 3.

Intrarater reliability of the first level of the classification was 0.888 (0.827-0.949) and 0.791 (0.709-0.873) for raters 1 and 2, respectively, according to the Cohen's Kappa statistics. Intrarater reliability of the second level of the classification was 0.776 (0.706-0.846) and 0.714 (0.634-0.794) for raters 1 and 2, respectively, according to the Cohen's Kappa statistics. The Intrarater reliability for both raters, for each plane of the first and second levels of the classification, are presented in Table 4.

4. Discussion

The gait classifications for CP have shown limited ability to point out gait deviations in the various planes of movement. As a result, they have limited utility for clinical decision making, outcome assessment, and research[6].

This is the first study to evaluate the performance of the CDCG-CP. The GDCS-CP showed utility in successfully classifying a large sample of individuals with CP, based upon sagittal and transverse kinematics at the ankle, knee, hip and pelvis; and sagittal plane kinetics of the knee. Measurement validity, and clinical utility, consider the extent to which an instrument measures what it is intended to measure [16]; and the GDCS-CP showed an ability to classify the gait of children with CP more completely than previous qualitative classifications[17–19].

The present classification uses a progressive hierarchy of the motor dysfunction gait patterns seen in children with CP to classify observed problems, allocating the alterations in the stance and swing phase of the sagittal and transverse planes. As the GCDS-CP is more inclusive and specific, as it offers the rater a greater number of options to allocate the deviations observed in an individual with CP, content validity was examined to provide objective evidence for the existence of joint motion patterns in CP classified as problem and as normal. To assess the ability of the classification to differentiate gait problems from normality, GPS was used. The GPS showed a statistically significant difference, in the stance phase of the sagittal plane, between the subjects classified as normal in relation to all groups in the GCDS-CP. The GPS showed no difference in the swing phase GCDS-CP groups, probably because these groups consisted of individuals with categorization of problems at a single anatomic level (the knee) during a relatively small portion of the gait cycle. However, the overall gait velocity of patients in the stiff gait/hip source group was slower and statistically different from the stiff gait/knee source, and the normal group, in the swing phase.

The classification did not consider the coronal plane because the authors of the classification[10] believe that true coronal plane gait disruption patterns in children with CP are less common and are generally of minimal magnitude and functional significance. According to Nieuwenhuys et al., there were no significant associations identified with any of the investigated variables in the coronal plane, leading these investigators to question their clinical relevance and the need to include them in gait classification schemes for children with CP[20].

Of the four unclassifiable participants, all had a jump gait pattern[21] at the knee, but increased ankle dorsiflexion in the stance phase. The pattern was named "crump" by one of the authors (JRD), due to the mix of crouch and jump gait parameters, who has characterized it as a transitional pattern between jump and crouch gait, which occurs as the foot equino plano valgus segmental malalignment and instability progress, resulting in lever arm deficiency for the ankle plantar flexors.

The GDCS-CP exhibited moderate to substantial intrarater reliability. The interrater reliability was moderate, even when only the first level of the classification was assessed. The explanation for the moderate interrater reliability of the GDCS-CP can be related to lack of sharp demarcations between the various patterns. This can be seen in Figures 1 and 2, which show overlap between the movements of several joints with similar features. However, in many biomedical studies, reliability of greater than 40% ($k>0.40$), is considered to be a clinically useful method of measurement[22]. The transverse plane had the lowest reliability, and again the explanation seems to be clear when looking at Figure 2, which shows significant overlap between the curves of the neutral normal and offset, internal single and multilevel, as well as external single and multilevel, subgroups. In the future, improved gait pattern definitions and classification training materials may result in improved reliability metrics.

Some limitations should be considered. Most of the participants in the study were referred for gait analysis for preoperative evaluation to improve ambulatory function. The walking velocity was not controlled during gait testing. Therefore, some deviations, such as stiff knee gait, may have been related to slow walking speed. Some patients used assistive devices during gait analysis testing, which could have impacted kinematic and kinetic data collection.

5. Conclusion

The GDCS-CP provides a powerful methodology to categorize gait patterns in children with CP, using kinematic data for multiple joints from more than one plane of movement, and kinetic data from a single joint in a single plane. It appears to be applicable for subjects with unilateral and bilateral CP. The validity and utility of the classification, in this study, has been established by its ability to classify the sample of individuals with CP, through data from 3DGA. The classification shows that, even with limited learning, evaluators will be able to use it. However, a more quantitative delineation of the categories, and improved training materials, may be required to improve reliability among raters.

Author contribution statement

Alessandro G. Melanda (Conceptualization) (Methodology) (Validation) (Formal Analysis) (Investigation) (Data Curation) (Writing – Original Draft) (Writing – Review & Editing) (Visualization) (Supervision).
Jon R. Davids(Conceptualization) (Writing – Review & Editing) (Visualization)
Ana C. Pauleto (Writing – Review & Editing) (Visualization).
Alana EK Ferreira (Writing – Review & Editing) (Visualization).
Alexandre R M Pelegrinelli (Data Curation) (Writing – Review & Editing) (Visualization).
Luiz Alberto Knaut (Methodology) (Validation) (Formal Analysis) (Visualization)
Suhaila Mahmoud Smaili (Conceptualization) (Formal Analysis) (Writing – Review & Editing) (Visualization) (Supervision).

All authors have read and approved the final manuscript.

Declaration of Competing Interest

All authors declare that they have no conflicting interests. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

Not applicable.

Supplementary material

Appendix A. Written orientation for raters (definitions).

Appendix B. Orientation for the raters (how to use the files).

References

1. Riad J, Haglund-Akerlind Y, Miller F. Classification of spastic hemiplegic cerebral palsy in children. *J Pediatr Orthop*. 2007;27(7):758-764. doi:10.1097/BPO.0b013e3181558a15
2. Thomason P, Baker R, Dodd K, et al. Single-Event Multilevel Surgery in Children with Spastic Diplegia. *J Bone Jt Surgery-American Vol*. 2011;93(5):451-460. doi:10.2106/JBJS.J.00410
3. McGinley JL, Dobson F, Ganeshalingam R, Shore BJ, Rutz E, Graham HK. Single-event multilevel surgery for children with cerebral palsy: A systematic review. *Dev Med Child Neurol*. 2012;54(2):117-128. doi:10.1111/j.1469-8749.2011.04143.x
4. Kim DJ, Park ES, Sim EG, Kim KJ, Kim YU, Rha D. Reliability of Visual Classification of Sagittal Gait Patterns in Patients with Bilateral Spastic Cerebral Palsy. *Ann Rehabil Med*. 2011;35(3):354. doi:10.5535/arm.2011.35.3.354
5. Nieuwenhuys A, Papageorgiou E, Desloovere K, Molenaers G, De Laet T. Statistical parametric mapping to identify differences between consensus-based joint patterns during gait in children with cerebral palsy. *PLoS One*. 2017;12(1):1-22. doi:10.1371/journal.pone.0169834
6. Dobson F, Morris ME, Baker R, Graham HK. Gait classification in children with cerebral palsy: A systematic review. *Gait Posture*. 2007;25(1):140-152. doi:10.1016/j.gaitpost.2006.01.003
7. Rodda JM, Graham HK, Carson L, Galea MP, Wolfe R. Sagittal gait patterns in spastic diplegia. *J Bone Jt Surg*. 2004;86(2):251-258. doi:10.1302/0301-620X.86B2.13878
8. Croskerry P. <Croskerry A universal model for diagnostic reasoning.pdf>. *Acad Med*. 2009;84(8):1022-1028.
9. Van Gestel L, De Laet T, Di Lello E, et al. Probabilistic gait classification in children with cerebral palsy: A Bayesian approach. *Res Dev Disabil*. 2011;32(6):2542-2552. doi:10.1016/j.ridd.2011.07.004
10. Davids JR, Bagley AM. Identification of Common Gait Disruption Patterns in Children With Cerebral Palsy. *J Am Acad Orthop Surg*. 2014;22(12):782-790. doi:10.5435/JAAOS-22-12-782
11. Steele KM, Rozumalski A, Schwartz MH. Muscle synergies and complexity of

neuromuscular control during gait in cerebral palsy. *Dev Med Child Neurol*. 2015;57(12). doi:10.1111/dmcn.12826

12. Papageorgiou E, Nieuwenhuys A, Vandekerckhove I, Campenhout A Van, Ortibus E, Desloovere K. Systematic review on gait classifications in children with cerebral palsy: an update. *Gait Posture*. 2019. doi:10.1016/j.gaitpost.2019.01.038
13. Kadaba M, Ramakrishnan H WM. Measurement of lower extremity kinematics during level walking. *J Orthop Res*. 1990;08:383–392.
14. Baker R, McGinley JL, Schwartz MH, et al. The Gait Profile Score and Movement Analysis Profile. *Gait Posture*. 2009;30(3):265-269. doi:10.1016/j.gaitpost.2009.05.020
15. Landis, J R ; Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1):159-174.
16. Portney, L.G., Watkins MP. *Foundations of Clinical Research*. 3rd Editio. Philadelphia: F.A. Davis Company; 2015. 2014960189.
17. McDowell BC, Kerr C, Kelly C, Salazar J, Cosgrove A. The validity of an existing gait classification system when applied to a representative population of children with hemiplegia. *Gait Posture*. 2008;28(3):442-447. doi:10.1016/j.gaitpost.2008.02.003
18. de Morais Filho MC, Kawamura CMC, Fernandes Lopes JA, et al. Most Frequent Gait Patterns in Diplegic Spastic Cerebral Palsy. *Acta Ortop Bras*. 2014;22(4):197-201. doi:10.1590/1413-78522014220400942
19. Walsh SJ, Nicol RO, Mackey AH, Stott NS, Atherton WG, Galley IJ. The Reliability and Validity of Assessment of Sagittal Plane Deviations in Children Who Have Spastic Diplegia. *Arch Phys Med Rehabil*. 2005;86(12):2337-2341. doi:10.1016/j.apmr.2005.06.021
20. Nieuwenhuys A, Papageorgiou E, Schless S-H, De Laet T, Molenaers G, Desloovere K. Prevalence of Joint Gait Patterns Defined by a Delphi Consensus Study Is Related to Gross Motor Function, Topographical Classification, Weakness, and Spasticity, in Children with Cerebral Palsy. *Front Hum Neurosci*. 2017;11(April):1-14. doi:10.3389/fnhum.2017.00185
21. Sutherland, DH; Davids J. Common Gait Abnormalities of the Knee in Cerebral Palsy. *Clin Orthop Relat Res*. 1993;march(288):139-147.
22. Walter SD, Eliasziw M, Donner A. Sample size and optimal designs for reliability

studies. *Stat Med*. 1998;17(1):101-110. doi:10.1002/(SICI)1097-0258(19980115)17:1<101::AID-SIM727>3.0.CO;2-E

Table 1. Definition of the gait parameter of the GDCS-CP, sagittal plane in the stance and swing phases, and the transverse plane.

	Kinematics			
Sagittal Plane	**Pelvic tilt**	**Hip Fx/Ext**	**Knee Fx/Ext**	**Ankle Df/Pf**
True Equinus	Normal Anterior	Normal Excessive extension Flexion	Normal Excessive extension Flexion	Plantarflexion
Apparent Equinus	Normal Anterior	Flexed	Flexed	Normal
Crouch Gait Compensated^	Anterior	Flexed	Flexed (more than 30° in the stance)	Excessive dorsiflexion
Crouch Gait Uncompensated*	Normal Posterior	Flexed	Flexed (more than 30° in the stance)	Excessive dorsiflexion
Stiff Gait knee source		hip profile in the stance-to-swing interval is normal	delayed and diminished peak knee flexion in swing phase (<45° flexion)	
Stiff gait hip source		hip profile in the stance-to-swing interval is abnormal (slow)	Delayed and diminished peak knee flexion in swing phase (<45° flexion)	
Transverse plane	**Pelvic rotation**	**Hip rotation**	**Knee rotation**	**Foot progression**
Neutral normal	neutral	Neut/ext	Neut/ext	Neutral
Neutral off-settings	Neut/ext/int	Internal	External	Neutral
Internal single/multilevel	Neut/ext/int	Neut/int	Neut/int	Internal
External single/multilevel	Neut/ext/int	Neut/ext	Neut/ext	External

Hip fx/Ext: hip flexion and extension. Knee Fx/Ext: knee flexion and extension. Ankle Df/Pf; ankle dorsiflexion and plantarflexion. Hyperext.: hyperextension. Neut/ext/int= neutral, external, internal.
^ = normal internal extensor moment during stance phase
* = increase internal extensor knee moment during stance phase.

Table 2. Median and interquartile range of age, GPS and velocity, according to the sagittal stance phase, the sagittal swing phase and the transverse plane of the gait patterns.

Stance phase Sagittal Plane

Gait pattern/ variables	Normal n = 21	Jump gait [true equinus] n = 15	Jump gait [apparent equinus] n = 42	Crouch gait Compensated n = 5	Crouch gait Uncompensated n = 8	Others n = 4	P
Age (years)	12.50 [9.75 – 14.00]	10.00 [8.00 – 10.00]	11.00 [9.50 – 14.00]	14.00 [12.50 – 15.50]	16.00 [12.50 – 17.00]	14.50 [8.75 – 15.75]	0.070
GPS st (°)	10.80 [9.09 – 12.15] [a,b,c,d]	13.60 [10.80 – 19.50]	12.90 [11.40 – 15.01]	15.10 [14.17 – 18.27]	16.45 [14.77 – 19.40]	14.08 [12.65 – 17.55]	<0.001
Velocity (cm/sec)	85.55 [71.10 – 107.55]	103.70 [70.30 – 112.40]	88.60 [66.60 – 102.85]	50.30 [36.37 – 82.97]	76.05 [56.17 – 83.65]	75.05 [37.90 – 114.67]	0.406

Swing phase Sagittal Plane

Gait pattern/ variables	Normal n = 110	Stiff gait Knee source n = 18	Stiff gait hip source n = 3	P
Age (years)	13.00 [10.00 – 15.00]	12.00 [10.00 – 13.50]	14.00 [12.00 – 14.00]	0.926
GPS st (°)	13.70 [11.70 – 17.52]	12.10 [10.75 – 17.31]	18.40 [16.20 – 20.30]	0.125
Velocity (cm/sec)	75.45 [62.05 – 91.30] [e]	89.1 [59.20 – 102.45] [f]	26.10 [20.10 – 26.70]	0.015

Stance phase Transverse plane

Gait pattern/ variables	Neutral – normal n = 46	Neutral – off setting n = 20	Internal single level n = 41	Internal multilevel n=3	External single level n = 6	External multilevel n=7	P
Age (years)	14.00 [12.00–15.00]	12.00 [10.00 – 14.00]	11.00 [9.00 – 15.00]	10.00 [7.50-10.00]	15.00 [7.50 – 16.50]	14.00 [10.00-16.25]	0.172
GPS st (°)	11.80 [10.04 – 13.88] [g,h,i]	14.00 [12.99 – 19.00]	13.70 [11.47 – 18.06]	15.40 [11.20-19.18]	13.90 [13.25 – 15.69]	19.50 [14.50-23.75]	<0,001
Velocity (cm/sec)	89.95 [67.35 – 103.07] [i]	74.08 [57.80 – 87.90]	83.10 [61.35 – 99.50] [j]	69.00 [65.20-76.10]	70.20 [44.10 – 82.85]	66.10 [35.00-79.75]	0.004

GPS st: Global Profile Score standard; (°) degrees; GMFCS: Gross Motor Function Classification System; cm/sec: centimeter per second.
a = statistically significant difference between normal and jump knee/true equinus.
b = statistically significant difference between normal and jump knee/ apparent equinus.
c = statistically significant difference between normal and crouch gait compensated.
d = statistically significant difference between normal and crouch gait uncompensated.
e = statistically significant difference between normal and stiff gait hip source.
f = statistically significant difference between stiff gait knee source and stiff gait hip source.
g = statistically significant difference between neutral normal and neutral off-settings.
h= statistically significant difference between neutral normal and external multilevel.
i = statistically significant difference between neutral normal and others.
j = statistically significant difference between internal single level and others.

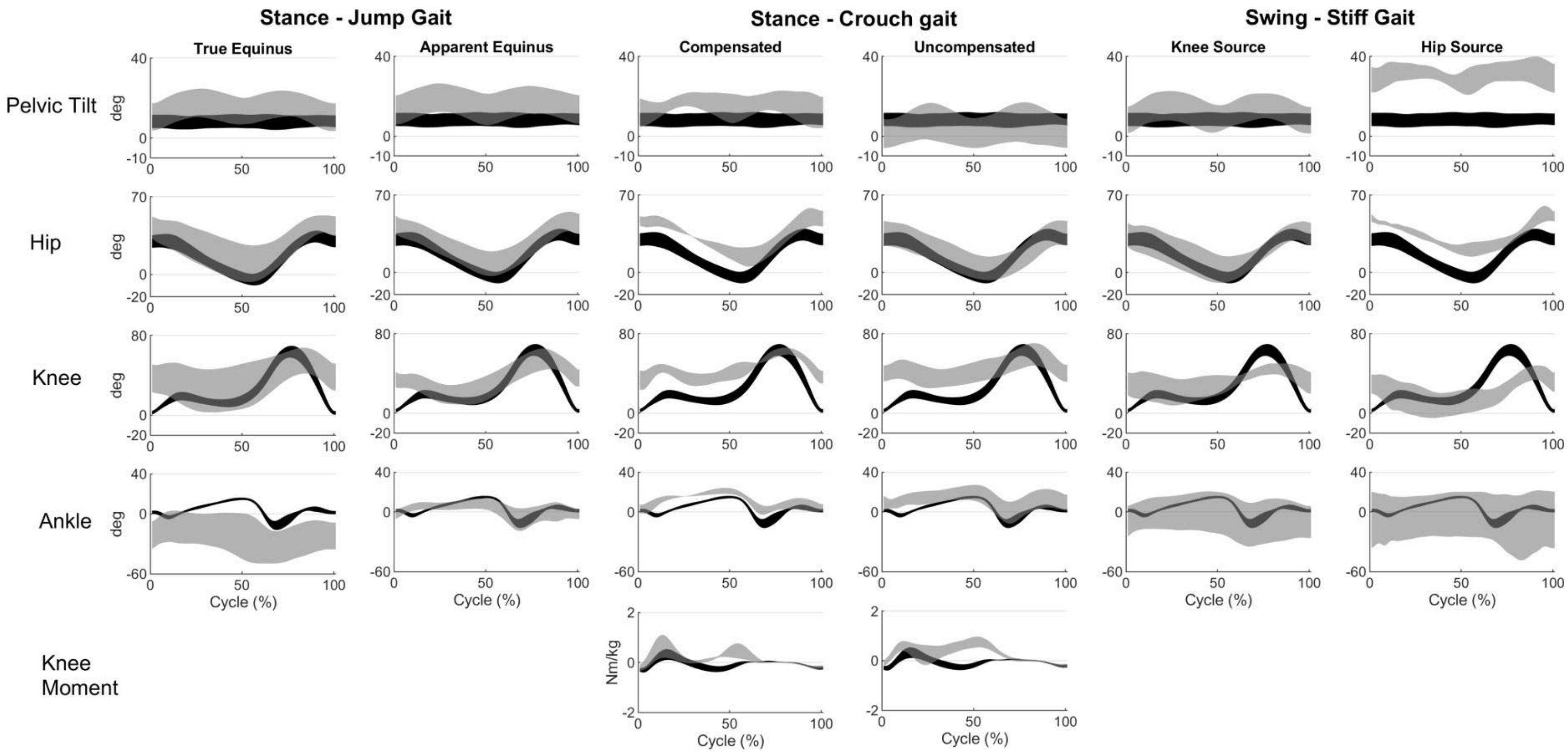


Figure 1. The summarized stance and swing phases of the sagittal plane kinematic data for each gait pattern from the study population. The black band represents the mean ± 1 SD of kinematic data normal database, and the grey band the mean ± 1 SD for each gait pattern. The vertical axis represents joint angular displacement and the horizontal axis, 100% of the gait cycle.

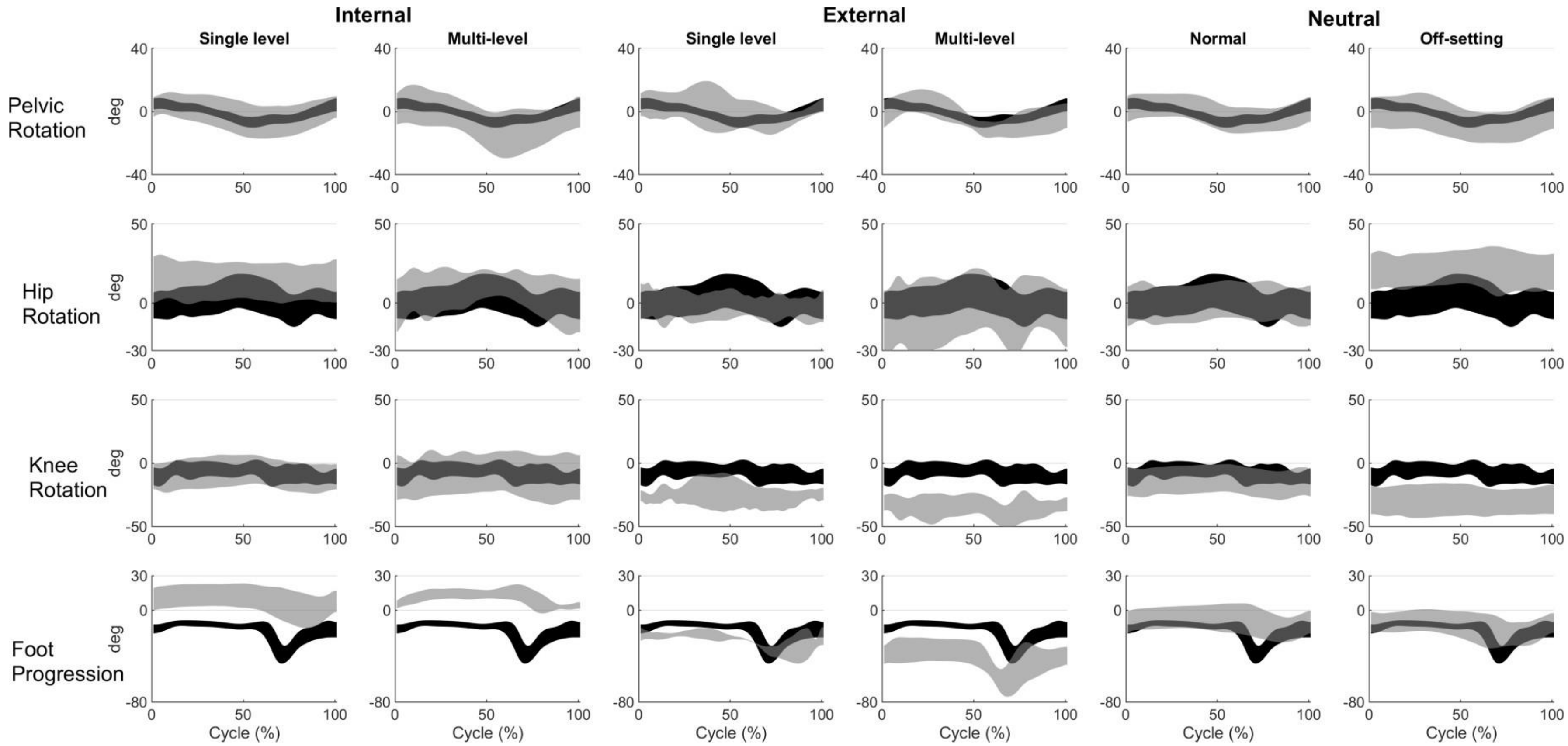


Figure 2. The summarized stance phase of the transverse plane kinematic data for each gait pattern from the study population. The black band represents the mean ± 1 SD of kinematic data normal database, and the grey band the mean ± 1 SD for each gait pattern. The vertical axis represents joint angular displacement and the horizontal axis, 100% of the gait cycle.

Table 3. Fleiss's Kappa (k) statistics with 95% CI for interrater reliability in the first and second level of the classification.

First Level n=60	**k**	**SE**	**CI 95%**	**P**
Stance sagittal	0.409	0.028	0.355-0.464	<0.001
Swing sagittal	0.570	0.037	0.498-0.642	<0.001
Stance transverse	0.516	0.030	0.456-0.575	<0.001
Total	0.596	0.018	0.562-0.631	<0.001
Second Level n=60	**k**	**SE**	**CI 95%**	**P**
Stance sagittal	0.434	0.021	0.394-0.475	<0.001
Swing sagittal	0.491	0.032	0.429-0.553	<0.001
Stance transverse	0.275	0.019	0.237-0.312	<0.001
Total	0.485	0.012	0.461-0.509	<0.001

SE= Standard Error; CI= Confidence Interval.

Table 4. Cohen's Kappa (k) statistics with 95% CI for intrarater reliability in the first and second level of the classification.

First Level n=60	**Rater**	**k**	**SE**	**CI 95%**	**P**
Stance Sagittal	1	0.913	0.060	0.795-1.000	<0.001
	2	0.797	0.066	0.667-0.926	<0.001
Swing Sagittal	1	0.550	0.226	0.107-0.993	<0.001
	2	0.643	0.188	0.274-1.000	<0.001
Stance transverse	1	0.807	0.067	0.747-0.867	<0.001
	2	0.692	0.089	0.518-0.866	<0.001
Total	1	0.888	0.031	0.827-0.949	<0.001
	2	0.791	0.042	0.709-0.873	<0.001
Second Level n=60		**k**	**SE**	**CI 95%**	**P**
Stance Sagittal	1	0.760	0.069	0.625-0.895	<0.001
	2	0.743	0.065	0.616-0.870	<0.001
Swing Sagittal	1	0.550	0.226	0.107-0.993	<0.001
	2	0.565	0.193	0.187-0.943	<0.001
Stance transverse	1	0.623	0.073	0.48-0.766	<0.001
	2	0.567	0.076	0.419-0.715	<0.001
Total	1	0.776	0.036	0.706-0.846	<0.001
	2	0.714	0.041	0.634-0.794	<0.001

SE= Standard Error; CI= Confidence Interval.

6.1. Supplementary material (Training material for raters).

Appendix A. Written orientation Classification of Gait Deviations for raters (definitions)

Classification of Gait Deviations
– Davids and Bagley – 2014.

-Definition of the classification.
-Figures.
-Graphics – kinematics and kinetics.
-Overview of the classification.
-Protocols.

Gait disruption patterns in the sagittal plane are best classified in a hierarchical manner, with the first level of distinction being between stance phase and swing phase[1].

In stance phase, the first level of distinction is between normal, jump, and crouch gait (Figure A1). The latter two gait patterns are differentiated by the foot contact pattern with the floor. Jump gait is characterized by the loss of heel strike at initial contact, with a toe contact pattern for the duration of the stance phase (Figure A2).

Crouch gait is characterized by a flatfoot or calcaneal contact pattern for the duration of stance phase (Figure A2)[2]. All children with CP and crouch gait will have increased knee flexion throughout stance phase (more than 30° of flexion)[3].

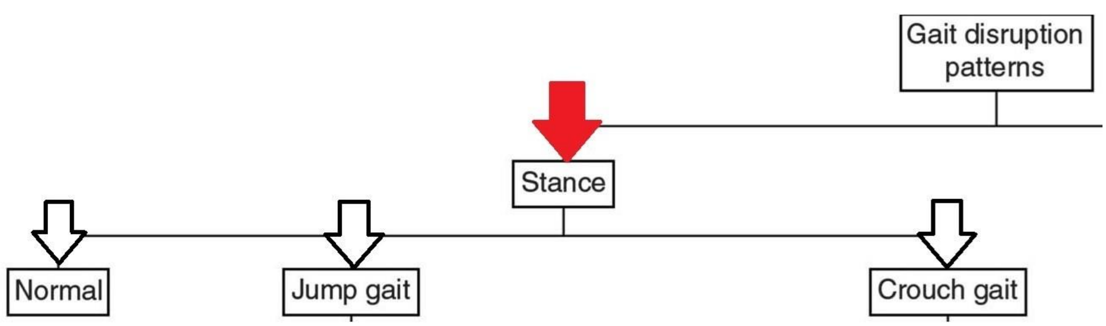


Figure A1. Flowchart of the first level of the classification in the stance phase of the sagittal plane

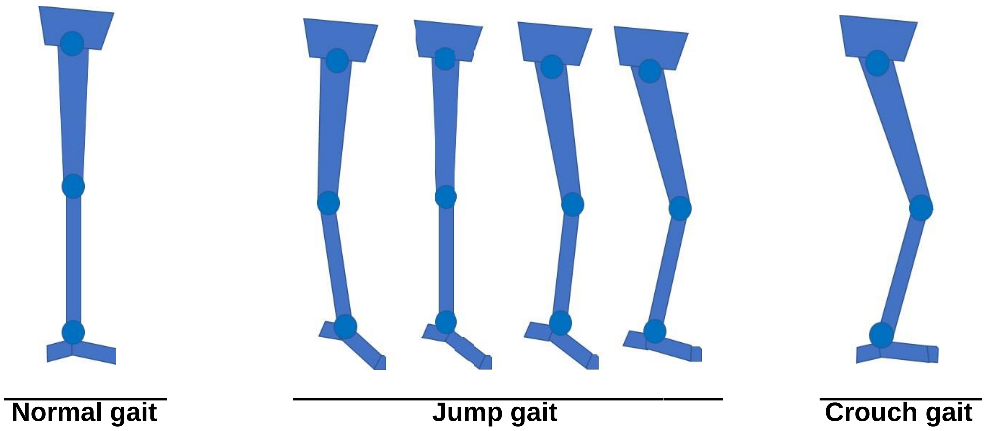


Figure A2. First level of the classification - stance phase of sagital plane (with permission from the author).

Jump gait may be further subdivided into true equinus and apparent equinus patterns (Figure A3). True equinus is characterized by plantar flexion of the foot relative to the tibia. In apparent equinus, the foot appears to be in plantar flexion (ie, relative to the floor) but is actually normally aligned relative to the tibia (Figure A4).

Crouch gait may be subdivided into compensated and uncompensated patterns, based on sagittal plane knee kinetics (Figure A3). In the compensated pattern, the knee is effectively offloaded in midstance (i.e., reflected by a decreased internal knee extensor moment), despite the increased knee flexion throughout the stance phase (Figure A5).

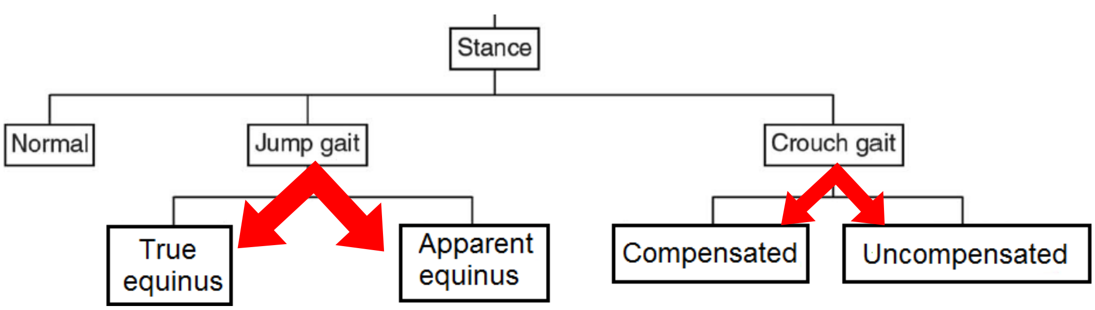


Figure A3. Flowchart of the second level of the classification in the stance phase of the sagittal plane

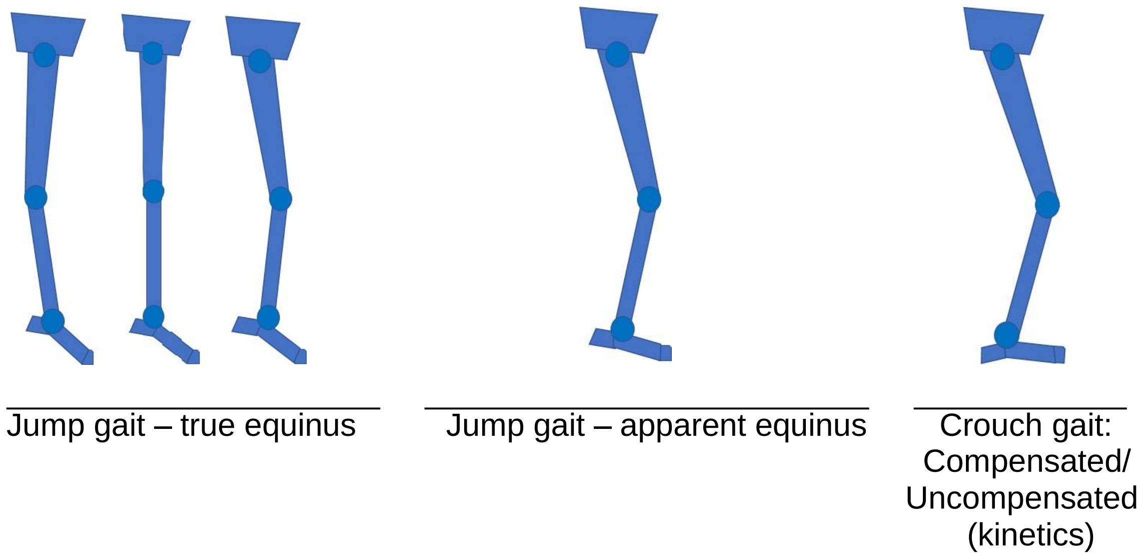


Figure A4. First and second level of the classification - stance phase of sagittal plane (with ask permission from the author).

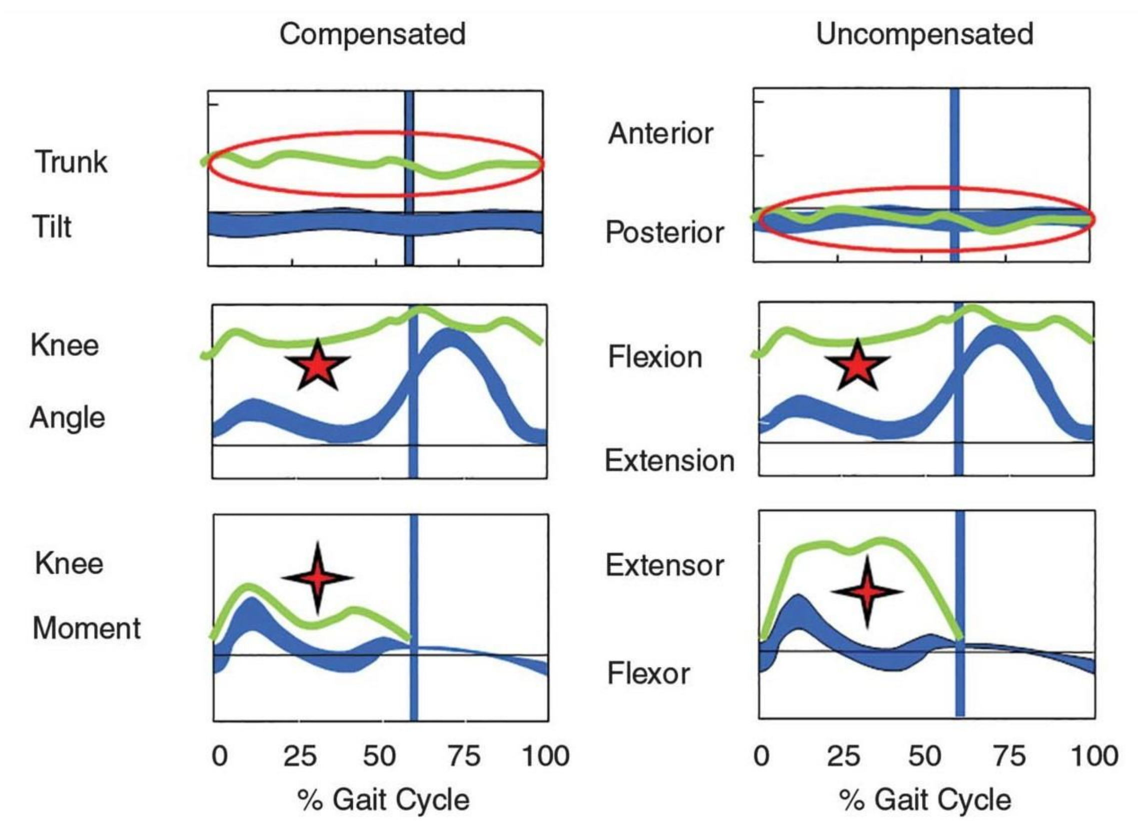


Figure A5. Example of compensated and uncompensated croch gait (kinematic and kinetic) (with permission from the author).

In swing phase, the first level of distinction is between normal gait and stiff gait (Figure A6). Stiff gait is characterized by delayed and diminished peak knee flexion in swing phase (less than 45° of flexion)[3].

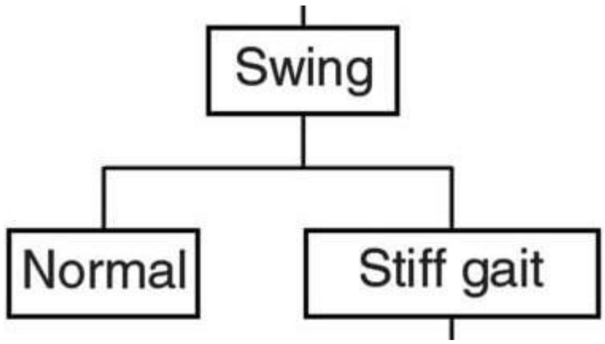


Figure A6. First level of the classification - swing phase of the sagittal plane (with permission from the author).

The stiff gait may be further subdivided into knee source and hip source (Figure A7).

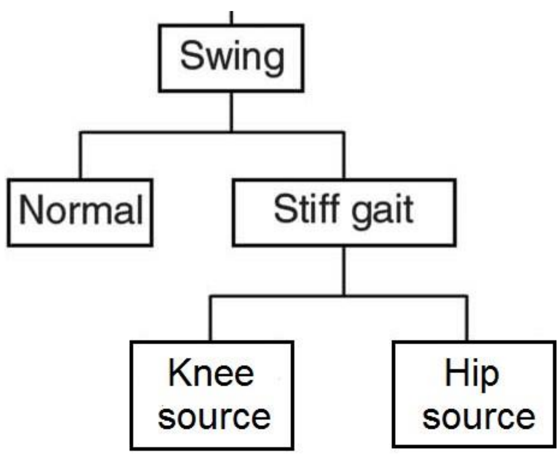


Figure A7. First and Second level of the classification – swing phase of sagittal plane (with permission from the author).

In the stiff gait knee source, the hip profile in the stance-to-swing interval is normal. In the stiff gait hip source, the swing-phase knee deviations are preceded by kinematic (i.e., diminished flexion slope) and kinetic (i.e., diminished internal flexor moment and decreased power generation) deviations at the hip in terminal stance and pre-swing of the gait cycle (Figure A8).

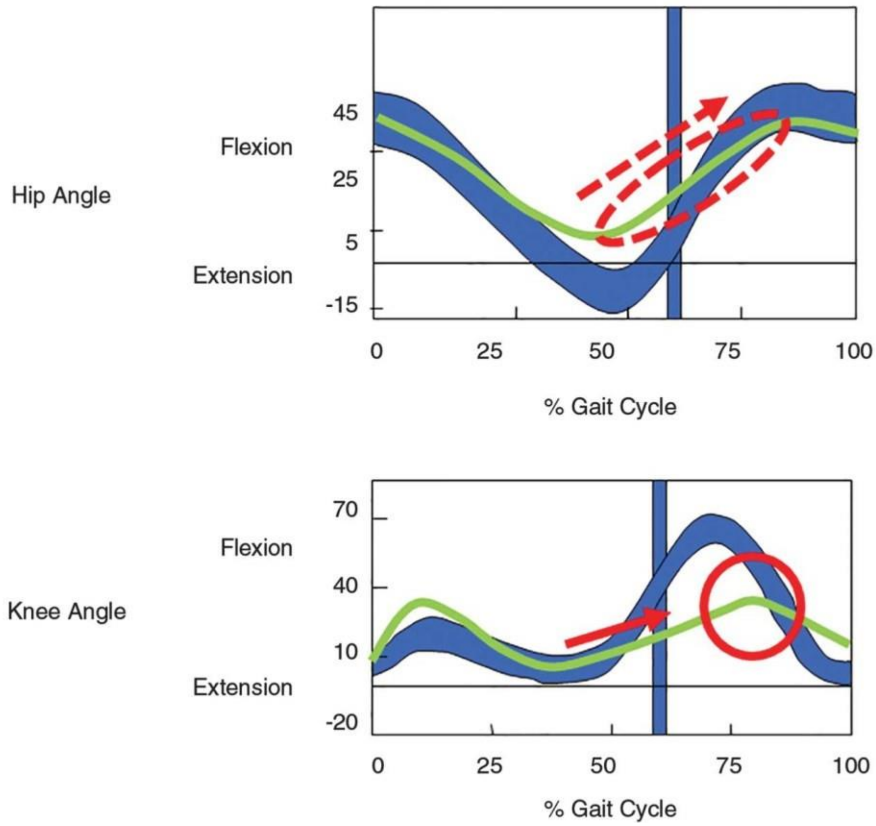


Figure A8. Kinematic of the stiff gait hip source (with permission from the author).

Gait disruption patterns in the transverse plane are best classified in a hierarchical manner, with the first level of distinction including internal, external, and neutral progression patterns (Figure A9). The internal progression pattern is characterized by an internal foot-progression angle (i.e., medial orientation of the

long axis of the foot relative to the line of progression of gait). The external progression pattern is characterized by an external foot-progression angle (i.e., lateral orientation of the long axis of the foot relative to the line of progression of gait). The neutral progression pattern is characterized by a neutral foot-progression angle (i.e., orientation of the long axis of the foot that is comparable to the line of progression of gait)

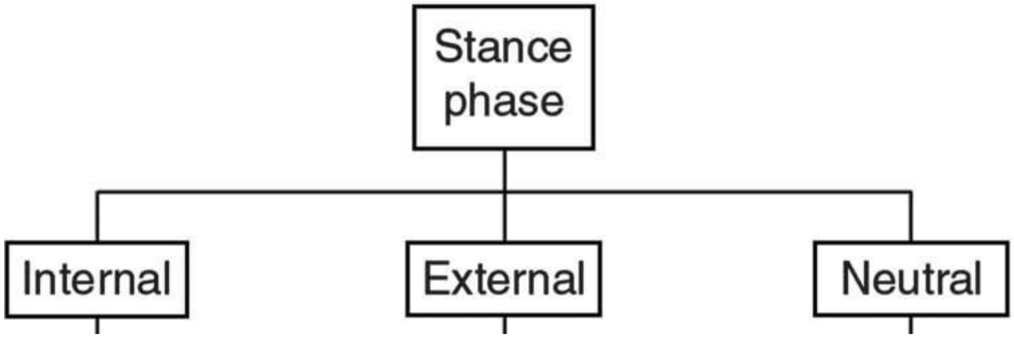


Figure A9. First level of the classification – transverse plane (with permission from the author).

Both internal and external progression patterns may be subdivided into single-level and multilevel patterns (Figure A10).

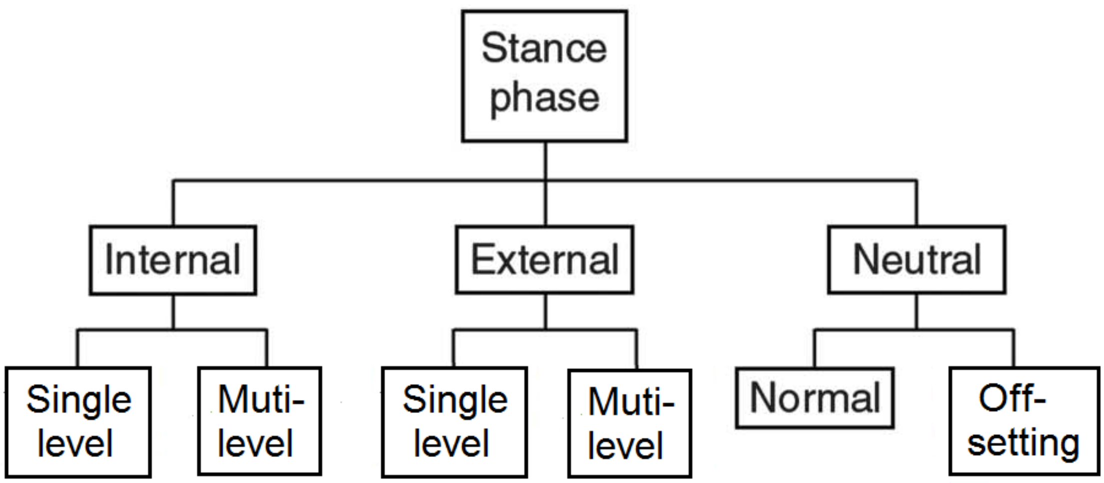


Figure A10. First and second level of the classification – transverse plane (with permission from the author).

The neutral progression pattern can be divided into normal and off-setting patterns (the latter is also known as miserable malalignment) (Figure A11).

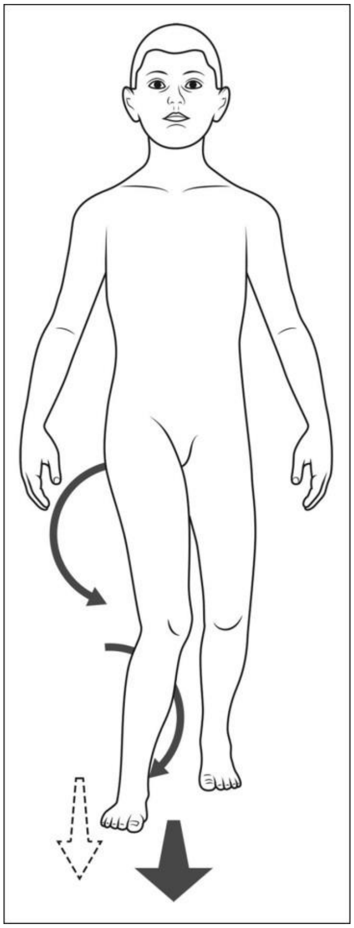


Figure A11. Illustration of the stance phase, neutral progression, gait disruption pattern. The foot-progression angle (dashed arrow) of the reference limb is comparable to the line of gait progression (solid arrow). Internal rotation of the hip, related to increased femoral anteversion (i.e., transverse plane), is offset by external rotation at the knee, related to increased external tibial torsion (i.e., transverse plane), resulting in a neutral foot progression angle. This gait disruption pattern may compromise patellar tracking and knee loading (with permission from the author).

Table A1. Overview of classification definitions.

	Kinematics			
Sagittal Plane	**Pelvic tilt**	**Hip Fx/Ext**	**Knee Fx/Ext**	**Ankle Df/Pf**
True Equinus	Normal Anterior	Normal Excessive extension Flexion	Normal Excessive extension Flexion	Plantarflexion
Apparent Equinus	Normal Anterior	Flexed	Flexed	Normal
Crouch Gait Compensated^	Anterior	Flexed	Flexed (more than 30° in the stance)	Excessive dorsiflexion
Crouch Gait Uncompensated *	Normal Posterior	Flexed	Flexed (more than 30° in the stance)	Excessive dorsiflexion
Stiff Gait knee source		hip profile in the stance-to-swing interval is normal	delayed and diminished peak knee flexion in swing phase (<45° flexion)	
Stiff gait hip source		hip profile in the stance-to-swing interval is abnormal (slow)	Delayed and diminished peak knee flexion in swing phase (<45° flexion)	
Transverse plane	**Pelvic rotation**	**Hip rotation**	**Knee rotation**	**Foot progression**
Neutral normal	neutral	Neut/ext	Neut/ext	Neutral
Neutral off-settings	Neut/ext/int	Internal	External	Neutral
Internal single/multilevel	Neut/ext/int	Neut/int	Neut/int	Internal
External single/multilevel	Neut/ext/int	Neut/ext	Neut/ext	External

Hip fx/Ext: hip flexion and extension. Knee Fx/Ext: knee flexion and extension. Ankle Df/Pf; ankle dorsiflexion and plantarflexion. Hyperext.: hyperextension. Neut/ext/int= neutral, external, internal.
^ = normal internal extensor moment during stance phase
* = increase internal extensor knee moment during stance phase.

Table A2. Research protocols right and left sides.

Gait Classification (right side)	Gait Classification (left side)
Participant n°	Participant n°
Sagittal Plane	**Sagittal Plane**
Stance	**Stance**
Normal ( )	Normal ( )
Jump gait ( ) { True equinus ( ) / Apparent equinus ( ) }	Jump gait ( ) { True equinus ( ) / Apparent equinus ( ) }
Crouch gait ( ) { Compensated ( ) / Uncompensated ( ) }	Crouch gait ( ) { Compensated ( ) / Uncompensated ( ) }
Swing	**Swing**
Normal ( )	Normal ( )
Stiff gait ( ) { Knee source ( ) / Hip source ( ) }	Stiff gait ( ) { Knee source ( ) / Hip source ( ) }
Transverse Plane	**Transverse Plane**
Stance	**Stance**
Internal ( ) { Single level ( ) / Multi-level ( ) }	Internal ( ) { Single level ( ) / Multi-level ( ) }
External ( ) { Single level ( ) / Multi-level ( ) }	External ( ) { Single level ( ) / Multi-level ( ) }
Neutral ( ) { Normal ( ) / Off-setting ( ) }	Neutral ( ) { Normal ( ) / Off-setting ( ) }

References

1. Davids JR, Bagley AM. Identification of Common Gait Disruption Patterns in Children With Cerebral Palsy. *J Am Acad Orthop Surg*. 2014;22(12):782-790. doi:10.5435/JAAOS-22-12-782
2. Rodda JM, Graham HK, Carson L, Galea MP, Wolfe R. Sagittal gait patterns in spastic diplegia. *J Bone Jt Surg*. 2004;86(2):251-258. doi:10.1302/0301-620X.86B2.13878
3. Sutherland, DH; Davids J. Common Gait Abnormalities of the Knee in Cerebral Palsy. *Clin Orthop Relat Res*. 1993;march(288):139-147.

Appendix B. Orientation for the raters (PowerPoint presentation).

Orientation of how to use the Classification System

Orientation for Raters

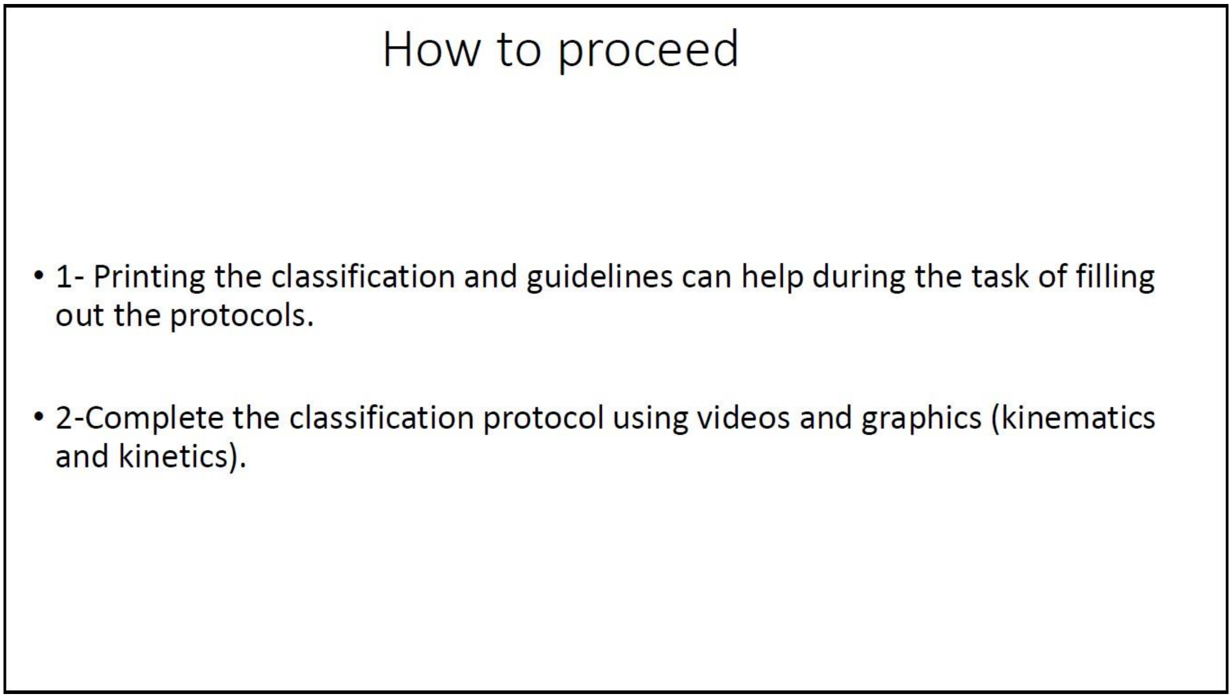
Slide B1. Orientation of how to use the classification.

Media

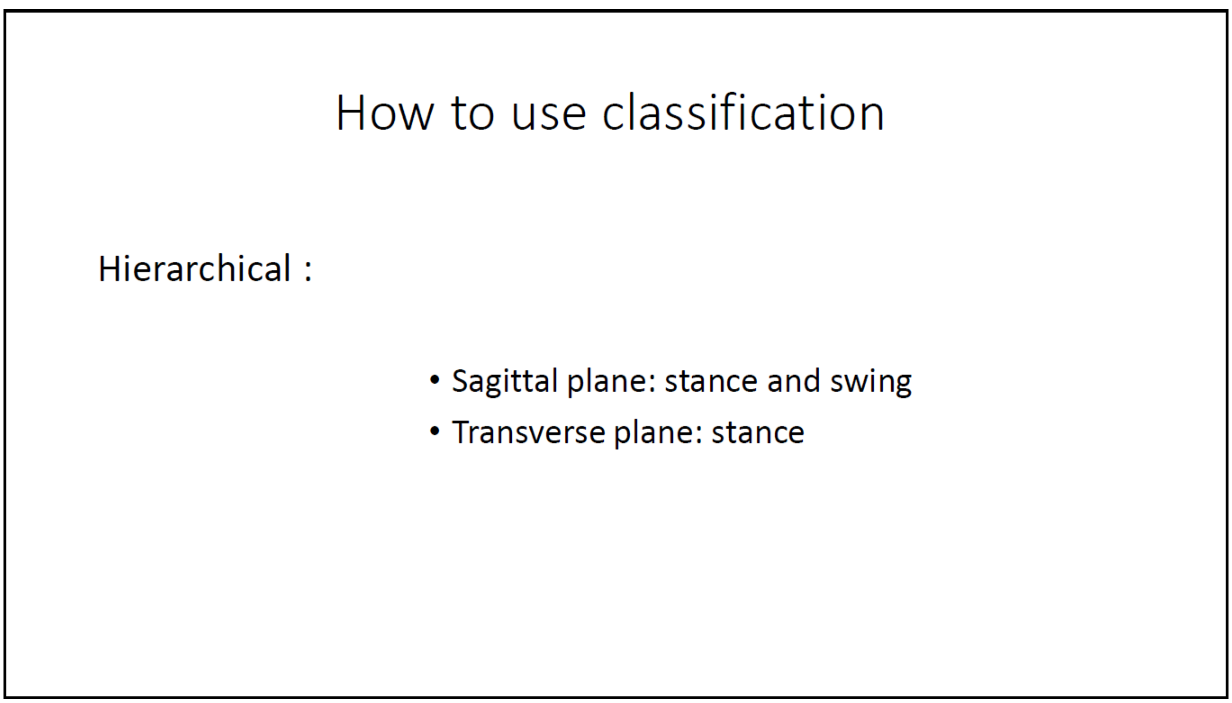
Cases - protocols, videos and graphics

The pen drive comes with this animated PowerPoint presentation of the classification with an example and separate written instructions.
The cases to be evaluated are in numbered files. For each case there are:
videos with anterior, posterior, right and left lateral views;
kinematics graphs on the right and left side;
in addition to kinetics graphs for GMFCS 1 and 2 patients.

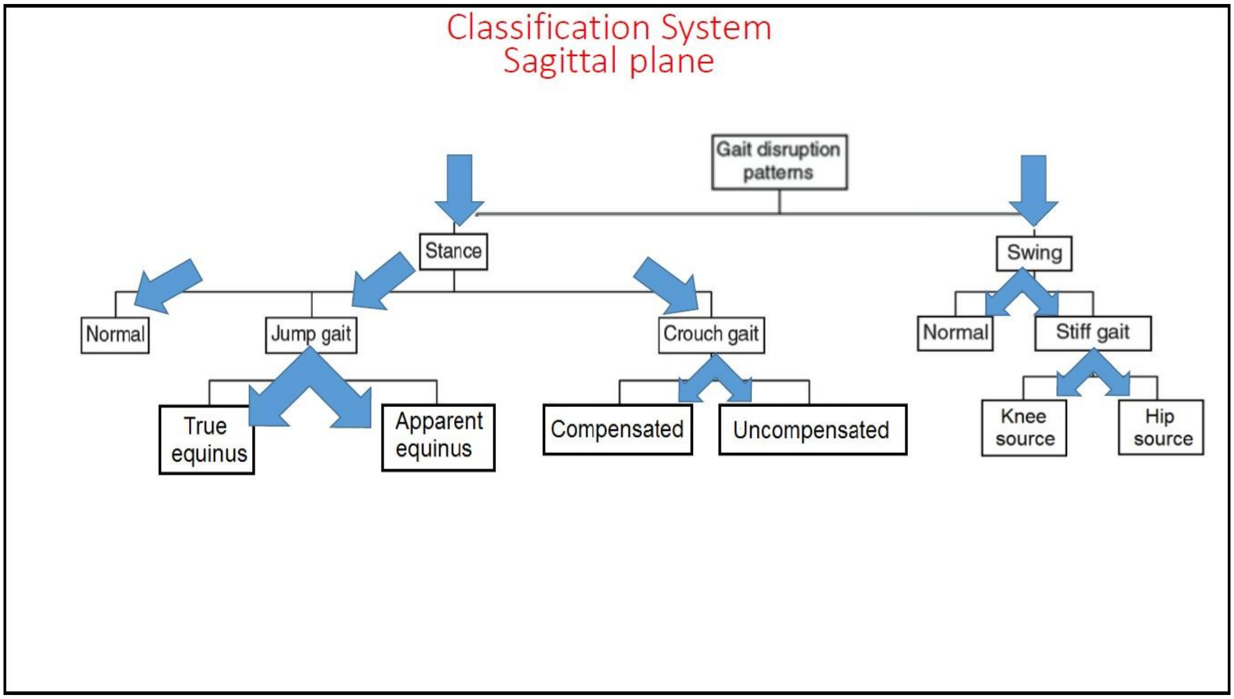
Slide B2. Media description.



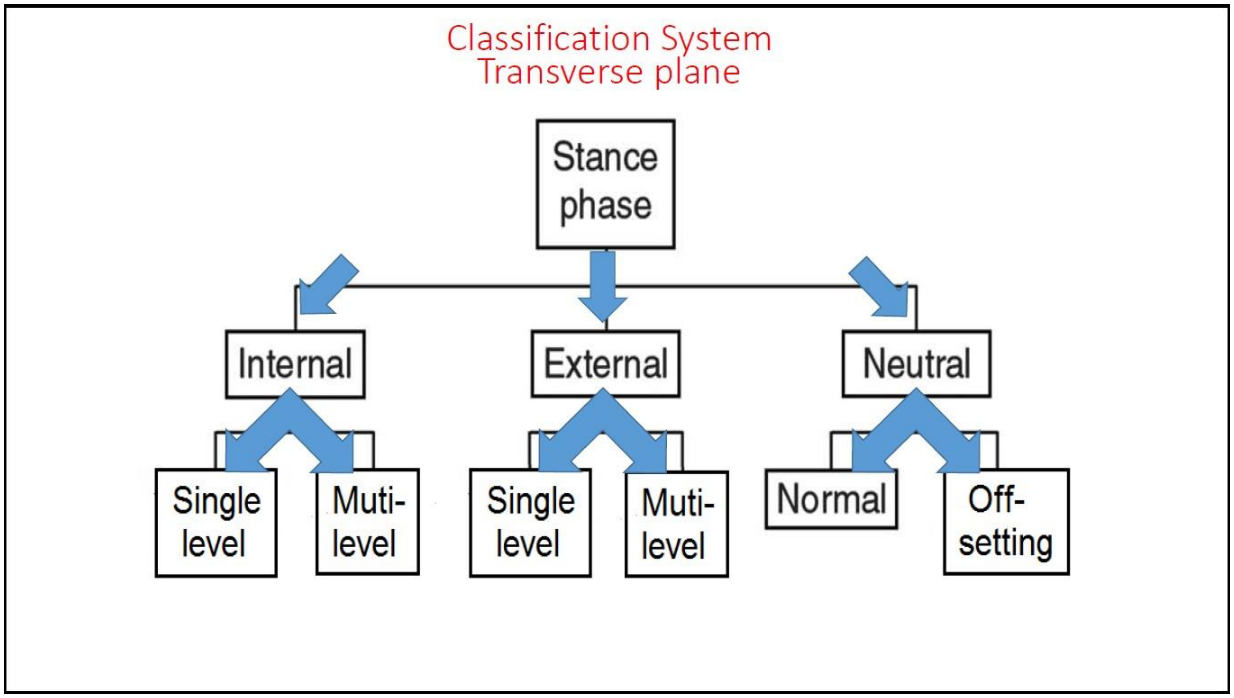
Slide B3. How to proceed to classify the sample of children.



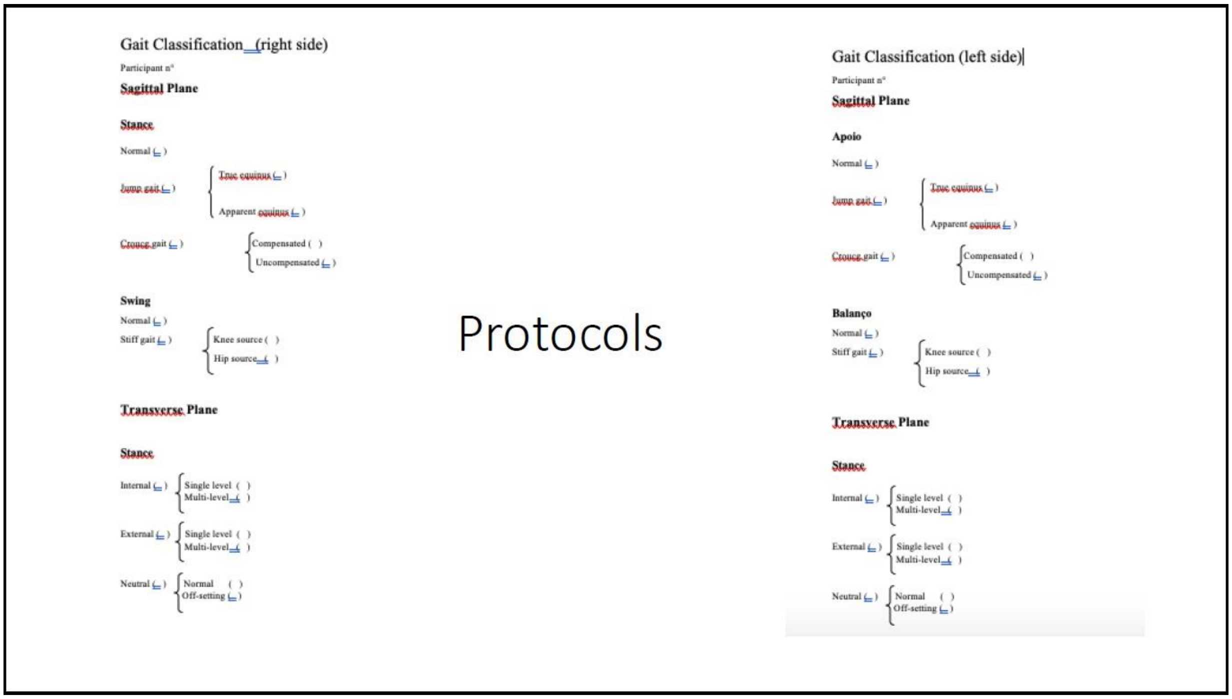
Slide B4. How to use de classification.



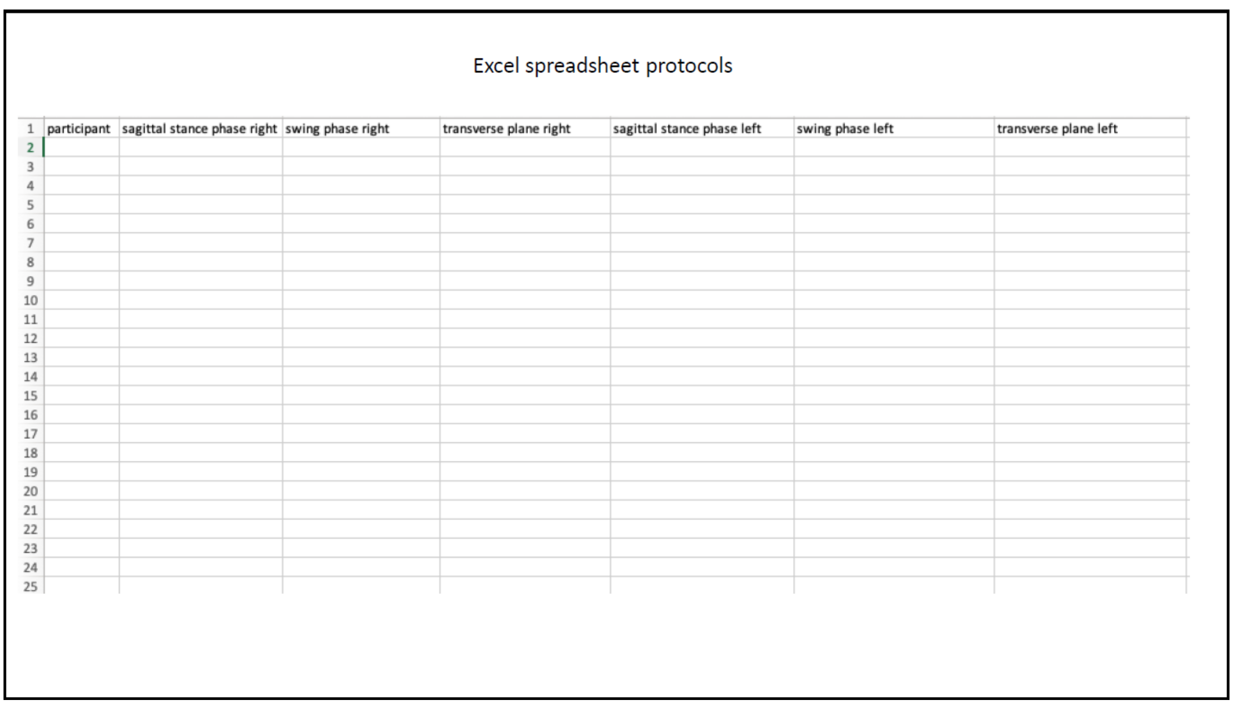
Slide B5. Flowchart of the sagittal plane of classification.



Slide B6. Flowchart of the transverse plane of classification.



Slide B7. Right and left sides protocols for use during the classification of the children.

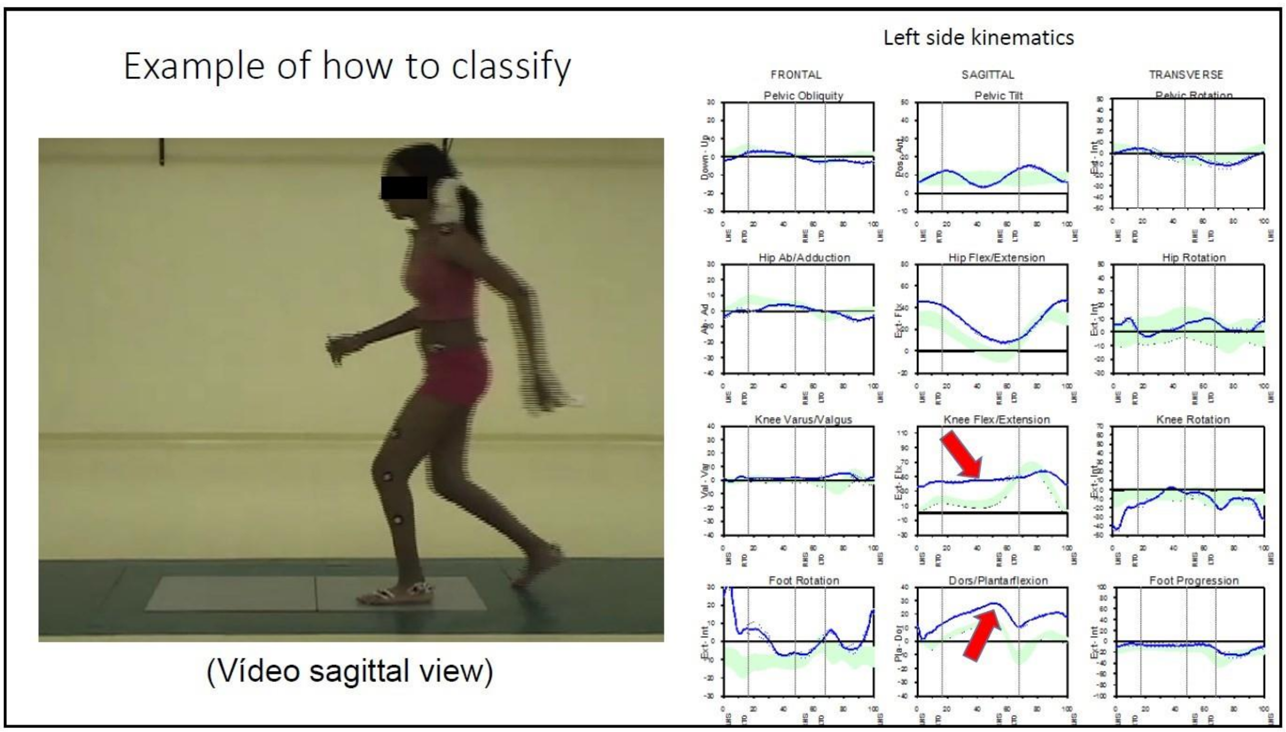


Slide B8. Example of excel spreadsheet protocol.

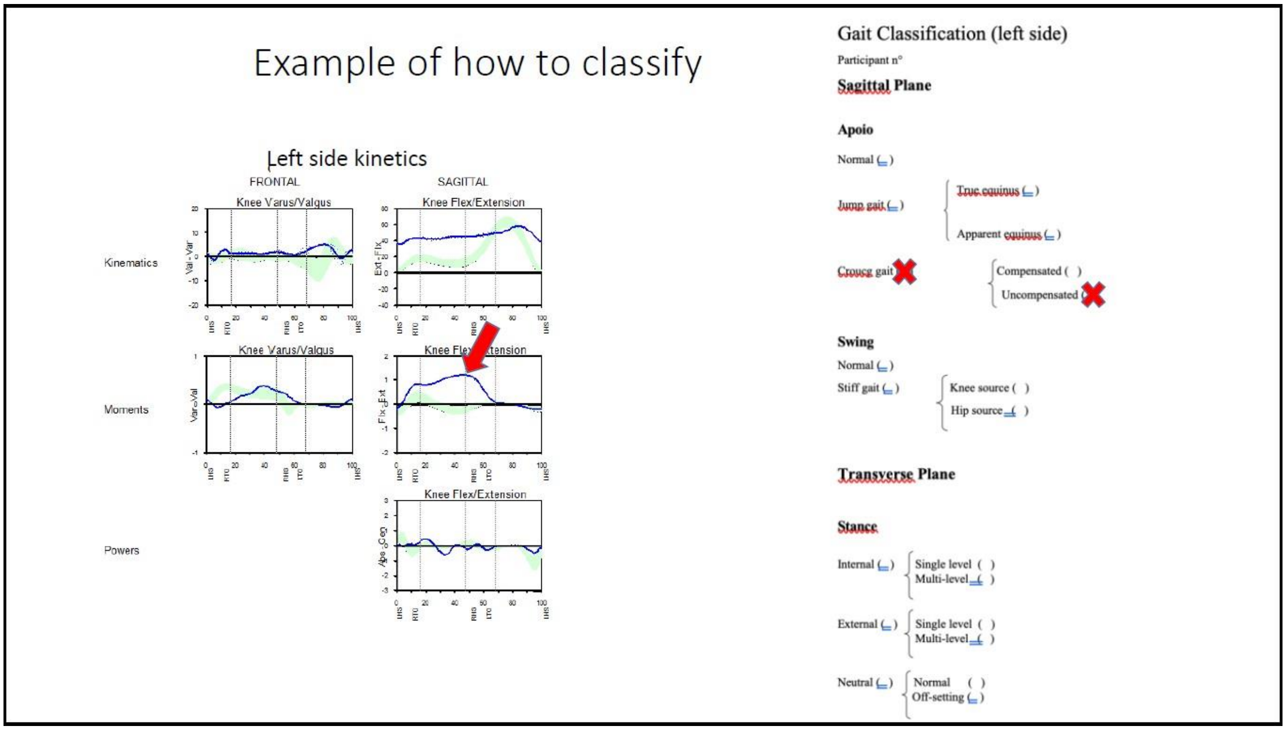
Example of how to fill out the excel spreadsheet

	participant	sagittal stance phase right	swing phase right	transverse plane right	sagittal stance phase left	swing phase left	transverse plane left
1	participant	sagittal stance phase right	swing phase right	transverse plane right	sagittal stance phase left	swing phase left	transverse plane left
2	1	jump gait/true equinus	normal	neutral/normal	jump gait/apparent equinus	normal	neutral/normal
3	2	crouch gait/compensated	normal	external/single level	crouch gait/compensated	normal	neutral/off-setting
4							

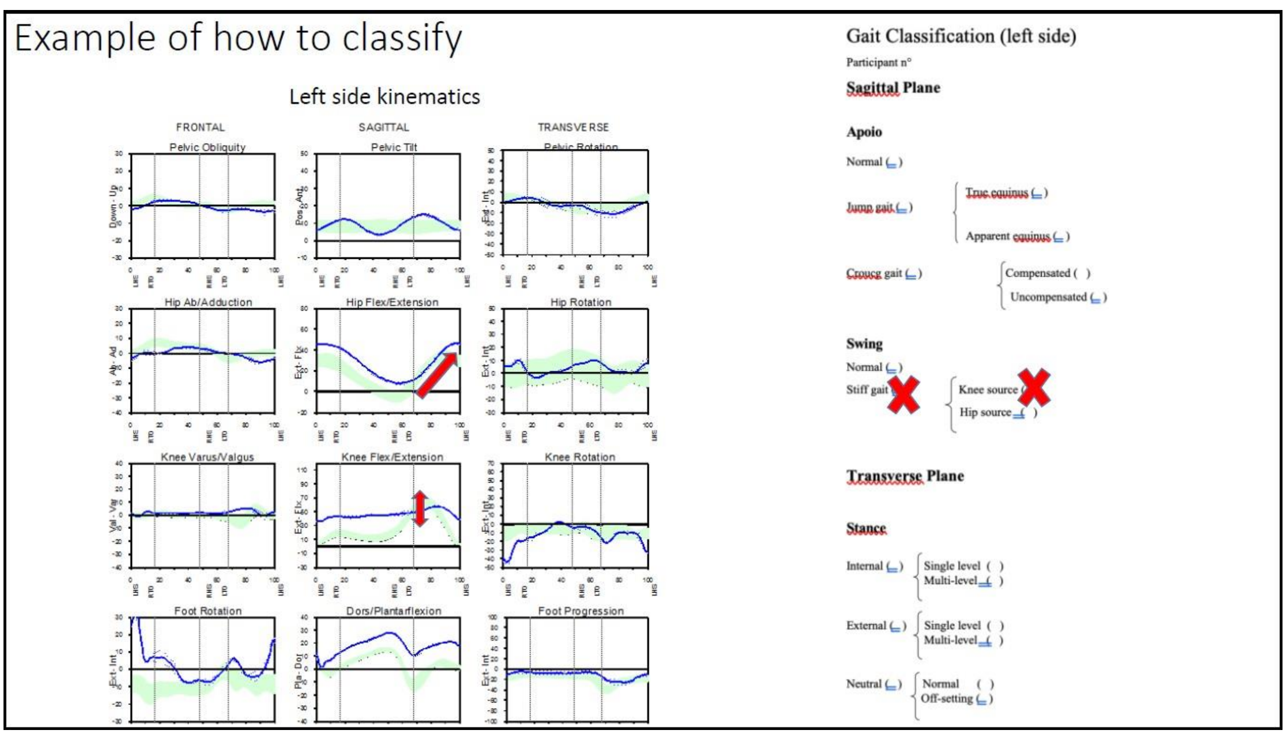
Slide B9. Example of how to fill out the excel spreadsheet protocol.



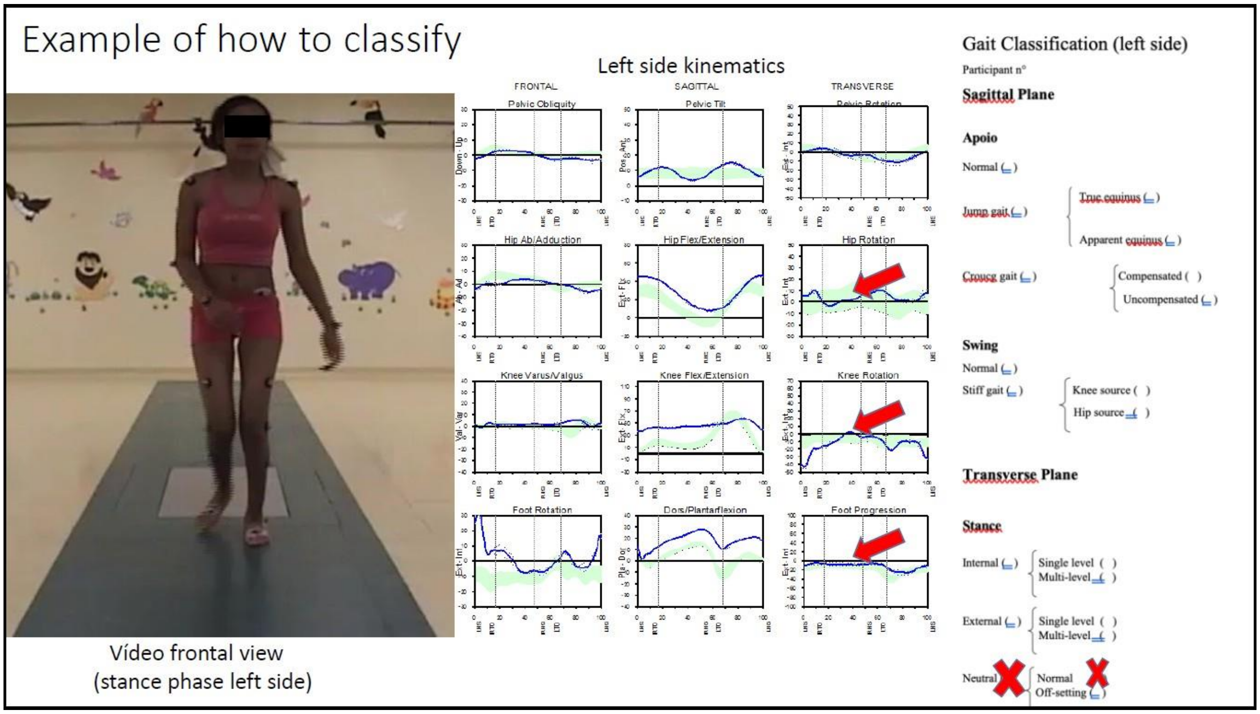
Slide B10. Example how to classify a child using the video and kinematics of the sagittal plane.



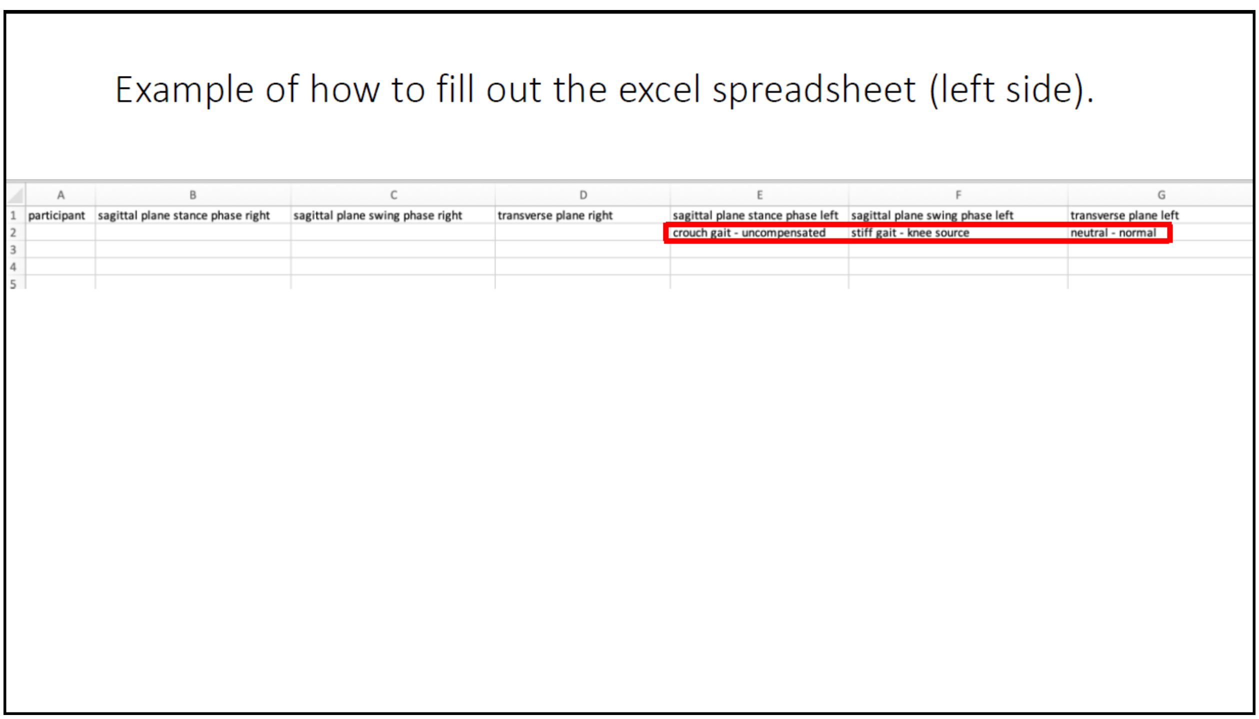
Slide B11. Example of how to use the kinetic data to classify the crouch gait pattern.



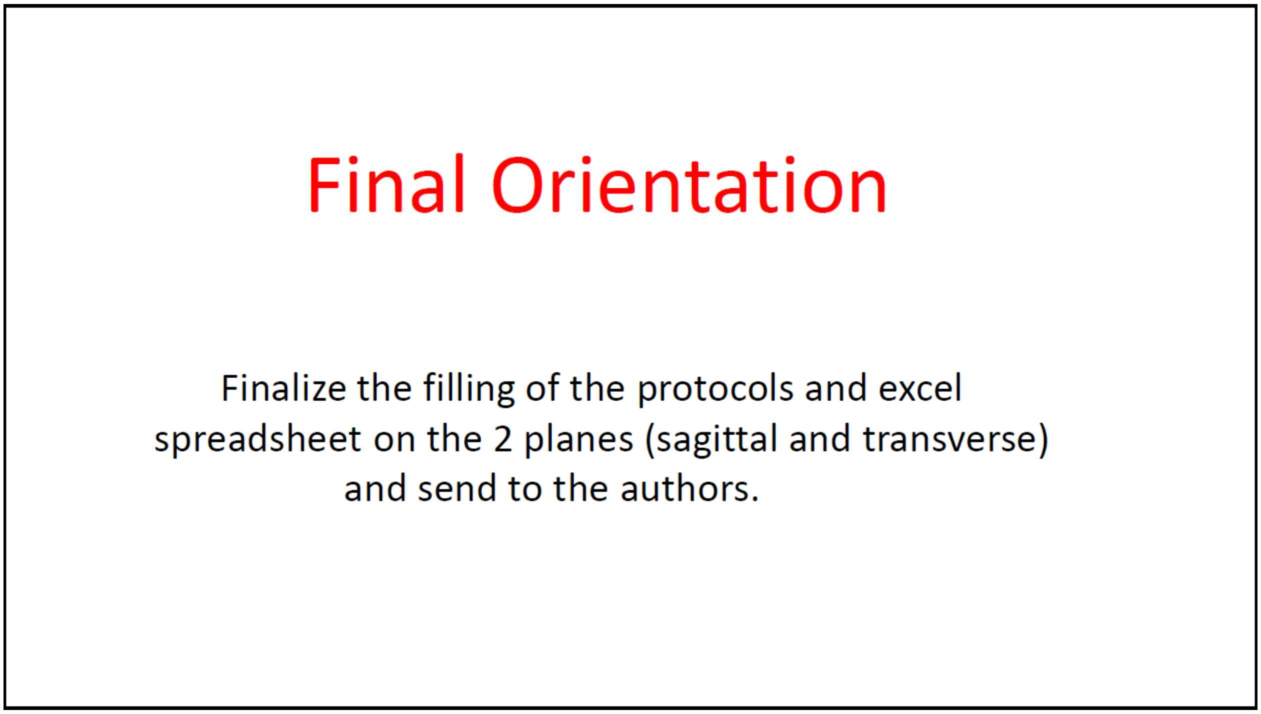
Slide B12. Example of how to use the kinematic data to classify the stiff gait pattern.



Slide B13. Example how to classify a child using the video and kinematics of the tranverse plane.



Slide B14. Example of how to fill out the excel spreadsheet protocol.



Slide B15. Final guidelines for evaluators.

7 ARTIGO 4

Artigo original formatado de acordo com as normas do periódico Gait and Posture.

Fator de Impacto: 2,414 Qualis: A1.

Title:

Constructing a classification for gait levels on a continuum for children with cerebral palsy.

Authors

Alessandro G. Melanda[ab], Alexandre RM. Pelegrinelli[c], Dirce Shizuko. Fujisawa[a]; Suhaila Mahmoud. Smaili[a]

[a] Program of Master and Doctoral degree in Rehabilitation Sciences, Londrina State University (UEL) - Health Sciences Center - Av. Robert Koch, 60 – Operária - 86038-440, Londrina - Paraná State – Brazil.
[b] Gait Analysis Laboratory, Ana Carolina Moura Xavier Hospital Rehabilitation Center. Rua Quintino Bocaiuva, 329 – Cabral – 80.350-090 – Curitiba – Pr – Brazil.
[c] State University of Londrina – Physical Education and Sports Center - Applied Biomechanics Laboratory – LBA. Rodovia Celso Garcia Cid, PR-445, Km 380 - Campus Universitário, 86044-766. Londrina - Paraná State – Brazil.

Corresponding Author:
Alessandro G. Melanda
State University of Londrina – Brazil.
Av. Adhemar Pereira de Barros, 1199.
Bela Suiça, Londrina – Paraná – Brazil.
Zip Code: 86047-250.
melanda@uel.br

Abstract

Background: Gait deviations in cerebral palsy (CP) tend to be a continuum of deviations rather than well delineated groups. The purpose of this study was to classify gait in CP children using the concept of levels rather than categorize into patterns.
Research question: Is the classification of gait levels of children with CP valid and reliable?
Methods: CP children (N=101; 51 F, 50 M; 12.2+-3.4 years), were assessed using observational gait analysis (OGA) and three-dimensional gait analysis (3DGA). Age, gait velocity, Gross Motor Function Classification System (GMFCS) and Global Profile Score (GPS) were used to characterize the sample. Build a classification using the increase of problems from ankle to more proximal joints in sagittal and transverse planes and the necessity of walking aids. The comparison between the levels was performed by the ANOVA test, according to the normality of the data. The reliability of the classification was determined by Kappa index.
Results: We determined 3 gait levels for children with CP. All levels were represented in the evaluated sample and all participants were classified. The GPS was on average three degrees different between the levels, increasing from level 1 to 3 ($p<0.001$). The interrater reliability was substantial for the classification using 3D data and observational gait analysis (OGA) according Fleiss's Kappa statistics. The intrarater reliability, between the raters and the authors consensus, and between the two professional categories, was substantial to almost perfect using OGA and 3DGA ($p<0.001$), according to weighted Kappa statistics.
Significance: The level classification presented validity in the sample of CP evaluated. The interrater reliability was substantial and substantial to almost perfect for intrarater and between raters and authors consensus. Longitudinal studies in the future can determine the utility of the classification to follow patients during the natural evolution or after treatments.

Keywords: cerebral palsy, gait, children, classification.

Highlights

- Classification with face, criterium and concurrent validity;
- Substantial reliability interrater and substantial to almost perfect reliability intra rater and between raters and authors consensus.
- Positive relationship between previous calf surgery, external and neutral off-setting rotated position with level 3.
- The classification can be used for evaluators with less experience in gait analysis with only observational analysis, which increases its applicability in the daily clinic.

1. Introduction

The cerebral palsy (CP) results from a primary injury in the central nervous system, and clinical symptoms are observed in the peripheral neuromuscular system [1]. Walking capacity is significantly impaired in children with CP, walking at 5 years of age was reported for 70% of the patients [2] [3]. The motor impairments are multifactorial and included: abnormal muscle tone, spasticity, loss of selectivity and muscle weakness [3]. To explain what happens in this group of patients it is necessary to remember that, during the ontogenetic phase of independent human locomotion, two separate forms of growth occur [4]: the infants physical size, their mass and their height increase [5]; and specific neural circuits develop during ontogeny and transform the infants locomotor pattern [6]. The developmental of neural circuits are impairment and the complexity of controls is reduced in children with CP [7]. With growth, musculoskeletal deformities usually appear as a result of abnormal forces acting on the developing body. Therefore, the gait of children with CP is the result of neurological changes and musculoskeletal disorders.

There is pronounced individual variety of movement patterns in ambulatory children with CP, depending on the severity of such disorders [8] [9]. Using computerized three-dimensional gait analysis (3DGA), it has been possible to identify the similarities and differences of abnormal gait patterns in patients with CP [9]. Gait Classification System (GCSs) have been reported to aid in clinical decision making, in improving communication among healthcare providers and in comparing gait between or within specific patients [10].

Several gait classifications of qualitative and quantitative data were described for the past few decades [11]–[19]. Accurate gait classification of CP has been shown challenging because of its heterogeneous presentations [20], and the difficulty in which gait parameters provide a faithful measure of neuromuscular function [21].

In 2016, Nieuwenhuys et al. identified 49 clinically important gait patterns across the pelvis, hip, knee and ankle [22]. Thus, seemingly infinite variation in and combinations of patterns are possible [10], [19].

According, Rodda et al., sagittal gait pattern changed in 50% of patients, some towards true equinus and others to crouch gait [14]. Bell et al., confirmed that deterioration in normalized walking speed, increased flexion and increased stiffness may be the natural history for children with spastic diplegia [23]. Rosenbaum et al. describes a plateau in motor development around the age of seven years [24] and in some there is deterioration in walking ability through adolescence and adulthood [23].

In children with CP, sagittal gait patterns and their associated classifications are not always static [14]. Gait deviations in CP tend to be a continuum of deviations rather than well delineated groups [25], and categorization approaches are often based on partial information, and data close to the boundary between classes could be erroneously classified [22].

The development of a classification of levels of gait, that allows the assisting professional to easily identify the current gait status of the children with CP and create a panorama with probable evolutions, seems desirable.

To build the classification, it was taking into account that the basic function of the lower limb during stance is to resist collapse and to extend sufficiently to achieve the required push-off. Collapse of the lower limb requires a flexion at all three joints: knee, ankle and hip [26]. A cycle of muscle damage, tendinous lengthening, bone deformity and increasing tension may explain the progressive nature of flexed-knee gait [27]. The excessive flexion of the hip, knee, and ankle during the stance phase of gait produce an inefficient walking pattern and if left untreated can lead to joint pain, bone deformities and, in some cases, loss of independent gait [28]. For that, we conceptualized that the joints of the ankles and knees would determine the progression of the classification. The increase in knee flexion with ankle dorsiflexion would be determinants of less gait functionality.

The aim of this study is to develop a classification with a concept of continuity using elements of previous classifications. The secondary objective was to evaluate the reliability of the new classification. Intra and interrater reliability was assessed using only observational gait analysis (OGA) and then including 3DGA data. Reliability was also assessed among different professionals, in relation to more and less experienced evaluators and between each evaluator and the authors' consensus rating.

2. Methods

After the project was approved by local research ethics committee, number: 2.447.001, the study was developed by an estimated sample of 51 individuals considering the prevalence of 0.3% [3] and maximum standard error of 1.5%. The search conducted from the database of the Gait Analysis Laboratory at the Ana Carolina de Moura Xavier Rehabilitation Hospital Center in Curitiba, Paraná, Brazil, provided a sample of 101 children who had undergone gait analysis with a diagnosis of spastic cerebral palsy and symmetrical lower limbs. Written informed consent was obtained from all subjects.

Eligible patients were between 5 years old and 18 years old, classified in Gross Motor Function Classification System (GMFCS) levels I to IV, had predominantly spastic CP, and had undergone OGA and 3DGA. Previous treatments such as single-event multilevel surgery or botulinum toxin type A injections were allowed.

The study was made in three parts. The first was a cross-sectional study to develop a classification of the gait levels for children with CP. The second part was to classify the sample using the new classification and to make comparisons between the groups formed. The third part was to investigate the reliability of the classification.

2.1. Measurements

Each participant's gait was recorded on video, using sagittal and coronal views. The OGA, was performed by visual observation of two-dimensional videos. The patients walked barefoot on a ten meters walkway at their normal self- selected speed. Instrumented 3DGA was performed using the conventional gait model (Helen-Hayes model)[13], with reflective markers (n =26), to obtain spatiotemporal parameters (step and stride lengths, cadence, walking velocity) and lower extremity kinematics at the pelvis, hip, knee, and ankle. 3D kinematic and kinetic gait data were collected bilaterally using 6 digital motion analysis cameras (Motion Analysis Corporation in Santa Rosa, CA) sampling at 60 Hz. Joint kinematics were calculated by the Cortex software (Motion Analysis Corp., Santa Rosa, CA). The data was processed using OrthoTrack software (OrthoTrack 6.5.1 software, Reference Manual 2007. Motion Analysis Corporation, Santa Rosa, CA). The data were smoothed using a Butterworth filter with a cut-off frequency of 6 Hz. The motion analysis system was calibrated before each analysis. All kinematic data were time-normalized to 100 % of one gait cycle.3DGA kinematics were used to calculate the GPS, which quantifies the overall deviation of an individual's gait from normal gait[14]The kinematic data were collected from a minimum of 7 gait cycles for each assessed leg and the most representative trial was reported, alongside the corresponding video clips, and classified according to the gait classification of level in CP children.

The GMFCS was assigned by a senior clinical physiotherapist and a pediatric orthopedist in consultation with the child and his or her parents.

2.2. Cross-sectional study

The sample of 101 participants, with symmetrical lower limbs, were assessed using OGA and 3DGA data to elaborate the classification of gait levels. The progressive knee flexion (sagittal plane), transverse plane deviations and need to use walking aids, were the determinants for the elaboration of the new classification.

After the elaboration of the new classification the sample of patients was classified into the levels, and the groups formed were compared in respect to age, gait velocity, GMFCS and GPS.

The face and criterium validity were assessed through the classification capacity to allocate the sample in the levels, and for the use of quantitative kinematic data, respectively. The concurrent validity was assessed by the clinical significance difference between the average GPS in the levels of the classification.

2.3. Reliability study

A brief learning phase was proposed, when all raters participated in an online presentation, with discussion of the classification and presentation of examples to illustrate how to grade the cases using the new classification. The raters were provided with written definitions and illustrations of the posture of the ankle, knee, hip and pelvis for each gait pattern in relation to the planes of motion (supplementary material).

To determine intra and interrater reliability, 20 participants were evaluated (40 lower limbs) with predominantly asymmetrical movement pattern of the lower limb, different from the 101 participants evaluated in the cross-sectional study. These participants were selected in order to create a sample that included variation in age and levels of neurological involvement (GMFCS). Four raters classified the sample (two PT and the two PO), three of them had more than 3 years of experience in gait analysis, and one had limited experience in 3DGA. The evaluators, during online presentation of the cases, were asked to initially classify using only video (OGA) and then using video and 3DGA data. To determine intrarater reliability, the raters evaluated the 20 participants (40 lower limbs) a second time, at the same way, one month after the initial assessment. The right and left sides of the lower limbs were classified. The authors produced a consensus classification of the sample under study of reliability. Then, the reliability between the raters and the consensus was calculated. The reliability between the two PT and the two PO was also assessed.

2.4. Statistical Analysis

Descriptive data were presented as means and standard deviations or as medians and interquartile ranges, according to the normality distribution, analyzed using the Shapiro-Wilk test. For the comparison between groups with normal distribution, one-way ANOVA analysis was performed using Tukey's post hoc test. For data with non-normal distribution, the Kruskal-Wallis test was used and Mann-Whitney´s post hoc test. The level of significance was set at $p < 0.05$.

The reliability of the classification was determined by Fleiss's Kappa for interrater evaluation. Weighted Kappa statistics were used to summarize intrarater reliability, between raters and golden standard, and between the two professional categories, with quadratic weight for the three ordered levels. The analyses were performed in SPSS statistical software, Version 27.

The strength of k was interpreted as: equal to zero, “without agreement”; between zero and 0.19, “poor agreement”; from 0.20 to 0.39, “weak agreement”; from 0.40 to 0.59, “moderate agreement”; from 0.60 to 0.79, "substantial agreement"; from 0.80 to 1.00, “almost perfect agreement” [31].

3. Results

3.1 Cross-sectional study

The sample consisted of 101 participants with spastic CP, being 50 boys (49.50%) and 51 girls (50.49%), 15 unilateral and 86 bilateral CP. Of these, 20 were GMFCS I, 62 were GMFCS II, 16 were GMFCS III and 3 were GMFCS IV. The mean age was 11.89 ± 3.4 years and 35.64% of the patients had prior orthopedics surgery. Walking assistive devices were used for 16 individuals (15.84%) in the sample, with 10 walkers, 4 crutches and 2 walking sticks. All groups of the classification were represented in the evaluated sample and all patients in the sample were classified according the levels.

3.1.1 Description of the gait classification categories.

The three levels of gait abnormalities were defined after reviewing the entire sample and are described in Table 1 and represented schematically in Figure 1. Figure 2 summarizes the kinematic data from the sagittal plane (pelvis, hip, knee, ankle) for each gait level within one standard deviation from normal.

Level 1 participants had kinematics in the sagittal plane as typical or minor deviations from normality in the hips and knees and normal or with a trend to plantar flexion in the ankles (Table 1). In the transverse plane they had normal rotational profile or deformity in just one level (pelvic/hip/knee/foot). The distribution of transverse plane alterations in level 1 participants was: normal in 40 lower limbs (86.95%), single level internal rotation in 5 (10.98%), and single level external rotation in 1 (2.17%). The Figure 3 presents a trend to internal foot progression angle. The level 1 participants did not use any walking aids.

The participants of levels 2 had the kinematics in sagittal plane of motion similar to level 1, when using walking aids. The participants level 2 presented, independently of walking aids or deformities in transverse plane, with knees in flexion or hyperextension and ankle in normal dorsiflexion or plantarflexion (Table 1). Level 2, normal transverse plane was present in 49 lower limbs (44.54%), normal off- setting alignment (compensated internal and external rotation) in 11 (10%), single level internal rotation in 42 (38.18%), multi-level internal rotation in 6 (5.45%), and multi external rotation in 2 (1.81%). The Figure 3 presents a trend to internal foot progression angle.

The participants of the level 3 had the kinematics in sagittal plane in triple flexion of the hip, knee and ankle (trend to excessive dorsiflexion). The participants level 3 could use walking aids and have transverse plane deformities in single or multilevel (Table 1). The level 3, presented with normal transverse plane in 19 lower limbs (41.30%), normal off-setting alignment (compensated internal and external rotation) in 12 (26.08%), single level internal rotation 3 (6.52%), single level external rotation in 3 (6.52%), and multi-level external rotation in 9 (19.56%). Figure 3 shows a more variable position of foot progression angle.

The characteristics of the three levels of the classification in relation to age, gait velocity, GMFCS and GPS, are shown in Table 2. The velocity decrease from the levels 1 and 2 to level 3, with statistically difference between level 1 and 3 and level 2 and 3. The GMFCS increases from level 1 to 2 and 3, with statistically difference between level 1 and 2 and level 1 and 3 (Table 2). The GPS overall showed decrease of functionality from level one to 3 with statistically difference between all groups of the classification (Table 2). The difference was progressively higher than 3 degrees between the levels ($p<0.001$).

Level 2, 8 participants (14.54%) used walking assistive devices, 4 crutches and 4 walkers. Level 3, 9 participants (39.13%) used walking aids, 6 walkers, 1 pair of crutches and 2 walking sticks.

Among GMFCS I participants, 12 were level 1 and 8 were level 2. Participants from GMFCS II, 11 were level 1, 36 were level 2 and 15 were level 3. The GMFCS III group, 11 were level 2 and 5 were level 3. All three GMFCS IV participants were level 3.

The relation between previous calf surgery and levels of gait was: 4 participants (17.39%) level 1, 17 participants level 2 (30.90%), and 15 participants level 3 (65.22%) had previous calf surgery.

3.2 Reliability study

The overall interrater reliability across the levels of the classification was 0.684 (0.595-0.774) using 3DGA, and 0.671 (0.581-0.761) using OGA, according Kappa Fleiss (k) statistics with 95% CI.

Intrarater reliability of the classification using OGA and 3D data is presented in Table 3. The reliability between the raters and authors consensus, using OGA and 3DGA were presented in Table 4.

An additional analysis was performed considering the comparison between different professionals and between more and less experienced raters. The reliability between the two PT and between the two PO was 0.870 (0.768-0.972) and 0.826 (0.715-0.938) for 3DGA, respectively. The reliability between the two PT and between the two PO was 0.936 (0.864-1.008) and 0.740 (0.599-0.881) using OGA, respectively, according Kappa weighted, with 95% confidence interval (CI). The reliability of the more and less experienced raters showed similar results.

4. Discussion

The current study uses the concept of gait in children with CP as a continuum of changes and not something that can be categorized in a static way. When assessing the gait of 101 children with CP, it was possible to develop a classification of gait levels. To construct the classification, data from 2D videos and kinematics of more than one plane of movement (sagittal and transverse planes) was used. The level classification uses concepts from previous classifications, such as the sagittal plane of the classification of Rodda et. al. [14] and Papageorgiou et al [32], and the transverse plane of the Davids and Bagley classification [15].

The classification developed also incorporated the use of walking aids because of the possibility of, when used, masking kinematic changes in the lower limbs [33]. The use of walking aids is a way to compensate for deficits in balance and/or muscle weakness [34].

In the sagittal plane, the levels of the gait were divided according to the position of the knee and ankle in the stance, this because over 80% of the variance of the support moment of CP patients is explained by a linear relationship with knee flexion [35]. In this sense, the levels classification use factors that lead children with CP to develop increased knee flexion. These are a combination of factors, including mechanical insufficiency of the plantar flexors and knee extensors muscles (sagittal plane), lever-arm dysfunction (transverse plane), and weakness (walking aids) [35].

The classification showed face and criterium validity, due capacity to allocate the sample in the levels and for the use of quantitative kinematic data, respectively. The concurrent validity was assessed by the difference between the average GPS of the levels of 3°, that is the minimal clinically important difference between levels of the GMFCS (2.98°) [36]. The GMFCS levels increased with the increase of the classification`s levels, and it also presents a progressive frequency of knee flexion in the stance phase of the gait [37]. However, the GMFCS has an overlap of motor patterns [37], and does not present mobility, it is almost stable. The level classification of the gait has the capacity to differentiate motor levels and present mobility between the levels, something uncommon to GMFCS.

Participants with complete knee extension were classified as level 1 and the ones with knee flexion in levels 2 and 3. The positioning of the ankle on the stance differentiates level 2 and 3, with the first presenting the ankle in a normal position or in plantar flexion, while the latter with tendency to excessive dorsiflexion. Therefore, level 1 resembles the mild gait and true equinus pattern; level 2, true equinus, jump gait and apparent equinus; and level 3, apparent equinus and crouch gait of the Rodda et al. classification [14]. The transverse plane used the concept of position of the foot progression angle and the elements that produce the alignment, single or multilevel [15]. The alignment of the transverse plane showed a progressive increase in the frequency and complexity of abnormalities. Level 1 had 86.95% of normal participants, while the percentage of normal was 44.54% and 41.30%, at levels 2 and 3, respectively. The abnormalities at level 3 showed a higher frequency of more complex disorders (multilevel), being 45.62% compared to 17.26% at level 2. This situation corroborates the classification's ability to identify progressive abnormalities in this plane of movement.

In ambulant children with cerebral palsy, the self-selected velocity of walking is reduced in proportion to the severity of disability [38]. This premise was confirmed by the progressive decrease in velocity according to the increase in classification levels (Table 2). The impairment of selective control is another significant factor for less motor function and the GPS has a negative correlation [39]. In the classification proposed in this study, there is a progressive increase of three degrees in the GPS between the classification levels. What seems to demonstrate that the progression of the levels was related to a decrease in the selective control and motor function of the participants.

The gait classification in levels for CP can be used for children with unilateral or bilateral impairment. However, only children with bilateral impairment will reach the most advanced level of the classification.

The authors recommend using the classification to guide treatments and future comparisons. The traffic light classification provides a simple and common language based upon three-level colors coding, according Novak et al [40]. Level 1 (green) would indicate that the patient is progressing without significant skeletal muscle problems. Level 2 (yellow), a warning signal should be recognized, as skeletal muscle problems are apparent and must be interfering with the walking ability. At level 3 (red), skeletal muscle changes are significantly altering gait capacity and should have their correction strongly considered.

Although there is an attempt to delimit the characteristics of each level, the data produces continuity between the classification ranges and allows a simple and practically automatic classification of the participants. The authors encourage the use of transition levels such as 1-2 and 2-3 in future work.

The classification showed substantial interrater reproducibility using OGA and using 3DGA and video. The intra rater reliability of the classification using 3D data and OGA was substantial to almost perfect.

The reliability between the raters and authors consensus, was substantial to almost perfect for all raters. In the evaluated sample, similar results were obtained by evaluators with and without experience with 3DGA. The reliability within the two professional categories was substantial to almost perfect. The daily clinical applicability of the classification was determined by the significant results obtained only with the analysis of the video, for the ability of less experienced evaluator and different professionals to use the classification properly.

Previous calf surgery may play a predisposing cause to evolution to level 3, in the sample evaluated. It's important to remember that crouch gait, one pattern of level 3, are also part of the natural history of spastic diplegia for some children [14]. However, as the age range of individuals from the other groups was not statistically different, triceps sural lengthening surgery should be considered a predisposing factor for the evolution to the level 3, since the soleus muscle provide significant stance phase support [41].

Limitations of this study are related to the fact that most of our participants were referred for gait analysis for preoperative evaluation to improve their ambulatory function, their gait problems may not reflect those of the general CP population. During the cross-sectional study the classification was not used in asymmetric patients. However, during the reliability study, symmetrical and asymmetric individuals were analyzed and the rater classified differently each lower limb.

5. Conclusion

The new classification proved to be valid, reliable and has advantages because uses the idea of continuity rather than rigid categorization. The classification can be used for evaluators with less experience in gait analysis using only OGA. Longitudinal studies in the future to determine the responsiveness of the classification during the natural evolution or after treatments is strongly encouraged.

Author contribution statement

Alessandro G. Melanda (Conceptualization) (Methodology) (Validation) (Formal Analysis) (Investigation) (Data Curation) (Writing – Original Draft) (Writing – Review & Editing) (Visualization) (Supervision).
Alexandre R M Pelegrinelli (Data Curation) (Writing – Review & Editing) (Visualization).
Dirce Shizuko. Fujisawa (Conceptualization) (Visualization) (Supervision).
Suhaila Mahmoud Smaili (Conceptualization) (Formal Analysis) (Writing – Review & Editing) (Visualization) (Supervision).

All authors have read and approved the final manuscript.

Declaration of Competing Interest

All authors declare that they have no conflicting interests. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

The authors would like to express appreciation to physiotherapists Alana Ferreira and Luiz Alberto Knaut, and the pediatric orthopedic surgeons Ana Carolina Pauleto and João Paulo M. B. Monteiro for their help in the interrater and intrarater reliability components of this study.

Supplementary data

Complementary material related to this article can be found after the illustrations.

Appendix A. Written description of the gait classification categories.
Appendix B. Orientation of how to use the Classification System (PowerPoint presentation).

References

[1] J.-P. L. H. Kerr Graham1–3, Peter Rosenbaum4, Nigel Paneth5, Bernard Dan6, A. C. Diane L. Damiano8, Jules G. Becher9, Deborah Gaebler-Spira10, and K. E. C. and R. L. L. Dinah S. Reddihough12, “Cerebral Palsy,” *Nat. Rev.* **|** *Dis. Prim.*, vol. 2, pp. 1–24, 2016, doi: 10.1038/nrdp.2015.82.

[2] E. Beckung, G. Hagberg, P. Uldall, and C. Cans, “Probability of walking in children with cerebral palsy in Europe,” *Pediatrics*, vol. 121, no. 1, 2008, doi: 10.1542/peds.2007-0068.

[3] L. F. Van Vulpen, S. De Groot, E. Rameckers, J. G. Becher, and A. J. Dallmeijer, “Improved Walking Capacity and Muscle Strength After Functional Power-Training in Young Children With Cerebral Palsy,” 2017, doi: 10.1177/1545968317723750.

[4] D. DeJaeger, P. A. Willems, and N. C. Heglund, “The energy cost of walking in children,” *Pflugers Arch. Eur. J. Physiol.*, vol. 441, no. 4, pp. 538–543, 2001, doi: 10.1007/s004240000443.

[5] D. H. Sutherland *et al.*, “The development of mature gait,” *J. Bone Jt. Surg.*, vol. 62, pp. 336–353, 1980, doi: 10.1016/S0966-6362(97)00029-5.

[6] H. Forssberg, “Experimental Br n Research,” *Exp. Brain Res.*, vol. 57, pp. 480–493, 1985, doi: 0014-4819.

[7] K. M. Steele, A. Rozumalski, and M. H. Schwartz, “Muscle synergies and complexity of neuromuscular control during gait in cerebral palsy,” *Dev. Med. Child Neurol.*, vol. 57, no. 12, 2015, doi: 10.1111/dmcn.12826.

[8] J. Riad, Y. Haglund-Akerlind, and F. Miller, “Classification of spastic hemiplegic cerebral palsy in children,” *J. Pediatr. Orthop.*, vol. 27, no. 7, pp. 758–764, 2007, doi: 10.1097/BPO.0b013e3181558a15.

[9] D. J. Kim, E. S. Park, E. G. Sim, K. J. Kim, Y. U. Kim, and D. Rha, “Reliability of Visual Classification of Sagittal Gait Patterns in Patients with Bilateral Spastic Cerebral Palsy,” *Ann. Rehabil. Med.*, vol. 35, no. 3, p. 354, 2011, doi: 10.5535/arm.2011.35.3.354.

[10] F. Dobson, M. E. Morris, R. Baker, and H. K. Graham, “Gait classification in children with cerebral palsy: A systematic review,” *Gait Posture*, vol. 25, no. 1, pp. 140–152, 2007, doi: 10.1016/j.gaitpost.2006.01.003.

[11] O. R. Wong MA, Simon S, “Statistical analysis of gait patterns of persons with cerebral palsy,” *Stat Med.*, vol. 2, no. 3, p. 345-354, 1983, doi: doi:10.1002/sim.4780020306.

[12] S. Õunpuu *et al.*, “Gait patterns in spastic hemiplegia in children and young adults Patterns in Spastic and Young Hemiplegia Adults.,” *J. Bone Jt. Surg.*, vol. 69, no. 10, pp. 437–441, 1987, doi: 10.1302/0301-620X.86B2.13878.

[13] J. Sutherland, DH; Davids, “Common Gait Abnormalities of the Knee in Cerebral Palsy,” *Clin. Orthop. Relat. Res.*, vol. march, no. 288, pp. 139–147, 1993.

[14] J. M. Rodda, H. K. Graham, L. Carson, M. P. Galea, and R. Wolfe, “Sagittal gait patterns in spastic diplegia,” *J. Bone Jt. Surg.*, vol. 86, no. 2, pp. 251–258, 2004, doi: 10.1302/0301-620X.86B2.13878.

[15] J. R. Davids and A. M. Bagley, “Identification of Common Gait Disruption Patterns in Children With Cerebral Palsy,” *J. Am. Acad. Orthop. Surg.*, vol. 22, no. 12, pp. 782–790, 2014, doi: 10.5435/JAAOS-22-12-782.

[16] A. Carriero, A. Zavatsky, J. Stebbins, T. Theologis, and S. J. Shefelbine, “Determination of gait patterns in children with spastic diplegic cerebral palsy using principal components,” *Gait Posture*, vol. 29, no. 1, pp. 71–75, 2009, doi: 10.1016/j.gaitpost.2008.06.011.

[17] A. Bonnefoy-Mazure, Y. Sagawa, P. Lascombes, G. De Coulon, and S. Armand, “Identification of gait patterns in individuals with cerebral palsy using multiple correspondence analysis,” *Res. Dev. Disabil.*, vol. 34, no. 9, pp. 2684–2693, 2013, doi: 10.1016/j.ridd.2013.05.002.

[18] L. Van Gestel *et al.*, “Probabilistic gait classification in children with cerebral palsy: A Bayesian approach,” *Res. Dev. Disabil.*, vol. 32, no. 6, pp. 2542–2552, 2011, doi: 10.1016/j.ridd.2011.07.004.

[19] E. Papageorgiou, A. Nieuwenhuys, I. Vandekerckhove, A. Van Campenhout, E. Ortibus, and K. Desloovere, “Systematic review on gait classifications in children with cerebral palsy: an update,” *Gait Posture*, 2019, doi: 10.1016/j.gaitpost.2019.01.038.

[20] Nirav K. Pandya; Scott P. Kaiser, “Cerebral Palsy,” in *Orthopaedic: Knowledge Update - Pediatrics (5)*, 5° Edition., J. E. Martus, Ed. Rosemont, Il: AAOS, 2016, pp. 4422–426.

[21] C. L. Vaughan and M. J. O’Malley, “A gait nomogram used with fuzzy clustering to monitor functional status of children and young adults with cerebral palsy,” *Dev. Med. Child Neurol.*, vol. 47, no. 6, pp. 377–383, 2005, doi: 10.1017/S0012162205000745.

[22] G. K. Id *et al.*, “Multi-joint gait clustering for children and youth with diplegic cerebral palsy,” vol. 1, no. C, pp. 1–18, 2018.

[23] K. J. Bell, S. Ounpuu, P. A. DeLuca, and M. J. Romness, “Natural progression of

gait in children with cerebral palsy," *J. Pediatr. Orthop.*, vol. 22, no. 5, pp. 677–682, 2002, doi: 10.1097/01.BPO.0000023143.69745.A9.

[24] P. L. Rosenbaum *et al.*, "Prognosis for gross motor function in cerebral palsy: Creation of motor development curves," *J. Am. Med. Assoc.*, vol. 288, no. 11, pp. 1357–1363, 2002, doi: 10.1001/jama.288.11.1357.

[25] S. Arma[1] S. Armand, G. Decoulon, and A. Bonnefoy-Mazure, "Gait analysis in children with cerebral palsy," EFORT Open Rev., vol. 1, no. 12, 2016.nd, G. Decoulon, and A. Bonnefoy-Mazure, "Gait analysis in children with cerebral palsy," *EFORT Open Rev.*, vol. 1, no. 12, 2016, doi: 10.1302/2058-5241.1.000052.

[26] D. A. Winter, "Overall principle of lower limb support during stance phase of gait," *J. Biomech.*, vol. 13, no. 11, pp. 923–927, 1980, doi: 10.1016/0021-9290(80)90162-1.

[27] A. E. McNee, A. P. Shortland, L. C. Eve, R. O. Robinson, and M. Gough, "Lower limb extensor moments in children with spastic diplegic cerebral palsy," *Gait Posture*, vol. 20, no. 2, pp. 171–176, 2004, doi: 10.1016/j.gaitpost.2003.08.009.

[28] K. M. Steele, A. Seth, J. L. Hicks, M. S. Schwartz, and S. L. Delp, "Muscle contributions to support and progression during single-limb stance in crouch gait," *J. Biomech.*, vol. 43, no. 11, pp. 2099–2105, 2010, doi: 10.1016/j.jbiomech.2010.04.003.

[29] W. M. Kadaba M, Ramakrishnan H, "Measurement of lower extremity kinematics during level walking," *J. Orthop. Res.*, vol. 08, pp. 383–392, 1990.

[30] R. Baker *et al.*, "The Gait Profile Score and Movement Analysis Profile," *Gait Posture*, vol. 30, no. 3, pp. 265–269, 2009, doi: 10.1016/j.gaitpost.2009.05.020.

[31] G. G. Landis, J R ; Koch, "The measurement of observer agreement for categorical data," *Biometrics*, vol. 33, no. 1, pp. 159–74, 1977.

[32] E. Papageorgiou, A. Nieuwenhuys, I. Vandekerckhove, and A. Van Campenhout, "Systematic review on gait classifications in children with cerebral palsy : An update," *Gait Posture*, vol. 69, no. November 2018, pp. 209–223, 2019, doi: 10.1016/j.gaitpost.2019.01.038.

[33] M. N. Eek, R. Tranberg, and E. Beckung, "Muscle strength and kinetic gait pattern in children with bilateral spastic CP," *Gait Posture*, vol. 33, no. 3, pp. 333–337, 2011, doi: 10.1016/j.gaitpost.2010.10.093.

[34] B. K. Krautwurst, T. Dreher, and S. I. Wolf, "The impact of walking devices on kinematics in patients with spastic bilateral cerebral palsy," *Gait Posture*, vol. 46, pp. 184–187, 2016, doi: 10.1016/j.gaitpost.2016.03.014.

[35] A. E. Mcnee, A. P. Shortland, L. C. Eve, R. O. Robinson, and M. Gough, “Lower limb extensor moments in children with spastic diplegic cerebral palsy,” vol. 20, pp. 171–176, 2004, doi: 10.1016/j.gaitpost.2003.08.009.

[36] R. Baker, J. L. McGinley, M. Schwartz, P. Thomason, J. Rodda, and H. K. Graham, “The minimal clinically important difference for the Gait Profile Score,” *Gait Posture*, vol. 35, no. 4, pp. 612–615, 2012, doi: 10.1016/j.gaitpost.2011.12.008.

[37] S. Õunpuu *et al.*, “Variation in kinematic and spatiotemporal gait parameters by Gross Motor Function Classification System level in children and adolescents with cerebral palsy,” *Dev. Med. Child Neurol.*, vol. 57, no. 10, pp. 955–962, 2015, doi: 10.1111/dmcn.12766.

[38] M. Pirpiris *et al.*, “Walking speed in children and young adults with neuromuscular disease: Comparison between two assessment methods,” *J. Pediatr. Orthop.*, vol. 23, no. 3, pp. 302–307, 2003, doi: 10.1097/01241398-200305000-00006.

[39] E. Chruscikowski, N. R. D. Fry, J. J. Noble, M. Gough, and A. P. Shortland, “Selective motor control correlates with gait abnormality in children with cerebral palsy,” *Gait Posture*, vol. 52, pp. 107–109, 2017, doi: 10.1016/j.gaitpost.2016.11.031.

[40] I. Novak *et al.*, “A systematic review of interventions for children with cerebral palsy : state of the evidence Study design,” 2013, doi: 10.1111/dmcn.12246.

[41] S. M. Gage JR, “The Treatment of Gait Problems in Cerebral Palsy,” First., Gage JR, Ed. London: Mac Keith Press, 2004, pp. 180–204.

Table 1. Characteristics definition of kinematics and walking aids for levels of gait in CP children.

Gait Level	Sagital plane				Transverse plane	Walking aids
	Pelvic tilt	Hip Fx/Ext	Knee Fx/Ext	Ankle Df/Pf	Rotation profile	canes/ Crutches/ walkers
Level 1 (n=23)	Normal Anterior	Normal or Minor deviations	Normal or Minor deviations	Normal or trend to plantarflex.	Normal or single level	No
* Level 2 (n=55)	Normal Anterior	Normal or Minor deviations	Minor deviations or hypertext.	Normal or Plantarflex .	Multi-level	and/or Yes
	Normal Anterior Posterior	Flexed	Flexed	Normal or Plantarflex	Normal Single/multi-level	No or Yes
Level 3 (n=23)	Anterior Normal Posterior	Flexed	Flexed	Excessive dorsiflex.	Normal Single/multi-level	No or Yes

Hip Fx/Ext: hip flexion and extension. Knee Fx/Ext: knee flexion and extension. Ankle Df/Pf; ankle dorsiflexion and plantarflexion. Hyperext.: hyperextension. Plantarflex.: plantarflexion. Dorsiflex.: dorsiflexion.

* Note that a child with sagittal plane characteristics of level 1 becomes level 2 when presenting multi-level deformity in the transversal plane of movement or use walking aids to walk.

Walking aids: walking sticks, crutches or walkers.

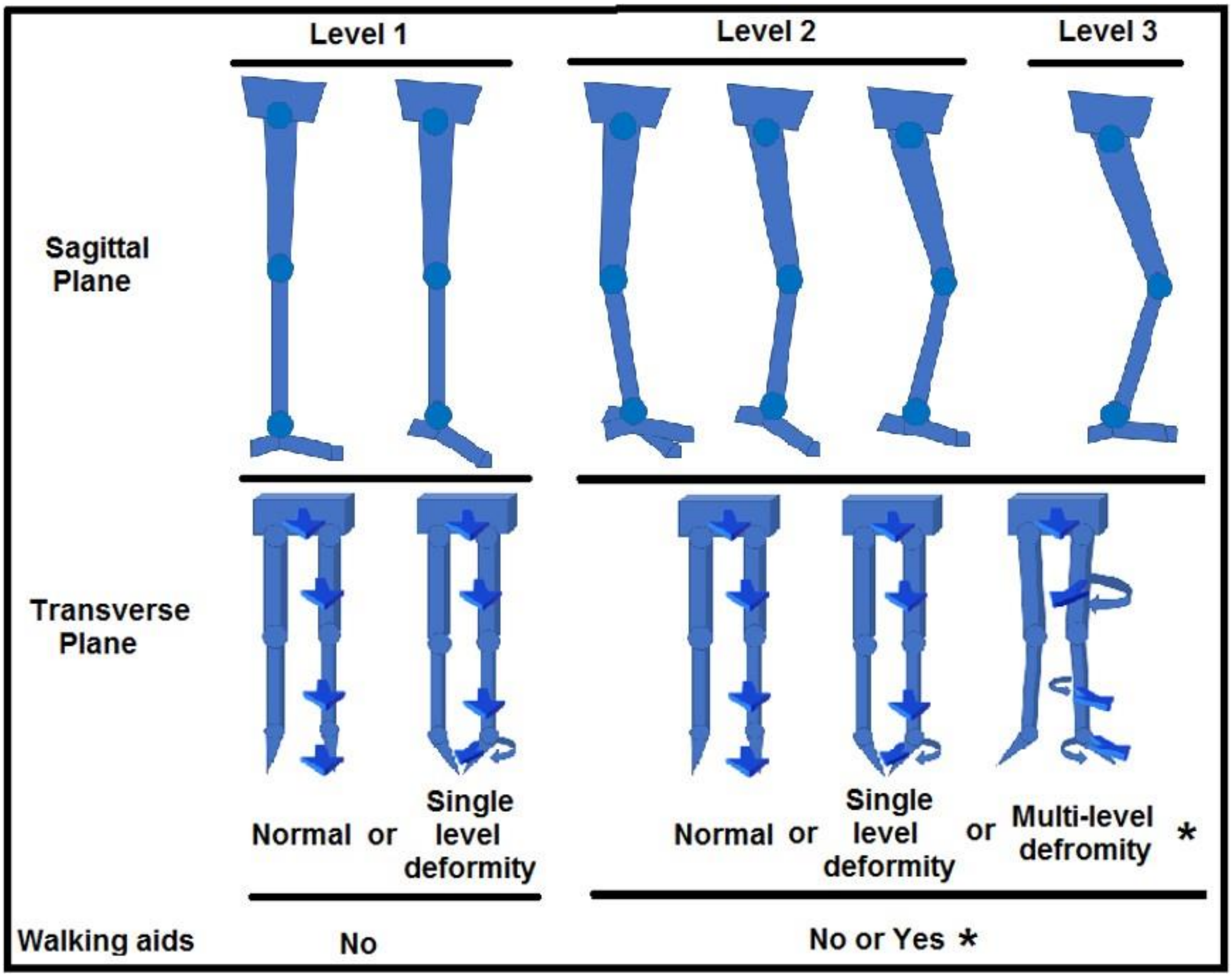


Figure 1. Diagrams showing schematic drawing of the sagittal and transverse plane gait characteristics of the lower limbs, as well as the use of walking aids for each gait level in children with CP.

***** Note that a child with sagittal plane characteristics of level 1 becomes level 2 when presenting multi-level deformity in the transverse plane of movement or use walking aids to walk.

Walking aids: canes, crutches or walkers.

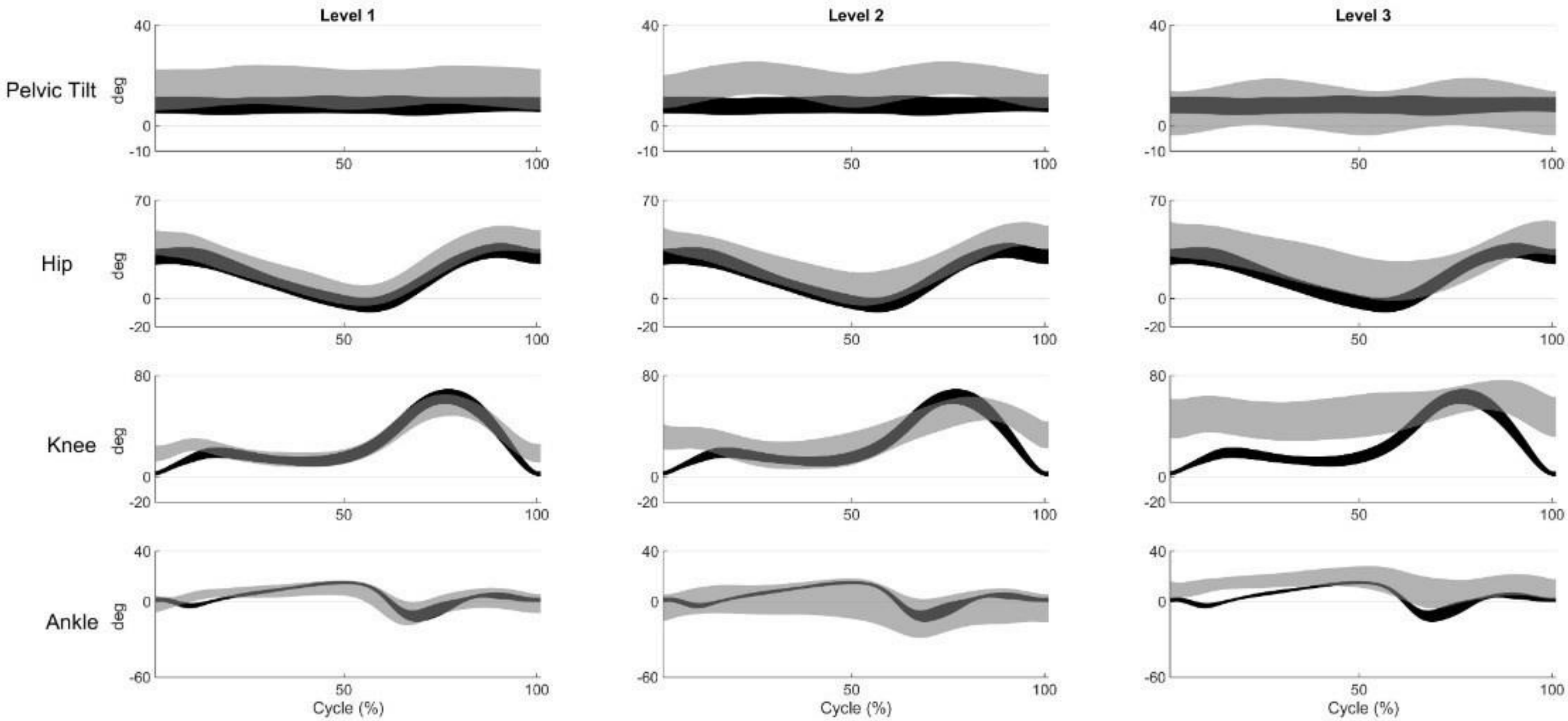


Figure 2. The summarized sagittal plane kinematic data for each gait level for the study population. The black band represented the mean ± 1 SD of kinematic data normal database, and the grey band the mean ± 1 SD for each gait pattern. The vertical axis represents joint angular displacement and the horizontal axis, 100% of the gait cycle

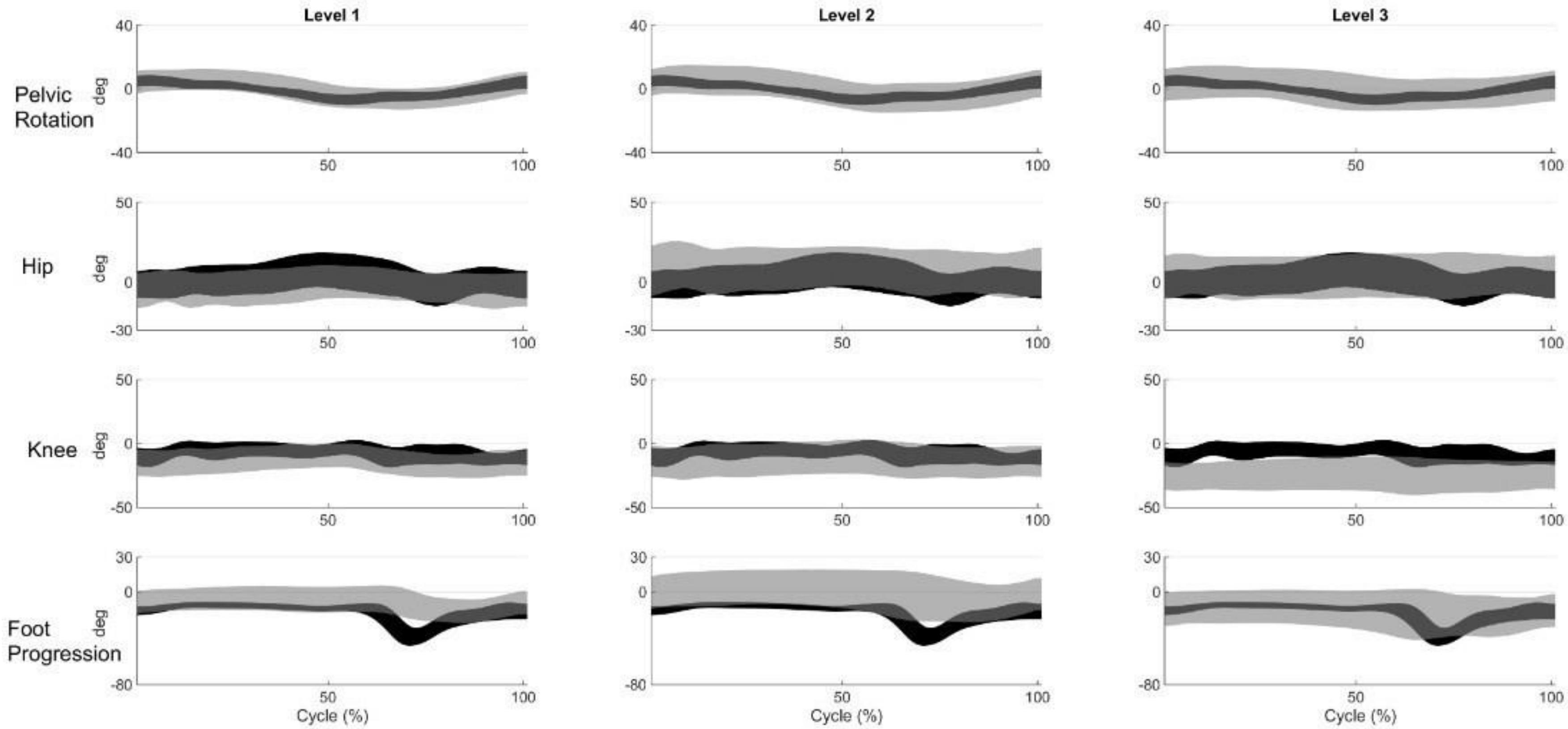


Figure 3. The summarized transverse plane kinematic data for each gait level for the study population. The black band represented the mean ± 1 SD of kinematic data normal database, and the grey band the mean ± 1 SD for each gait pattern. The vertical axis represents joint angular displacement and the horizontal axis, 100% of the gait cycle.

Table 2. Mean and standard deviation or median and interquartile range of the variables age, gait velocity, GMFCS and GPS according to gait level under investigation.

Gait levels/ variables	Level 1 (n=23)	Level 2 (n=55)	Level 3 (n=23)	P
Age (years)	12.16 ±2.81	11.31±3.37 [a]	13.95±2.76 [b]	0.008
Velocity (cm/s)	90.00 [73.00-106.80]	84.00 [64.90-98.10]	56.85 [39.90-83.60] [b,c]	0.001
GMFCS	1 [1-2]	2 [2-2] [a]	2 [2-3] [b]	<0.001
GPS (°)	10.40 [8.60-11.70]	13.40 [11.40-16.10] [a]	16.40 [15.00-19.80] [b,c]	<0.001

cm/s= centimeters per second, GMFCS= Gross Motor Function Classification System, (°) = degrees.

a = statistically significant difference between level 1 and level 2.
b = statistically significant difference between level 1 and level 3.
c = statistically significant difference between level 2 and level 3.

Table 3. Weighted Kappa (k) statistics with 95% CI for intrarater reliability using OGA and 3DGA to classify the sample.

Raters/ OGA n=40	**k**	**SE**	**CI 95%**	**P**
*rater 1	0.887	0.046	0.796-0.978	<0.001
*rater 2	0.774	0.067	0.642-0.906	<0.001
*rater 3	0.814	0.057	0.702-0.926	<0.001
rater 4	0.767	0.066	0.639-0.896	<0.001
Raters/ 3DGA n=40	**k**	**SE**	**CI 95%**	**P**
*rater 1	0.857	0.054	0.752-0.963	<0.001
*rater 2	0.892	0.049	0.796-0.987	<0.001
*rater 3	0.867	0.046	0.776-0.958	<0.001
rater 4	0.717	0.091	0.539-0.895	<0.001

SE= Standard Error; CI= Confidence Interval; OGA: observational gait analysis.
*Experienced clinicians (>3y experience assessing 3DGA).

Table 4. Weighted Kappa (k) statistics with 95% CI for reliability between the raters and the authors consensus using OGA and 3DGA to classify the sample.

Raters/ OGA n=40	**k**	***SE***	**CI 95%**	**P**
*rater 1	0.941	0.034	0.873-1.008	<0.001
*rater 2	0.879	0.049	0.784-0.975	<0.001
*rater 3	0.781	0.065	0.653-0.908	<0.001
rater 4	0.896	0.046	0.805-0.987	<0.001

Raters/ 3DGA n=40	**k**	**SE**	**CI 95%**	**P**
*rater 1	0.876	0.050	0.777-0.974	<0.001
*rater 2	0.842	0.057	0.731-0.954	<0.001
*rater 3	0.845	0.054	0.739-0.950	<0.001
rater 4	0.942	0.034	0.876-1.008	<0.001

SE= Standard Error; CI= Confidence Interval. OGA: observational gait analysis; *Experienced clinicians (>3y experience assessing 3DGA).

7.1. Supplementary data (Training material for raters)

Appendix A. Written description of the gait classification categories.

The three levels of gait abnormalities have been defined after the review of the entire sample. Figure A1 and Table A1 summarizes the kinematic data from the sagittal plane (pelvis, hip, knee, ankle) for each gait level within one standard deviation from normal.

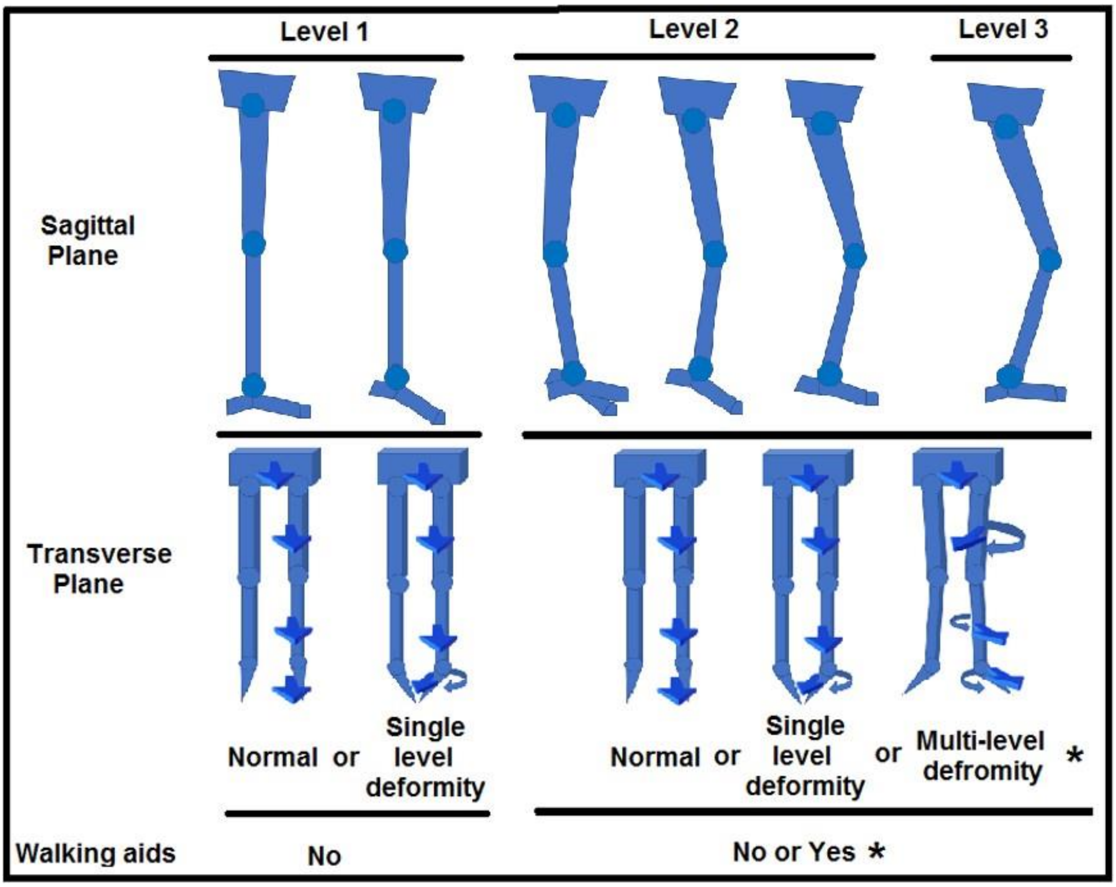


Figure A1. Diagrams showing schematic drawing of the sagittal and transverse plane gait characteristics of the lower limbs, as well as the use of walking aids for each gait level in children with CP.

***** Note that a child with sagittal plane characteristics of level 1 becomes level 2 when presenting multi-level deformity in the transverse plane of movement or use walking aids to walk.

Walking aids: canes, crutches or walkers.

Level 1 participants had kinematics in the sagittal plane as typical or minor deviations from normality in the hips and knees and normal or with a trend to plantar flexion in the ankles (Figure A2). In the transverse plane they had normal rotational profile or deformity in just one level (pelvic/hip/knee/foot). The level 1 participants did not use any walking aids.

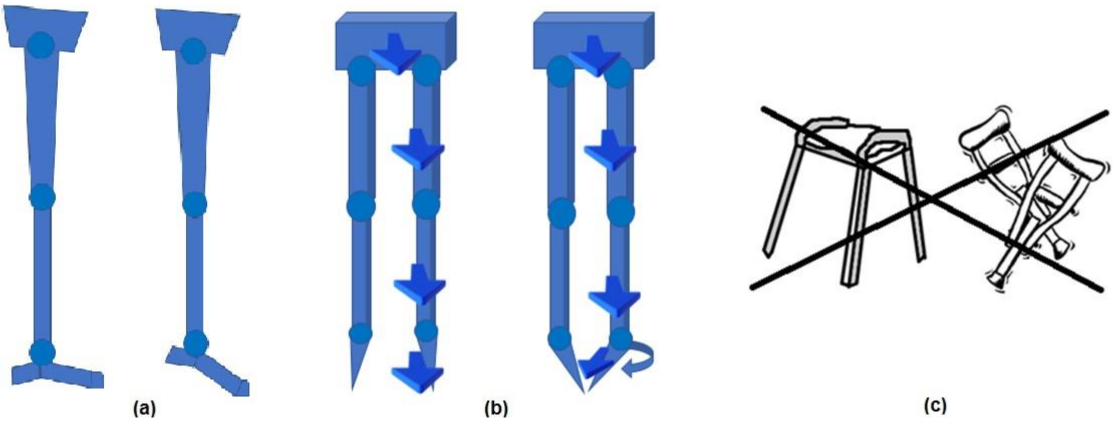


Figure A2. Schematic drawing of the first level of the classification. Sagittal plane (a), transverse plane (b), walking aids (c).

The participants of levels 2 had the kinematics in sagittal plane of motion similar to level 1, when using walking aids. The participants level 2 presented, independently of walking aids or deformities in transverse plane, with knees in flexion or hyperextension and ankle in normal dorsiflexion or plantarflexion (Figure A3).

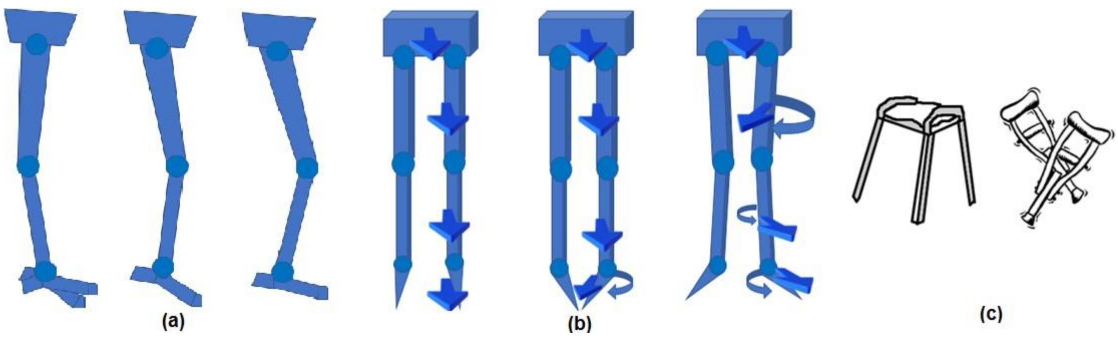


Figure A3. Schematic drawing of the first level of the classification. Sagittal plane (a), transverse plane (b), walking aids (c).

The participants of the level 3 had the kinematics in sagittal plane in triple flexion of the hip, knee and ankle (trend to excessive dorsiflexion). The participants level 3 could use walking aids and have transverse plane deformities in single or multilevel (Figure A4).

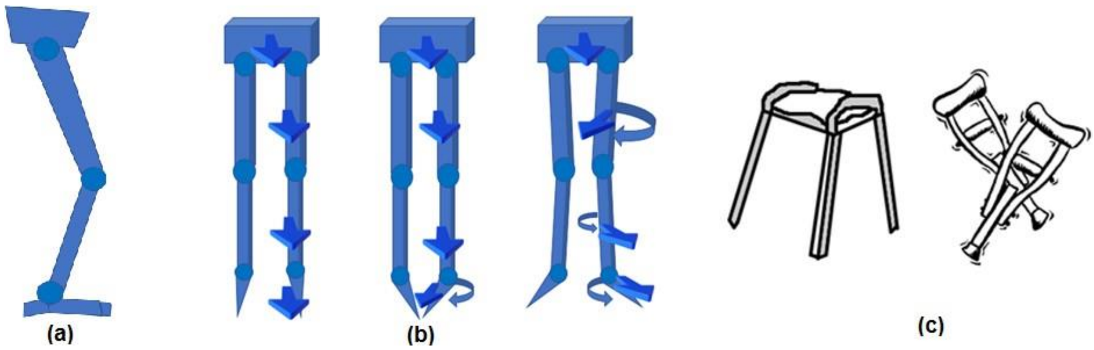


Figure A4. Schematic drawing of the first level of the classification. Sagittal plane (a), transverse plane (b), walking aids (c).

Table A1. Characteristics definition of kinematics and walking aids for levels of gait in CP children.

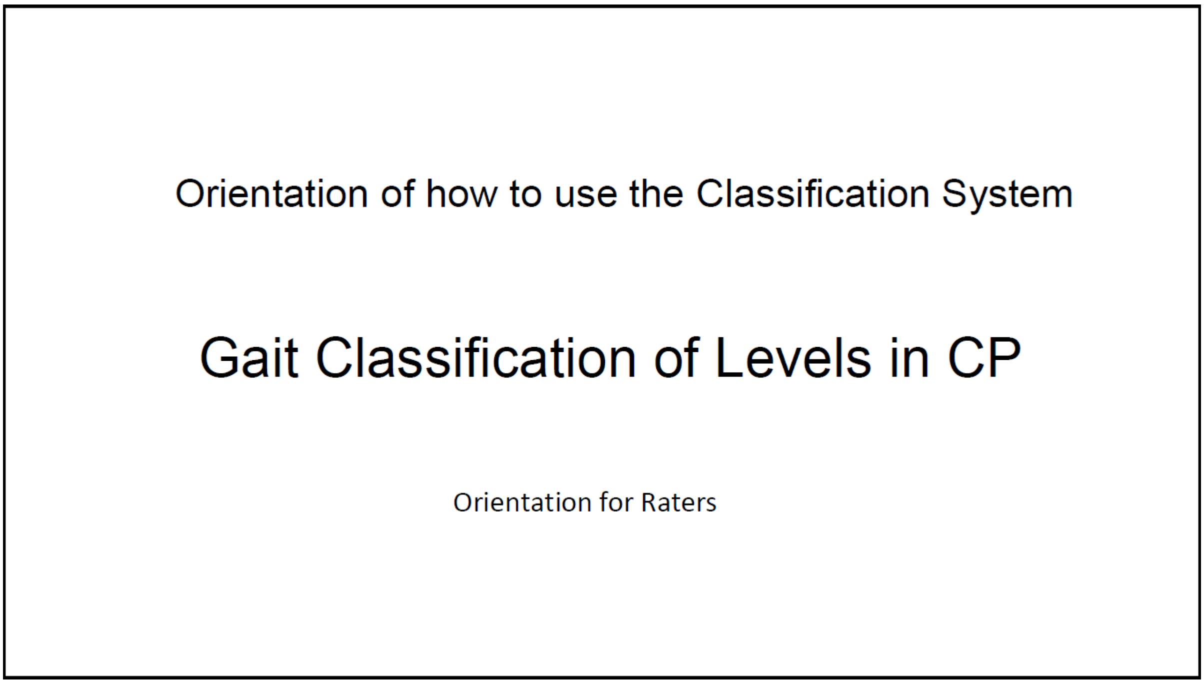
Gait Level	Sagital plane				Transverse plane	Walking aids
	Pelvic tilt	Hip Fx/Ext	Knee Fx/Ext	Ankle Df/Pf	Rotation profile	canes/ Crutches / walkers
Level 1 n=23	Normal Anterior	Normal or Minor deviations	Normal or Minor deviations	Normal or trend to plantarflex.	Normal or single level	No
* Level 2 n=55	Normal Anterior	Normal or Minor deviations	Minor deviations or hypertext.	Normal or Plantarflex.	Multi-level	and/or Yes
	Normal Anterior Posterior	Flexed	Flexed	Normal or Plantarflex	Normal Single/ multi-level	No or Yes
Level 3 n=23	Anterior Normal Posterior	Flexed	Flexed	Excessive dorsiflex.	Normal Single/ multi-level	No or Yes

Hip Fx/Ext: hip flexion and extension. Knee Fx/Ext: knee flexion and extension. Ankle Df/Pf; ankle dorsiflexion and plantarflexion. Hyperext.: hyperextension. Plantarflex.: plantarflexion. Dorsiflex.: dorsiflexion.

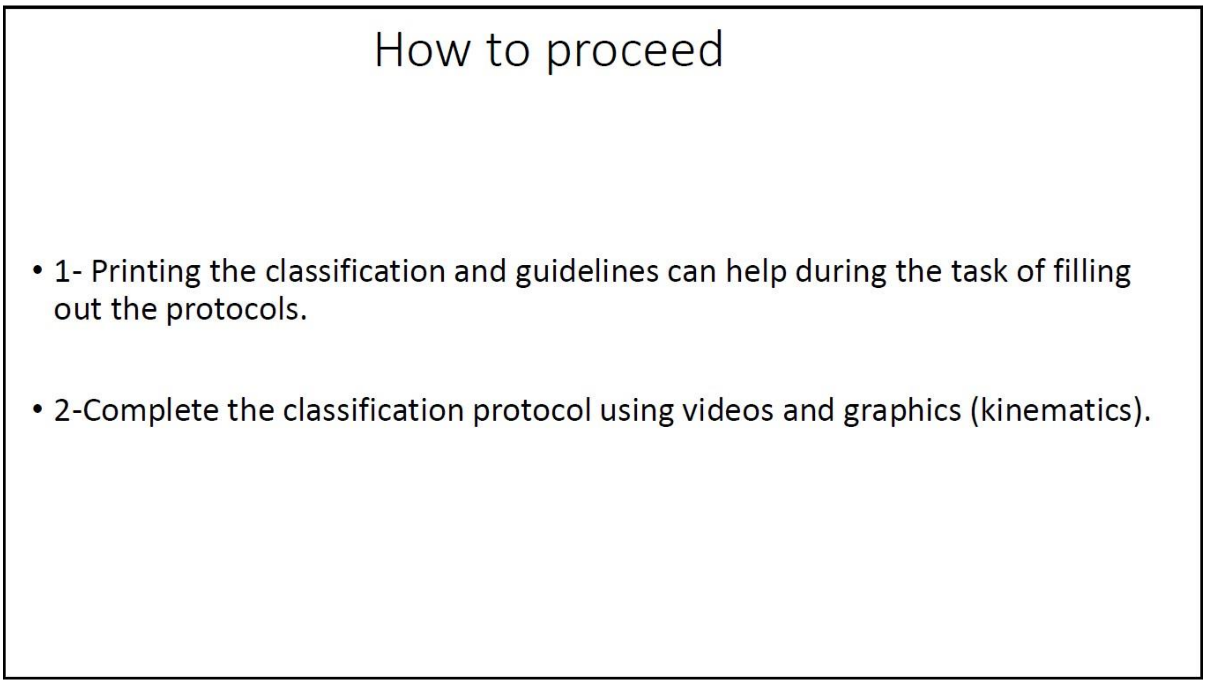
* Note that a child with sagittal plane characteristics of level 1 becomes level 2 when presenting multi-level deformity in the transversal plane of movement or use walking aids to walk.

Walking aids: walking sticks, crutches or walkers.

Appendix B. Orientation of how to use the classification system (PowerPoint presentation).



Slide B1. Orientation of how to use the classification system

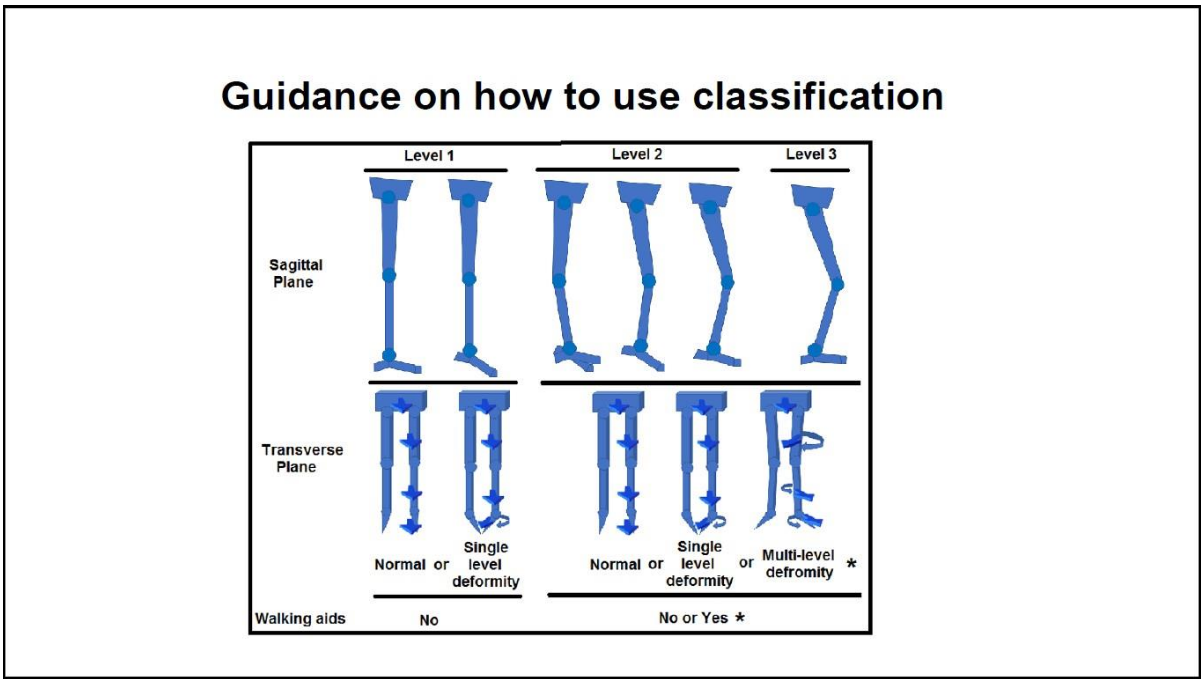


Slide B2 How to proceed to classify the sample of children.

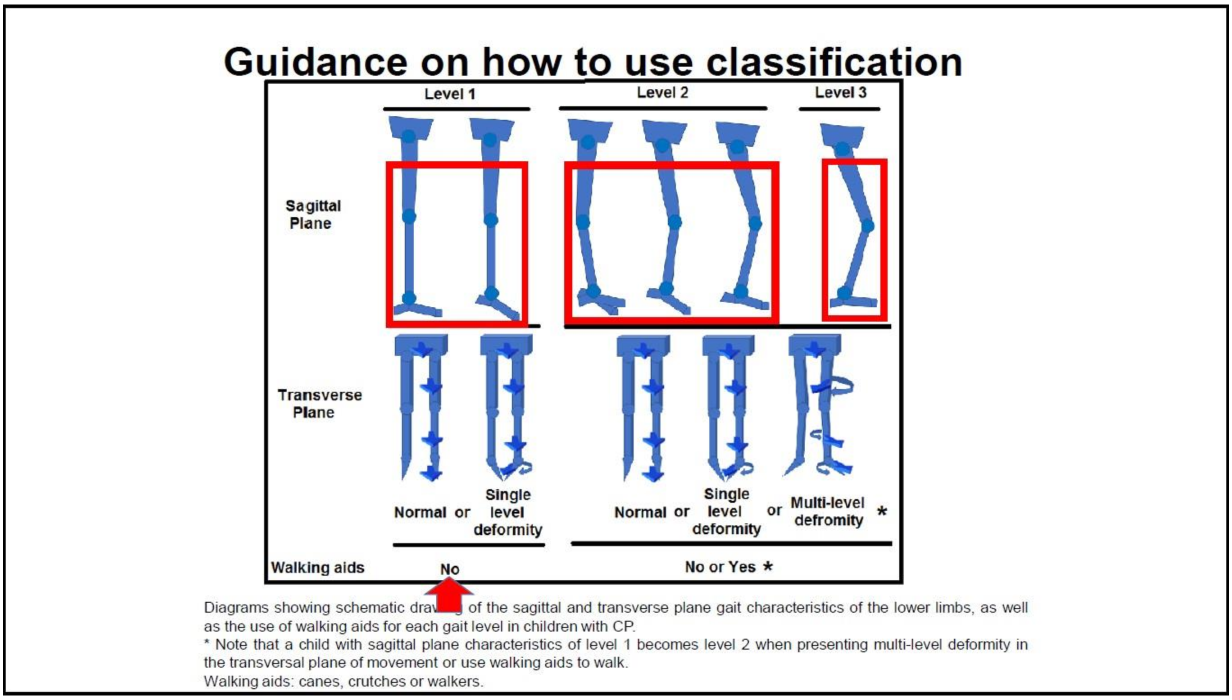
Description of the classification of gait levels in children with CP

Gait Level	Sagital plane				Transverse plane	Mobility aids
	Pelvic tilt	Hip fx/Ext	Knee Fx/Ext	Ankle Df/Pf	Rotation profile	Crutches/ walkers
Level 1 N=23	Normal Anterior	Normal or Minor deviations	Normal or Minor deviations	Normal dorsiflexion or trend to plantarflex.	Normal or single level	NO
Level 2 N=55	Normal Anterior	Normal or Minor deviations Flexed	Minor deviations or hypertext. Flexed	Normal dorsiflex. or Plantarflex.	Normal Single/multi level	NO or Yes
Level 3 N=23	Anterior Normal Posterior	Flexed	Flexed	Excessive dorsiflexion	Normal Single/multi level	No or Yes

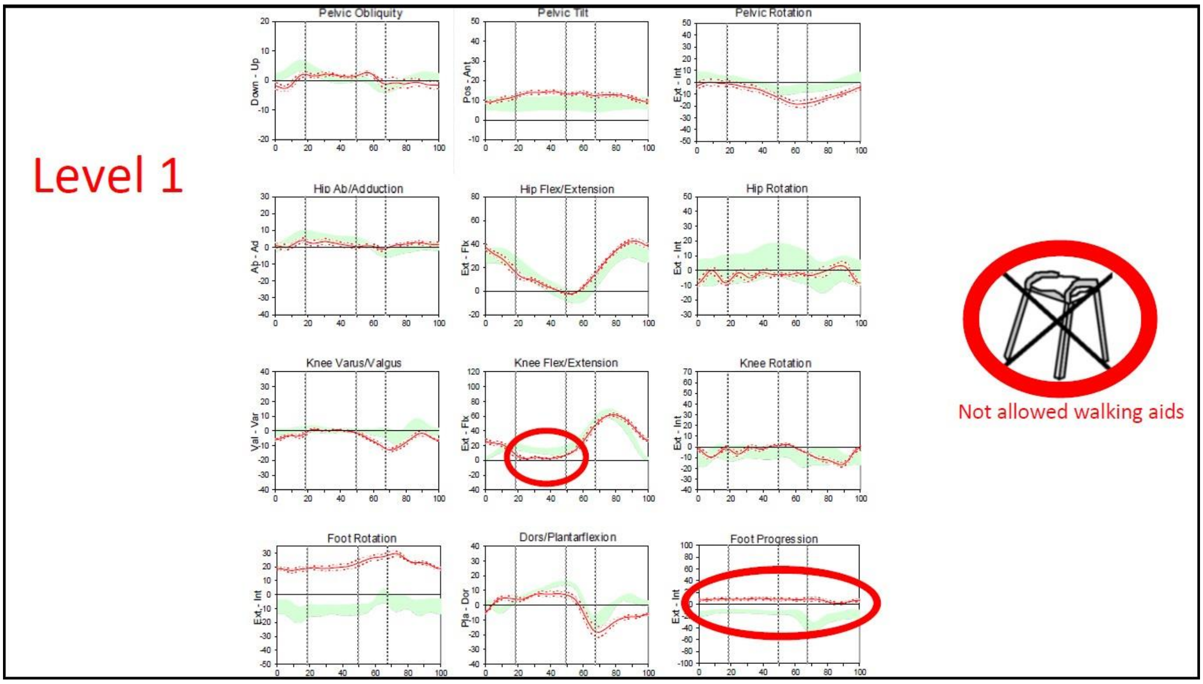
Slide B3. Definitions of the gait patterns.



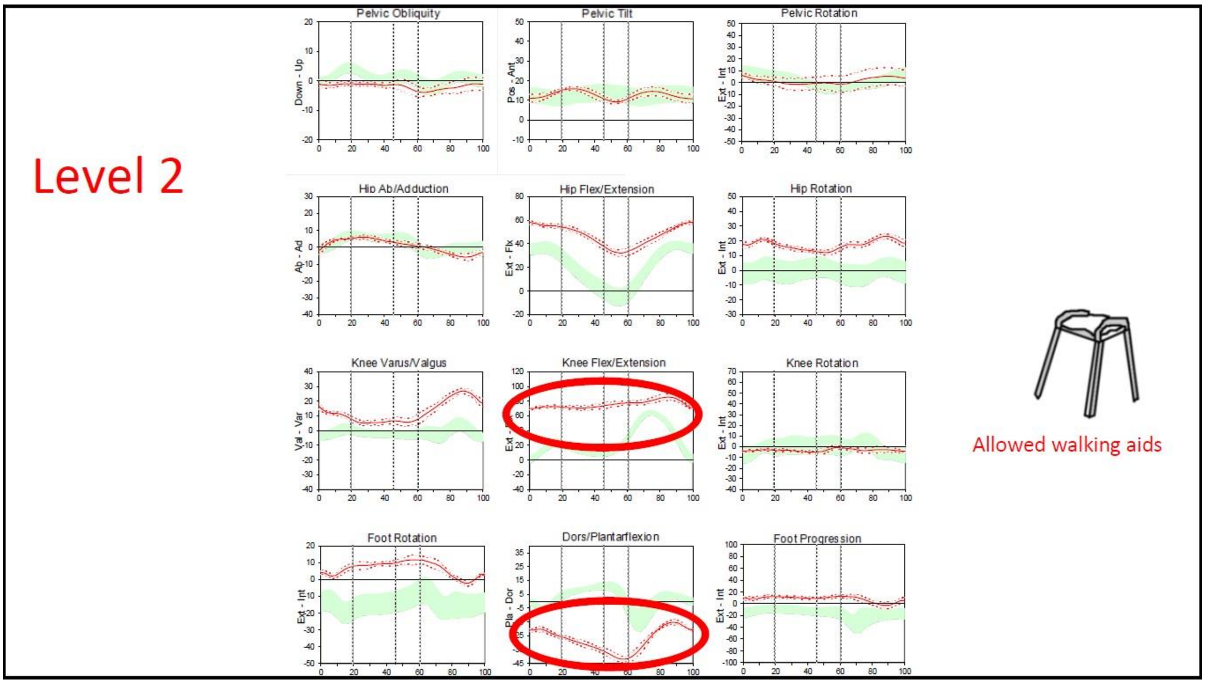
Slide B4. Schematic drawing and explantions of the gait patterns of the classification



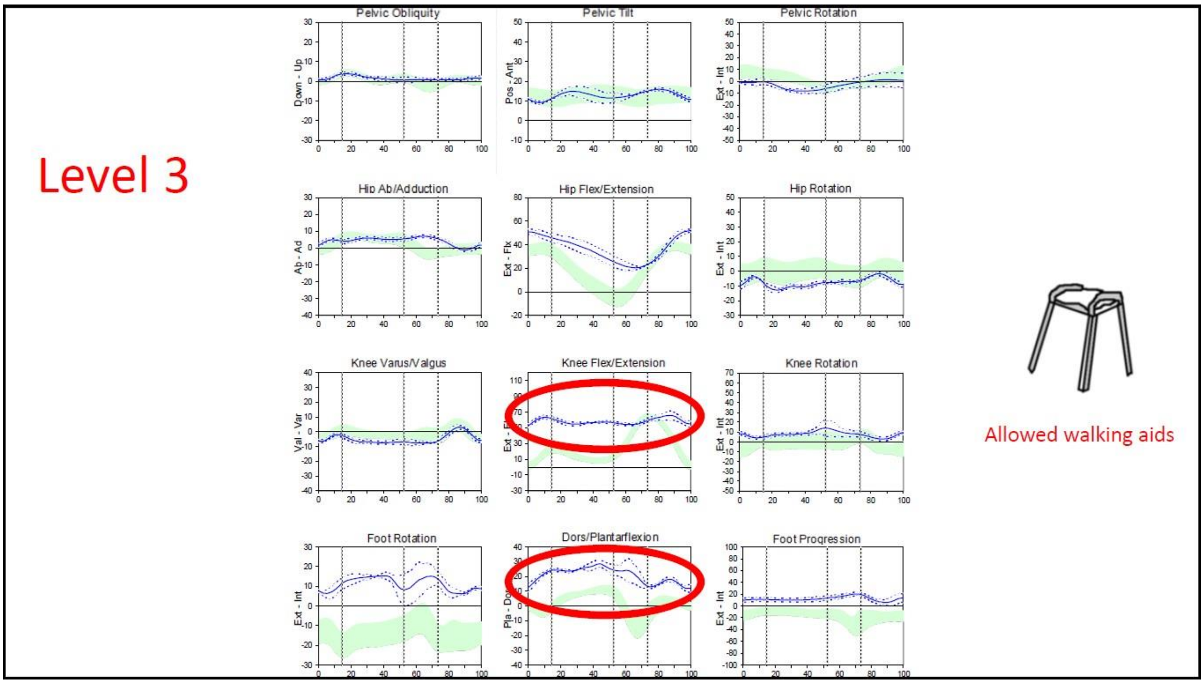
Slide B5. Guidance on how to use classification.



Slide B6. Example of kinematics of the lower limb and use of walking aids in level 1 of the classification



Slide B7. Example of kinematics of the lower limb and use of walking aids in level 2 of the classification



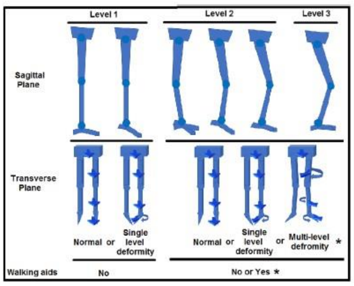
Slide B8. Example of kinematics of the lower limb and use of walking aids in level 3 of the classification

Excel spreadsheet protocol

participant	right side	left side
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		

Use one of the options below to fill the protocol, for both the right and left side of each participant of the study.

Level 1;
Level 2;
Level 3.



Slide B9. Example of excel spreadsheet protocol.

Final Orientation

Finalize the filling of the excel spreadsheet and send to the authors.

Slide B10. Final guidance for evaluators.

8 CONCLUSÃO GERAL DA TESE

A presente tese acrescenta para a literatura atual achados científicos relacionados a marcha de crianças com PC. Foram realizados quatro estudos originais, sendo o primeiro relacionado ao impacto do uso de OSP durante a marcha e os demais relacionados à classificação da marcha nessa população.

O primeiro estudo mostrou que as OSP quando prescritas por profissionais sem o uso de dados da A3DM, não alteraram significativamente o índice da marcha (GPS), mas melhoraram os dados de tempo e espaço, na amostra avaliada. A determinação de parâmetros clínicos quantitativos para a prescrição de órteses em pacientes com PC bilateral, bem como, órteses que atendam aos requisitos específicos são pontos a serem abordados no futuro, a fim de obter efeitos mais significativos.

A tese avaliou duas classificações da marcha na PC, de forma pioneira, em amostras de indivíduos da faixa etária pediátrica. A utilização de ambas as classificações em uma série de casos, com grande número de participantes, possibilitou determinar a capacidade das classificações em avaliar o universo de situações encontradas na marcha de crianças com diagnóstico de PC, e determinar a reprodutibilidade inter e intraobservador dos instrumentos.

Deste modo, o segundo estudo validou a classificação derivada da revisão sistemática da literatura realizada por Papageorgiou *et al*.[110]. Essa classificação avalia vários níveis articulares e classifica indivíduos com envolvimento unilateral e bilateral.

Apesar dos grupos do sistema de classificação apresentarem sobreposição de características cinemáticas, a reprodutibilidade inter e intraobservador foi substancial e quase perfeita, respectivamente. Uma porcentagem significativa da amostra (>95%), foi classificada utilizando-se esse instrumento. Embora a comparação entre os grupos tenha apresentado algumas diferenças estatisticamente significativas, não foi possível determinar uma tendência evolutiva de maior ou menor comprometimento funcional com a classificação em estudo e os grupos formados. Como limitação, esta classificação só leva em consideração o plano sagital de movimento em sua avaliação.

O terceiro estudo validou e determinou a reprodutibilidade inter e intraobservador do Sistema de Classificação das Alterações da Marcha em Crianças com Paralisia Cerebral (GDCS-CP)[107]. Com uso da GDCS-CP, mais de 96% dos casos da amostra avaliada foram classificados. Por avaliar mais de um plano de movimento, ser categorizada de maneira hierárquica e possibilitar ao avaliador um número maior de opções para a categorização da marcha deste grupo de pacientes, a sua utilidade clínica foi considerada significativa. Entretanto, a reprodutibilidade interobservador foi moderada por conta da significativa sobreposição cinemática dos padrões.

No quarto estudo foi construída uma nova classificação, a partir de elementos de classificações anteriores, para preencher as lacunas observadas. A classificação teve o objetivo de determinar níveis de comprometimento da marcha nas crianças com PC, sem categorizar de maneira estática as alterações. Foi utilizado na construção desta nova classificação o conceito de que a função básica dos membros inferiores durante a marcha é resistir ao colapso em flexão e apresentar extensão eficiente para a produção de potência no final do apoio. A classificação avalia mais de um plano de movimento e incorporou, quando necessário, a utilização de tutores externos durante a marcha (muletas/andadores/bengalas). A reprodutibilidade da classificação foi substancial interobservadores e substancial a quase perfeita intraobservadores. A reprodutibilidade foi quase perfeita, quando calculada entre cada observador e o resultado de um consenso entre os autores da classificação. Quando a reprodutibilidade foi testada com os observadores utilizando a A3DM ou somente análise observacional do vídeo, os resultados foram similares em ambas as situações. Desta forma, a classificação proposta mostrou utilidade na prática clínica diária.

A marcha de pacientes com PC apresenta grande variabilidade e seu estudo continua desafiador. A utilização da A3DM auxiliou, na presente tese, a verificação das alterações do andar possibilitando determinar a aplicabilidade de classificações nesses indivíduos, assim como, na determinação do resultado do uso de OSP.

Além disso, as fragilidades observadas nas classificações existentes, impulsionaram a criação de uma nova classificação da marcha pelos autores deste estudo, lembrando que elas se destinam à: classificar adequadamente a marcha dessa população, servir de guia para a tomada de decisões terapêuticas (cirúrgicas e/ou conservadoras), auxiliar nos estudos de responsividade aos tratamentos propostos e melhorar a comunicação entre a equipe de reabilitação.

Novas pesquisas são incentivadas para melhorar ainda mais a compreensão da marcha e suas classificações em crianças com PC. No futuro, estudos que explorem a relação entre a estrutura cerebral e os padrões observados nas classificações da marcha poderiam prever a evolução clínica e as necessidades de tratamentos desta população.

9 REFERÊNCIAS

1. Rosenbaum P, Paneth N, Leviton A, et al. A report: The definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol*. 2007;49(SUPPL.109):8-14. doi:10.1111/j.1469-8749.2007.tb12610.x
2. Sellier E, Platt MJ, Andersen GL, et al. Decreasing prevalence in cerebral palsy: A multi-site European population-based study, 1980 to 2003. *Dev Med Child Neurol*. 2016;58(1):85-92. doi:10.1111/dmcn.12865
3. S. Ashwal; B.S. Russman; P.A. Blasco MD; G. Miller; A. Sandler;, Stevenson MS and R. Practice Parameter: Diagnostic assessment of the child with cerebral palsy Report of the Quality Standards Subcommittee of the American Academy of Neurology and the Practice Committee of the Child Neurology Society. *Am Acad Neurol*. 2004;62:851-863. doi:DOI 10.1212/01
4. Colver A, Fairhurst C, Pharoah POD. Cerebral palsy. *Lancet*. 2014;383(9924):1240-1249. doi:10.1016/S0140-6736(13)61835-8
5. H. Kerr Graham1–3, Peter Rosenbaum4, Nigel Paneth5, Bernard Dan6 J-PL, Diane L. Damiano8, Jules G. Becher9, Deborah Gaebler-Spira10 AC, Dinah S. Reddihough12 KEC and RLL. Cerebral Palsy. *Nat Rev* | *Dis Prim*. 2016;2:1-24. doi:10.1038/nrdp.2015.82
6. Paneth N, Hong T, Korzeniewski S. The Descriptive Epidemiology of Cerebral Palsy. *Clin Perinatol*. 2006;33(2):251-267. doi:10.1016/j.clp.2006.03.011
7. Winter S, Autry A, Boyle C, Yeargin-Allsopp M. Trends in the prevalence of cerebral palsy in a population-based study. *Pediatrics*. 2002;110(6 I):1220-1225. doi:10.1542/peds.110.6.1220
8. Gage, James R., Schwartz Michael H., Koop Steven E. NTF. *The Identification and Treatment of Gait Problems in Cerebral Palsy*. Second Edi. (M. HH, ed.). London: Mc Keith Press; 2009.
9. Beckung E, Hagberg G, Uldall P, Cans C. Probability of walking in children with cerebral palsy in Europe. *Pediatrics*. 2008;121(1). doi:10.1542/peds.2007-0068
10. (CDC). C for DC and P. Economic costs associated with mental retardation, cerebral palsy, hearing loss, and vision impairment--United States, 2003. *MMWR Morb Mortal Wkly Rep*. 2004;Jan 30(53 (3)):57-59.
11. Park MS, Kim SJ, Chung CY, Kwon DG, Choi IH, Lee KM. Prevalence and lifetime healthcare cost of cerebral palsy in South Korea. *Health Policy (New*

York). 2011;100(2-3):234-238. doi:10.1016/j.healthpol.2010.09.010

12. Sacaze E, Garlantezec R, Rémy-néris O, et al. A survey of medical and paramedical involvement in children with cerebral palsy in Britanny: Preliminary results. *Ann Phys Rehabil Med*. 2013;56(4):253-267. doi:10.1016/j.rehab.2012.11.003
13. Lintanf M, Bourseul J, Houx L, Lempereur M, Brochard S, Pons C. Effect of ankle-foot orthoses on gait , balance and gross motor function in children with cerebral palsy : a systematic review and meta-analysis. 2018. doi:10.1177/0269215518771824
14. Meldrum D, Shouldice C, Conroy R, Jones K, Forward M. Test-retest reliability of three dimensional gait analysis: Including a novel approach to visualising agreement of gait cycle waveforms with Bland and Altman plots. *Gait Posture*. 2014;39(1):265-271. doi:10.1016/j.gaitpost.2013.07.130
15. Wren TAL, Gorton GE, Õunpuu S, Tucker CA. Efficacy of clinical gait analysis: A systematic review. *Gait Posture*. 2011;34(2):149-153. doi:10.1016/j.gaitpost.2011.03.027
16. Wren TAL, Otsuka NY, Bowen RE, et al. Outcomes of lower extremity orthopedic surgery in ambulatory children with cerebral palsy with and without gait analysis: Results of a randomized controlled trial. *Gait Posture*. 2013;38(2):236-241. doi:10.1016/j.gaitpost.2012.11.018
17. Lofterød B, Terjesen T. Results of treatment when orthopaedic surgeons follow gait-analysis recommendations in children with CP. *Dev Med Child Neurol*. 2008;50(7):503-509. doi:10.1111/j.1469-8749.2008.03018.x
18. Cook RE, Schneider I, Hazlewood ME, Hillman SJ, Robb JE. Gait analysis alters decision-making in cerebral palsy. *J Pediatr Orthop*. 2003;23(3):292-295. doi:10.1097/01241398-200305000-00004
19. Van Gestel L, De Laet T, Di Lello E, et al. Probabilistic gait classification in children with cerebral palsy: A Bayesian approach. *Res Dev Disabil*. 2011;32(6):2542-2552. doi:10.1016/j.ridd.2011.07.004
20. Dobson F, Morris ME, Baker R, Graham HK. Gait classification in children with cerebral palsy: A systematic review. *Gait Posture*. 2007;25(1):140-152. doi:10.1016/j.gaitpost.2006.01.003
21. Bax M, Goldstein M, Rosenbaum P, et al. Proposed definition and classification of cerebral palsy , April 2005 Executive Committee for the Definition of Cerebral

Palsy. *Dev Med Child Neurol*. 2005;47(April):571-576. doi:http://dx.doi.org/10.1017/S001216220500112X

22. Little. WJ. On the Influence of Abnormal Parturition, Difficult Labour, Premature Birth, and Asphyxia Neonatorum on the Mental and Physical Condition of the Child, Especially in Relation to Deformities. *Lancet*. 1861:378-380.
23. Barnett R. Perspectives Case histories Cerebral palsy. *Lancet*. 2005;392(10147):545. doi:10.1016/S0140-6736(18)31702-1
24. Blair E. Epidemiology of the cerebral palsies. *Orthop Clin North Am*. 2010;41(4):441-455. doi:10.1016/j.ocl.2010.06.004
25. Gulati S, Sondhi V. Cerebral Palsy: An Overview. *Indian J Pediatr*. 2018;85(11). doi:10.1007/s12098-017-2475-1
26. Aisen ML, Kerkovich D, Mast J, et al. Cerebral palsy: Clinical care and neurological rehabilitation. *Lancet Neurol*. 2011;10(9):844-852. doi:10.1016/S1474-4422(11)70176-4
27. Himmelmann K, Horber V, De La Cruz J, et al. MRI classification system (MRICS) for children with cerebral palsy: development, reliability, and recommendations. *Dev Med Child Neurol*. 2017;59(1). doi:10.1111/dmcn.13166
28. Graham HK, Rosenbaum P, Paneth N, et al. Cerebral palsy. *Nat Rev Dis Prim*. 2016;2. doi:10.1038/nrdp.2015.82
29. Serdaroglu A., Cansu A., Ozkan S. TS. Prevalence of cerebral palsy in Turkish children between the ages of 2 and 16 years. *Dev Med Child Neurol*. 2006;48:413-416.
30. Zanini G, Peralles SN. Paralisia Cerebral: causas e prevalências. *Fisioter em Mov*. 2009;22(3):375-381.
31. FONSECA, L. F.; XAVIER, C. C.; PIANETTI G. Encefalopatia crônica (paralisia cerebral). In: *Compêndio de Neurologia Infantil*. 2. ed. Rio de Janeiro: Medbook; 2011:669-679.
32. Meehan E, Reid SM, Williams K, et al. Hospital admissions in children with cerebral palsy: a data linkage study. *Dev Med Child Neurol*. 2017;59(5):512-519. doi:10.1111/dmcn.13350
33. Kancherla V, Amendah DD, Grosse SD, Yeargin-allsopp M, Naarden K Van. Research in Developmental Disabilities Medical expenditures attributable to cerebral palsy and intellectual disability among Medicaid-enrolled children. *Res Dev Disabil*. 2012;33(3):832-840. doi:10.1016/j.ridd.2011.12.001

34. MA Hoving, SMAA Evers AA, EPM van Raak JV. S Illsinger MD. *Dev Med Child Neurol*. 2007;49:397-398.

35. Tonmukayakul U, Shih STF, Bourke-Taylor H, et al. Systematic review of the economic impact of cerebral palsy. *Res Dev Disabil*. 2018;80(July 2017):93-101. doi:10.1016/j.ridd.2018.06.012

36. Eunson P. Aetiology and epidemiology of cerebral palsy. *Paediatr Child Heal (United Kingdom)*. 2016;26(9):367-372. doi:10.1016/j.paed.2016.04.011

37. Kuban KCK, Allred EN, O'Shea MT, et al. Cranial ultrasound lesions in the NICU predict cerebral palsy at age 2 years in children born at extremely low gestational age. *J Child Neurol*. 2009;24(1):63-72. doi:10.1177/0883073808321048

38. Korzeniewski SJ, Birbeck G, DeLano MC, Potchen MJ, Paneth N. A systematic review of neuroimaging for cerebral palsy. *J Child Neurol*. 2008;23(2):216-227. doi:10.1177/0883073807307983

39. Fahey MC, Maclennan AH, Kretzschmar D, Gecz J, Kruer MC. The genetic basis of cerebral palsy. *Dev Med Child Neurol*. 2017;59(5):462-469. doi:10.1111/dmcn.13363

40. Thompson N, Stebbins J, Seniorou M, Newham D. Muscle strength and walking ability in Diplegic Cerebral Palsy: Implications for assessment and management. *Gait Posture*. 2011;33(3):321-325. doi:10.1016/j.gaitpost.2010.10.091

41. Kerr Graham H, Selber P. Musculoskeletal aspects of cerebral palsy. *J Bone Jt Surg*. 2003;85(2):157-166. doi:10.1302/0301-620X.85B2.14066

42. Lampe R, Grassl S, Mitternacht J, Gerdesmeyer L, Gradinger R. MRT-measurements of muscle volumes of the lower extremities of youths with spastic hemiplegia caused by cerebral palsy. *Brain Dev*. 2006;28(8):500-506. doi:10.1016/j.braindev.2006.02.009

43. Wiley, ME; Damiano D. Lower -extremity strength profiles in spastic cerebral palsy. *Developmental Med Child Neurol*. 1998;(40):100-107.

44. Barrett RS, Lichtwark GA. Gross muscle morphology and structure in spastic cerebral palsy: a systematic review. *Dev Med Child Neurol*. 2010;52(9):794-804. doi:10.1111/j.1469-8749.2010.03686.x

45. Mathewson MA, Lieber RL. Pathophysiology of Muscle Contractures in Cerebral Palsy. *Phys Med Rehabil Clin N Am*. 2015;26(1):57–67. doi:10.1016/j.pmr.2014.09.005

46. Cans C, Dolk H, Platt MJ, Colver A PA, I K-M. SCPE Collaborative Group.

Recommendations from the SCPE collaborative group for defining and classifying cerebral palsy. *Dev Med Child Neurol*. 2007;49(109 Suppl):35–38.

47. Souza, Angela Maria Costa de; Ferrareto I. *Paralisia Cerebral: Aspectos Práticos*. 1° Edição. (Cerebral AB de P, ed.). São Paulo: Memnon Edições Científicas; 1998.
48. Cans C. Surveillance of cerebral palsy in Europe: A collaboration of cerebral palsy surveys and registers. *Dev Med Child Neurol*. 2000;42(12):816-824. doi:10.1017/S0012162200001511
49. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol*. 1997;39(2):214-223. doi:10.1111/j.1469-8749.1997.tb07414.x
50. Hiratuka E, Matsukura TS, Pfeifer LI. Cross-cultural adaptation of the gross motor function classification system into Brazilian-Portuguese (GMFCS). *Rev Bras Fisioter*. 2010;14(6):537-544. doi:10.1590/s1413-35552010000600013
51. Kerr Graham H. Classifying Cerebral Palsy. *J Pediatr Orthop*. 2005;25(1):127-128.
52. World Health Organization. *Interantional Classification of Functioning, Disability and Health*. Geneva; 2001. doi:9241545429
53. Rethlefsen SA, Ryan DD, Kay RM. Classification systems in cerebral palsy. *Orthop Clin North Am*. 2010;41(4):457-467. doi:10.1016/j.ocl.2010.06.005
54. Ishikawa S, Kang M, Bjornson KF, Song K. Reliably measuring ambulatory activity levels of children and adolescents with cerebral palsy. *Arch Phys Med Rehabil*. 2013;94(1):132-137. doi:10.1016/j.apmr.2012.07.027
55. Schiariti V, Selb M, Cieza A, O'Donnell M. International Classification of Functioning, Disability and Health Core Sets for children and youth with cerebral palsy: A consensus meeting. *Dev Med Child Neurol*. 2015;57(2):149-158. doi:10.1111/dmcn.12551
56. Graham HK, Harvey A, Rodda J, Nattrass GR, Pirpiris M. The Functional Mobility Scale (FMS). *J Pediatr Orthop*. 2004;24(5):514-520. doi:10.1097/01241398-200409000-00011
57. da Paz Junior AC, Burnett SM BL. Walking prognosis in cerebral palsy: a 22-year retrospective analysis. *Dev Med Child Neurol*. 1994;36(2):130-134. doi:10.1111/j.1469-8749.1994.tb11821.x

58. Badell-Ribera A. Cerebral palsy: postural-locomotor prognosis in spastic diplegia. *Arch Phys Med Rehabil*. 1985;66(9):614-619.

59. Bleck E. Locomotor Prognosis in Cerebral Palsy. *Dev Med Child Neurol*. 1975;vol 17(1):18-25. doi:https://doi.org/10.1111/j.1469-8749.1975.tb04952.x

60. Andersson C, Mattsson E. Adults with cerebral palsy: A survey describing problems, needs, and resources, with special emphasis on locomotion. *Dev Med Child Neurol*. 2001;43(2):76-82. doi:10.1017/S0012162201

61. Bell KJ, Ounpuu S, DeLuca PA, Romness MJ. Natural progression of gait in children with cerebral palsy. *J Pediatr Orthop*. 2002;22(5):677-682. doi:10.1097/01.BPO.0000023143.69745.A9

62. Brooks JC, Strauss DJ, Shavelle RM, Tran LM, Rosenbloom L, Wu YW. Recent trends in cerebral palsy survival. Part II: Individual survival prognosis. *Dev Med Child Neurol*. 2014;56(11):1065-1071. doi:10.1111/dmcn.12519

63. Saunders M, Inman V, Eberhart H. The major determinant in normal and pathological gait. *J Bones Jt Surg*. 1953;35(3):543-558. doi:10.1007/978-1-4471-5451-8_102

64. Sutherland D. The evolution of clinical gait analysis: Part II Kinematics. *Gait Posture*. 2002;16(2):159-179. doi:10.1016/S0966-6362(02)00004-8

65. Inman VT, Ralston HJ TF. *Human Walking*. Baltimore: Williams & Wilkins; 1981.

66. Alessandro Giurizatto Melanda, Catia Kawamura, Wagner de Godoy, Priscila Orifice PRL. Laboratório de Marcha. In: Moura, Elcinete Wentz; Campos e Silva P do A, ed. *Fisioterapia: Aspectos Clínicos e Práticos Da Reabilitação*. 1° Edição. São Paulo: Artes Medicas; 2005:615-640.

67. Kadaba M, Ramakrishnan H WM. Measurement of lower extremity kinematics during level walking. *J Orthop Res*. 1990;08:383–392.

68. Richard Baker. *Measuring Walking: A Handbook of Clinical Gait Analysis*. First Edit. (Hart HM, ed.). London: Mac Keith Press; 2013.

69. Zwaan E, Becher JG, Harlaar J. Synergy of EMG patterns in gait as an objective measure of muscle selectivity in children with spastic cerebral palsy. *Gait Posture*. 2012;35(1):111-115. doi:10.1016/j.gaitpost.2011.08.019

70. Perry J. BJ. *Gait Analysis: Normal and Pathological Function*. 2nd ed.,. Thorofare, NJ:; 2010.

71. DeLuca, Peter A. M.D.; Davis, Roy B. III Ph.D.; Ounpuu, Sylvia M.Sc.; Rose, Sally P.T.; Sirkin RMD. Alterations in Surgical Decision Making in Patients with

Cerebral Palsy Based on Three-Dimensional Gait Analysis. *J Pediatr Orthop*. 1997;17(5):608-614.

72. Gough M, Shortland AP. Can clinical gait analysis guide the management of ambulant children with bilateral spastic cerebral palsy? *J Pediatr Orthop*. 2008;28(8):879-883. doi:10.1097/BPO.0b013e31818e197c
73. Rasmussen HM, Nielsen DB, Pedersen NW, Overgaard S, Holsgaard-Larsen A. Gait Deviation Index, Gait Profile Score and Gait Variable Score in children with spastic cerebral palsy: Intra-rater reliability and agreement across two repeated sessions. *Gait Posture*. 2015;42(2). doi:10.1016/j.gaitpost.2015.04.019
74. Melanda, Alessandro G.; Pauleto, Ana C.; Knaut, Luiz A.; Ferreira, Alana E.K.; Iucksch, Dielise D.; da Silva, Rauce M.; Cunha RFM. Avaliação de pacientes com Distrofia Muscular de Duchenne em Laboratório Computadorizado de Marcha Através do Índice de Alteração da Marcha. *Rev Bras Ortop*. 2011;46(Suppl 4):10-13.
75. Schwartz MH, Rozumalski A. The gait deviation index: A new comprehensive index of gait pathology. *Gait Posture*. 2008;28(3):351-357. doi:10.1016/j.gaitpost.2008.05.001
76. Baker R, McGinley JL, Schwartz MH, et al. The Gait Profile Score and Movement Analysis Profile. *Gait Posture*. 2009;30(3):265-269. doi:10.1016/j.gaitpost.2009.05.020
77. Baker R, Mcginley JL, Schwartz MH, et al. The Gait Profile Score and Movement Analysis Profile. *Gait Posture*. 2009;30:265–269. doi:10.1016/j.gaitpost.2009.05.020
78. Beynon S, Mcginley JL, Dobson F, Baker R. Correlations of the Gait Profile Score and the Movement Analysis Profile relative to clinical judgments. doi:10.1016/j.gaitpost.2010.01.010
79. Zehr EP, Barss TS, Dragert K, et al. Neuromechanical interactions between the limbs during human locomotion: an evolutionary perspective with translation to rehabilitation. *Exp Brain Res*. 2016;234(11):3059-3081. doi:10.1007/s00221-016-4715-4
80. Forssberg H. Experimental Br n Research. *Exp Brain Res*. 1985;57:480-493. doi:0014-4819
81. Hatala KG, Demes B, Richmond BG. Laetoli footprints reveal bipedal gait biomechanics different from those of modern humans and chimpanzees. *Proc R*

Soc B Biol Sci. 2016;283(1836). doi:10.1098/rspb.2016.0235
82. Gamble J.G. RJ. *Marcha Humana*. Baltimore: Premier; 1998.
83. Schmid S, Schweizer K, Romkes J, Lorenzetti S, Brunner R. Secondary gait deviations in patients with and without neurological involvement: A systematic review. *Gait Posture*. 2013;37(4):480-493. doi:10.1016/j.gaitpost.2012.09.006
84. Sutherland DH, Sutherland DH, Olshen R, et al. The development of mature gait. *J Bone Jt Surg*. 1980;62:336-353. doi:10.1016/S0966-6362(97)00029-5
85. Gage JR, Deluca PA, Renshaw TS. Gait Analysis : Principles and Applications Gait Analysis: Principles and Applications. *J Bone Jt Surg*. 1995;77:1607-1623.
86. Perry J. *Gait Analysis: Normal and Pathological Function.* New York: SLACK Incorporated; 1992.
87. Sutherland D. *Gait Disordens in Childhood and Adolescence.* First Edit. Baltimore: Williams and Wilkins; 1984.
88. Lieber RL. *Skeletal Muscle Structure, Function, and Plasticity. The Physiological Basis, Rehabilitation*. 3a Edi. Philadelphia; 2010.
89. Roy B. Davis, Sylvia Õunpuu, Dennis Tyburski JRG. A gait analysis data collection and reduction technique. *Hum Mov Sci*. 1991;10(5):575-587. doi:https://doi.org/10.1016/0167-9457(91)90046-Z
90. Gage JR. The clinical use of kinetics for evaluation of pathologic gait in cerebral palsy. *J Bone Jt Surg Am*. 1994;76:622-623. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=7797889.
91. Shuman BR, Goudriaan M, Desloovere K, Schwartz MH, Steele KM. Muscle synergies demonstrate only minimal changes after treatment in cerebral palsy. 2019;3:1-10.
92. Steele KM, Rozumalski A, Schwartz MH. Muscle synergies and complexity of neuromuscular control during gait in cerebral palsy. *Dev Med Child Neurol*. 2015;57(12):1176-1182. doi:10.1111/dmcn.12826
93. Gage J. *Gait Analysis in Cerebral Palsy*. first. London: MacKeith Press.; 1991.
94. Wren T a L, Rethlefsen S, Kay RM. Prevalence of specific gait abnormalities in children with cerebral palsy: influence of cerebral palsy subtype, age, and previous surgery. *J Pediatr Orthop*. 2005;25(1):79-83. doi:00004694-200501000-00018 [pii]
95. Liptak, Gregory S.; Accardo Pj. Health And Social Outcomes Of Children With

Cerebral Palsy. *J Pediatr*. 2004;145(2):S36-S41.

96. International Organization for Standardization. ISO 8549- 1:1989 prosthetics and orthotics – vocabulary. General terms for external limb prostheses and external orthoses. ISO.

97. Eddison N, Mulholland M, Chockalingam N. Do research papers provide enough information on design and material used in ankle foot orthoses for children with cerebral palsy? A systematic review. *J Child Orthop*. 2017;11(4):263-271. doi:10.1302/1863-2548.11.160256

98. Davids JR, Rowan F, Davis RB. Indications for orthoses to improve gait in children with cerebral palsy. *J Am Acad Orthop Surg*. 2007;15(3):178-188. doi:15/3/178 [pii]

99. Totah D, Menon M, Jones-Hershinow C, Barton K, Gates DH. The impact of ankle-foot orthosis stiffness on gait: A systematic literature review. *Gait Posture*. 2019;69(October 2018):101-111. doi:10.1016/j.gaitpost.2019.01.020

100. Lintanf M, Bourseul JS, Houx L, Lempereur M, Brochard S, Pons C. Effect of ankle-foot orthoses on gait, balance and gross motor function in children with cerebral palsy: a systematic review and meta-analysis. *Clin Rehabil*. 2018;32(9):1175-1188. doi:10.1177/0269215518771824

101. Ries AJ, Novacheck TF, Schwartz MH. A data driven model for optimal orthosis selection in children with cerebral palsy. *Gait Posture*. 2014;40(4):539-544. doi:10.1016/j.gaitpost.2014.06.011

102. De Laet T, Papageorgiou E, Nieuwenhuys A, Desloovere K. Does expert knowledge improve automatic probabilistic classification of gait joint motion patterns in children with cerebral palsy? *PLoS One*. 2017;12(6):1-18. doi:10.1371/journal.pone.0178378

103. Rethlefsen SA, Blumstein G, Kay RM, Dorey F, Wren TAL. Prevalence of specific gait abnormalities in children with cerebral palsy revisited: influence of age, prior surgery, and Gross Motor Function Classification System level. *Dev Med Child Neurol*. 2017;59(1):79-88. doi:10.1111/dmcn.13205

104. Kolman SE, Ruzbarsky JJ, Spiegel DA, et al. P111 Classification of gait patterns in children with cerebral palsy. *Gait Posture*. 2016;28(4):S116-S117. doi:10.1016/S0966-6362(08)70180-2

105. Carriero A, Zavatsky A, Stebbins J, Theologis T, Shefelbine SJ. Determination of gait patterns in children with spastic diplegic cerebral palsy using principal

components. *Gait Posture*. 2009;29(1):71-75. doi:10.1016/j.gaitpost.2008.06.011

106. Bonnefoy-Mazure A, Sagawa Y, Lascombes P, De Coulon G, Armand S. Identification of gait patterns in individuals with cerebral palsy using multiple correspondence analysis. *Res Dev Disabil*. 2013;34(9):2684-2693. doi:10.1016/j.ridd.2013.05.002
107. Davids JR, Bagley AM. Identification of Common Gait Disruption Patterns in Children With Cerebral Palsy. *J Am Acad Orthop Surg*. 2014;22(12):782-790. doi:10.5435/JAAOS-22-12-782
108. Nieuwenhuys A, Papageorgiou E, Schless S-H, De Laet T, Molenaers G, Desloovere K. Prevalence of Joint Gait Patterns Defined by a Delphi Consensus Study Is Related to Gross Motor Function, Topographical Classification, Weakness, and Spasticity, in Children with Cerebral Palsy. *Front Hum Neurosci*. 2017;11(April):1-14. doi:10.3389/fnhum.2017.00185
109. Nieuwenhuys A, Õunpuu S, Van Campenhout A, et al. Identification of joint patterns during gait in children with cerebral palsy: A Delphi consensus study. *Dev Med Child Neurol*. 2016;58(3):306-313. doi:10.1111/dmcn.12892
110. Papageorgiou E, Nieuwenhuys A, Vandekerckhove I, Campenhout A Van, Ortibus E, Desloovere K. Systematic review on gait classifications in children with cerebral palsy: an update. *Gait Posture*. 2019. doi:10.1016/j.gaitpost.2019.01.038
111. Sutherland, DH; Davids J. Common Gait Abnormalities of the Knee in Cerebral Palsy. *Clin Orthop Relat Res*. 1993;march(288):139-147.
112. Lin CJ, Guo LY, Su FC, Chou YL, Cherng RJ. Common abnormal kinetic patterns of the knee in gait in spastic diplegia of cerebral palsy. *Gait Posture*. 2000;11(3):224-232. doi:10.1016/S0966-6362(00)00049-7
113. Winters TF, Gage JR, Hicks R. Gait patterns in spastic hemiplegia in children and young adults Patterns in Spastic and Young Hemiplegia Adults. *J Bone Jt Surg*. 1987;69:437-441. doi:10.1302/0301-620X.86B2.13878
114. Rodda JM, Graham HK, Carson L, Galea MP, Wolfe R. Sagittal gait patterns in spastic diplegia. *J Bone Jt Surg*. 2004;86(2):251-258. doi:10.1302/0301-620X.86B2.13878
115. Winter DA. Overall principle of lower limb support during stance phase of gait. *J Biomech*. 1980;13(11):923-927. doi:10.1016/0021-9290(80)90162-1

ANEXOS

ANEXO A: Autorização Da Direção Do Centro Hospitalar De Reabilitação Ana Carolina De Moura Xavier – Curitiba – Paraná, Para Utilização Dos Dados Para A Pesquisa.

HOSPITAIS DO PARANÁ

PARANÁ
GOVERNO DO ESTADO
Secretaria da Saúde

AUTORIZAÇÃO DE USO DE DADOS

Declaramos para os devidos fins, que cederemos ao pesquisador Alessandro Giurizatto Melanda, CPF 746831799-20, o acesso aos dados de prontuários do Laboratório de Marcha do Centro Hospitalar de Reabilitação Ana Carolina de Moura Xavier – Curitiba – Paraná, para serem utilizados na pesquisa: Classificação dos Desvios da Marcha de Pacientes com Paralisia Cerebral Utilizando a Análise Tridimensional da Marcha, que está sob a orientação da Profa. Dra. Suhaila M. Smaili Santos e co-orientado pela Profa Dra. Dirce Shizuko Fujisawa no programa de doutorado em Ciências da Reabilitação na Universidade Estadual de Londrina – Paraná.

Esta autorização está condicionada ao cumprimento do pesquisador aos requisitos da Resolução 466/12 e suas complementares, comprometendo-se o mesmo a utilizar os dados pessoais dos sujeitos da pesquisa, exclusivamente para os fins científicos, mantendo o sigilo e garantindo a não utilização das informações em prejuízo das pessoas e/ou das comunidades.

Antes de iniciar a coleta de dados o pesquisador deverá apresentar o Parecer Consubstanciado devidamente aprovado, emitido por Comitê de Ética em Pesquisa Envolvendo Seres Humanos, credenciado ao Sistema CEP/CONEP.

Marcos Takimura

____

Nome/assinatura e carimbo do responsável pela Instituição ou pessoa por ele delegada

Dr. Marcos Takimura
Ginecologia e Obstetrícia
CRM-PR [illegible]

MARCOS TAKIMURA
Centro Hospitalar de Reabilitação
Ana Carolina Moura Xavier
DIRETOR TÉCNICO - CRM-PR [illegible]

CENTRO HOSPITALAR DE REABILITAÇÃO ANA CAROLINA MOURA XAVIER
CNPJ – 76.416.866/0049-54
[illegible] - Cabral - [illegible] - Curitiba - Paraná - Brasil
[illegible] - Fone: (41) 3281-2600/ 3281-2778

ANEXO B: Parecer Consubstanciado do Comitê de Ética em Pesquisa.

Comitê de Ética em Pesquisa Envolvendo Seres Humanos

UNIVERSIDADE ESTADUAL DE LONDRINA - UEL

Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Classificação dos Desvios da Marcha de Pacientes com Paralisia Cerebral Utilizando a Análise Tridimensional da Marcha

Pesquisador: ALESSANDRO GIURIZATTO MELANDA

Área Temática:

Versão: 2

CAAE: 79599517.9.0000.5231

Instituição Proponente: CCS - Progr. de Pós-Grad. em Ciências da Reabilitação

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 2.447.001

Apresentação do Projeto:

Resumo:

Segundo o pesquisador, o projeto sobre classificação da marcha de sujeitos com diagnóstico clínico de paralisia cerebral (PC). Será realizada revisão sistemática da literatura e elaboração de nova classificação dos desvios da marcha deste grupo de sujeitos. Serão pesquisadas eletrônicamente bases de dados (Medline, Embase, Lilacs, Cochrane Controlled Trials Database, SciSearch) nas línguas portuguesa e inglesa. As palavras chaves usadas para a estratégia de pesquisas incluirão paralisia cerebral (cerebral palsy), marcha, andar (gait), análise da marcha, análise do andar (gait analysis), classificação (classification), padrão da marcha, padrão do andar (gait pattern). Serão avaliadas a validade externa com determinação do método de amostragem, características dos sujeitos e validade interna com avaliação da construção da classificação e propriedades psicométricas da classificação. Na segunda etapa do projeto será elaborada classificação dos desvios da marcha de pacientes com paralisia cerebral que deverá conter desvios da marcha clinicamente significativos nos 3 planos de movimento (sagital, coronal e transverso) e ser reprodutível. Para construção da classificação serão avaliados os exames tridimensionais da marcha de sujeitos com diagnóstico de paralisia cerebral realizados no Laboratório de Marcha do Centro Hospitalar de Reabilitação Ana Carolina de Moura Xavier de Curitiba Paraná, durante o período de 2010 a 2017. A direção do Centro Hospitalar de Reabilitação Ana Carolina de Moura Xavier (CHR) liberou a utilização dos dados requeridos pelos autores.A revisão sistemática da

Endereço: LABESC - Sala 14
Bairro: Campus Universitário **CEP:** 86.057-970
UF: PR **Município:** LONDRINA
Telefone: (43)3371-5455 **E-mail:** cep268@uel.br

02. Documento de autorização expedido pela Direção do Centro Hospitalar de Reabilitação Ana Carolina de Moura Xavier, em Curitiba.
03. Folha de rosto devidamente preenchida e assinada pela Coordenadora do Programa de Pós Graduação em Ciências da Reabilitação/uel - CCB
04. Termo de sigilo e confidencialidade encaminhado por e-mail para o parecerista, mediante autorização da coordenadora do Comitê.

Recomendações:

Não existem recomendações.

Conclusões ou Pendências e Lista de Inadequações:

O pesquisador atendeu os pedidos encaminhados no primeiro parecer, ou seja, apresentação do termo de sigilo, alteração no cronograma principalmente e apresentação dos gastos com o projeto, no valor total de R$286,00.

Considerações Finais a critério do CEP:

Não existem pendências.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1009386.pdf	14/12/2017 10:55:13		Aceito
Projeto Detalhado / Brochura Investigador	brochura.docx	31/10/2017 22:18:54	ALESSANDRO GIURIZATTO MELANDA	Aceito
Declaração de Instituição e Infraestrutura	Liberacao.pdf	31/10/2017 21:59:17	ALESSANDRO GIURIZATTO MELANDA	Aceito
Folha de Rosto	rosto.pdf	31/10/2017 21:54:15	ALESSANDRO GIURIZATTO MELANDA	Aceito

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

LONDRINA, 19 de Dezembro de 2017

Assinado por:
Rosana Lopes
(Coordenador)

ANEXO C: Normas de formatação do periódico Acta Ortopédica Brasileira Instruções para Autores

O periódico Acta Ortopédica Brasileira, órgão oficial do Departamento de Ortopedia e Traumatologia da Faculdade de Medicina da Universidade de São Paulo (DOT/ FMUSP é publicado bimestralmente em seis edições ao ano (jan/ fev, mar/ abr, maio/ jun, jul/ ago, set/ out e nov/ dez) com versão em inglês. Os t í tulos, resumos e descritores são publicados em inglês e português. A Acta é distribuída para médicos ortopedistas e principais instituições de ensino e pesquisa do Brasil. A publicação segue integralmente o padrão internacional do International Committee of Medical Journal Editors (ICMJE) ou Convenção de Vancouver e seus requisitos de uniformização [http:// www. icmje. org/]. Os artigos submetidos são enviados para avaliação por pareceristas (peer review) que recebem o texto de forma anônima (modalidade duplo- cego) e decidem ou não por sua publicação, sugerem modificações, requisitam esclarecimentos aos autores e efetuam recomendações ao Editor- Chefe. Os conceitos e declarações contidos nos t rabalhos são de total responsabilidade dos autores. Solicitamos aos autores a atenção às seguintes instruções para publicação.

FORMATAÇÃO DE ARTIGOS

Número de palavras recomendadas por t ipo de publicação: Os critérios abaixo especificados devem ser observados para cada t ipo de publicação. A contagem eletrônica de palavras deve começar na Introdução e terminar na Conclusão.

PREPARAÇÃO DE MANUSCRITO: A Revista Acta Ortopédica Brasileira recebe para publicação os seguintes t ipos de manuscritos: Artigo Original, Artigo de Atualização e Revisão. Os artigos de

Atualização e Revisão, somente serão aceitos a convite do Corpo Editorial.
Os manuscritos enviados deverão estar em arquivos . txt ou . doc, em espaço duplo, com margem larga. Os artigos deverão ser submetidos idealmente em inglês e português. As medidas deverão ser expressas no Sistema Internacional (Système International, SI), disponível em http:// physics. nist. gov/ cuu/ Units e unidades padrão quando aplicável. A revista adota o sistema Writecheck de detecção de plágio, porém todo conteúdo publicado nos artigos é de inteira responsabilidade dos autores. Recomenda- se aos autores não usar abreviações no t í tulo e l imitar a sua utilização no resumo e ao longo do texto. Os nomes genéricos devem ser usados para todas as drogas. Os fármacos podem ser referidos pelo nome comercial, porém, deve constar o nome, cidade e país ou endereço eletrônico do fabricante entre parênteses na seção Materiais e Métodos.

ABREVIATURAS: O uso de abreviaturas deve ser minimizado. As abreviaturas deverão ser definidas por ocasião de sua primeira utilização no resumo e também no texto. Abreviaturas fora do padrão não devem ser utilizadas, a menos que essas apareçam pelo menos t rês vezes no texto. Unidades de medida (3 ml ou 3 m L, e não 3 mililitros) ou símbolos científicos padrão (elementos químicos, por exemplo, Na, e não sódio) não são consideradas abreviaturas, e portanto, não devem ser definidos. Abreviar nomes longos ou substâncias químicas e termos utilizados para combinações terapêuticas. Abreviaturas em f iguras e tabelas podem ser utilizadas por razões de espaço, porém devem ser definidas na legenda, mesmo que tenham sido definidas no texto do artigo.

CARTA DE APRESENTAÇÃO: A carta de apresentação que acompanha a submissão do manuscrito deve ser assinada pelo autor correspondente, contendo as seguintes informações: Título do artigo, Nome (s) de todo (s) autor (es), texto autorizando a publicação do artigo, declarando que o mesmo é inédito (publicação em outro idioma é considerado como o mesmo artigo) e que não foi, ou está sendo submetido à publicação em outro periódico. Os autores devem se certificar que o manuscrito está inteiramente em conformidade com as instruções.

ENSAIOS CLÍNICOS: O periódico Acta Ortopédica Brasileira apoia a política de Registro de Ensaios Clínicos da Organização Mundial de Saúde (OMS) e do ICMJE, reconhecendo a importância destas iniciativas para o registro e divulgação internacional sobre estudos clínicos em acesso aberto. Desta forma, somente serão aceitos para publicação os artigos envolvendo pesquisas clínicas que tenham recebido um número de identificação em uma das plataformas de registros de ensaios clínicos validados pelos critérios da OMS e ICMJE. Os endereços eletrônicos destas plataformas de registro estão disponíveis na página do ICMJE [http:// www. icmje. org/ about - icmje/faqs/clinical-trials-registration/].

CONFLITO DE INTERESSES: Conforme recomendação do ICMJE e resolução do Conselho Federal de Medicina nº 1595 / 2000 os autores têm a responsabilidade de reconhecer e declarar potenciais conflitos de interesse f inanceiros e outros (comercial, pessoal, político, etc.) envolvidos no desenvolvimento do t rabalho apresentado para publicação.

AGRADECIMENTOS: Os autores podem agradecer o apoio f inanceiro ao t rabalho, na forma de auxílios a pesquisa, bolsas de estudo e outros, bem como profissionais que não qualificam como ao- autores do artigo e que contribuíram para o seu desenvolvimento.

CORREÇÃO DE PROVAS GRÁFICAS: Logo que prontas, as provas gráficas em formato eletrônico serão enviadas por e- mail para o autor correspondente. Os autores deverão devolver, também por e- mail, a prova gráfica com as devidas correções em no máximo, 48h após o seu recebimento. A medida visa agilizar o processo de revisão e publicação do artigo.

DIREITOS AUTORAIS: Todas as declarações publicadas nos artigos são de inteira responsabilidade dos autores. Entretanto, todo material publicado torna- se propriedade da Editora, que passa a reservar os direitos autorais. Portanto, nenhum material publicado na ACTA ORTOPEDICA BRASILEIRA poderá ser comercializado sem a permissão por escrito da Editora. Todos os autores de artigos submetidos deverão assinar um Termo de Transferência de Direitos Autorais, que entrará em vigor a partir da data de aceite do trabalho.

ORGANIZAÇÃO DO ARQUIVO ELETRÔNICO: Todas as partes do manuscrito devem ser incluídas em um único arquivo. O mesmo deverá ser organizado com a página de rosto, a seguir o texto, referências, figuras (com respectivas legendas) e ao final, as tabelas e quadros (com as respectivas legendas).

PÁGINA DE ROSTO: A página de rosto deve conter:

a) O tipo do artigo (artigo original, de revisão ou atualização);

b) O título completo em português e inglês com até 80 caracteres. O título deve ser conciso, porém informativo;

c) O nome completo de cada autor (sem abreviações); e sua afiliação institucional (as unidades hierárquicas devem ser apresentadas em ordem decrescente, por exemplo, universidade, faculdade/ instituto e departamento. Os nomes das instituições e programas deverão ser apresentados preferencialmente por extenso e na língua original da instituição ou na versão em inglês quando a escrita não é latina (p. ex. árabe, mandarim, grego);

d) Local onde o trabalho foi desenvolvido;

e) Nome, endereço completo, telefone e e- mail do autor correspondente.

RESUMO: O resumo em português e inglês deve ser estruturado em caso de artigo original e deve apresentar os objetivos do estudo com clareza, métodos, resultados e as principais conclusões, não devendo ultrapassar 200 palavras (não incluir quaisquer citações de referência). Ademais, o resumo deve incluir o Nível de Evidência, e o t ipo de Estudo, conforme tabela de classificação anexada ao f inal deste texto.

DESCRITORES: O artigo deve incluir no mínimo t rês e no máximo seis descritores em português e em inglês, baseados nos Descritores de Ciências da Saúde (De CS) ou no Medical Subject Headings (Me SH) da National Library of Medicine, disponível em

INTRODUÇÃO: A introdução do artigo deve apresentar o assunto e objetivo do estudo, incluindo citações, sem, no entanto, fazer uma revisão extensa da matéria.

MATERIAIS E MÉTODOS: Esta seção deve descrever os experimentos (quantitativa e qualitativamente) e os procedimentos em detalhes suficientes que permitam que outros pesquisadores reproduzam os resultados ou deem continuidade ao estudo.

Ao relatar experimentos com seres humanos ou animais, indicar se os procedimentos seguiram as normas do Comitê Ético sobre Experiências Humanas da instituição na qual a pesquisa foi realizada, e se os procedimentos estão de acordo com a declaração de Helsinki de 1995 e a Animal Experimentation Ethics, respectivamente. Os autores devem incluir uma declaração indicando que o protocolo foi aprovado pelo Comitê de Ética da Instituição (instituição de afiliação de pelo menos um dos autores), com o respectivo número de identificação. Também deve incluir que o Termo de Consentimento Livre e Esclarecido foi assinado por todos os participantes.

Identificar precisamente todas as drogas e substâncias químicas utilizadas, incluindo os nomes genéricos, dosagens e formas de administração. Não citar nomes dos pacientes, iniciais, ou registros de hospitais. Citar referências para o emprego de procedimentos estatísticos.

RESULTADOS: Apresentar os resultados em sequência lógica no texto, usando tabelas e ilustrações. Não repetir no texto todos os dados constantes das tabelas e ou ilustrações, porém enfatizar ou resumir somente as descobertas mais relevantes.

DISCUSSÃO: Enfatizar aspectos novos e importantes do estudo e as conclusões que decorrem destes no contexto da melhor evidência disponível. Não repetir em detalhes dados ou outras informações mencionadas em outras partes do manuscrito, como na Introdução ou Resultados. Para estudos experimentais, é recomendável iniciar a discussão resumindo brevemente os principais achados, depois explorar os possíveis mecanismos ou explicações para esses achados, comparar e contrastar os resultados com outros estudos relevantes, declarar as limitações do estudo e explorar as implicações destes resultados para pesquisas futuras e para a prática clínica.
Relacionar as conclusões com os objetivos do estudo, mas evitar afirmações e conclusões que não sejam suportadas pelos dados, em particular, a distinção entre relevância clínica e estatística. Evitar fazer afirmações sobre benefícios econômicos e custos, a menos que o manuscrito inclua dados e análises econômicas adequadas. Evitar reivindicação de prioridade (“ este é o primeiro estudo sobre...”) ou se referir a trabalho que não tenha sido concluído.

CONCLUSÃO: A conclusão deve ser clara e concisa, estabelecendo uma ligação entre a conclusão e os objetivos do estudo. Evitar conclusões não baseadas nos dados do estudo em questão. Evitar sugerir que estudos com amostras maiores são necessários para confirmar os resultados do trabalho em questão.

AGRADECIMENTOS: Quando aplicável agradecer brevemente as pessoas que tenham colaborado intelectual ou tecnicamente com o estudo, porém cuja contribuição não justifica coautoria. O autor deve garantir que as pessoas concordem em ter seus nomes e instituições divulgados. O apoio f inanceiro para a pesquisa e bolsas de estudo devem ser reconhecidos nesta seção (entidade de fomento e número do projeto).

IDENTIFICAÇÃO DOS AUTORES: O número ORCID (Open Researcher and Contributor ID, de cada um dos autores deve ser informado na declaração de contribuição dos autores, conforme modelo abaixo.

DECLARAÇÃO DA CONTRIBUIÇÃO DE AUTORES: A declaração da contribuição dos autores deverá ser incluída ao f inal do artigo com utilização de dois critérios mínimos de autoria, entre eles:

Contribuição substancial na concepção ou desenho do t rabalho, ou aquisição, análise ou interpretação dos dados para o t rabalho;

Redação do t rabalho ou revisão crítica do seu conteúdo intelectual; Aprovação f inal da versão do manuscrito a ser publicado;

Estar de acordo em ser responsabilizado por todos os aspectos do t rabalho, no sentido de garantir que qualquer questão relacionada à integridade ou exatidão de qualquer de suas partes sejam devidamente investigadas e resolvidas;

a) Participar ativamente da discussão dos resultados; b) Revisão e aprovação da versão f inal do t rabalho.

Todos os artigos deverão incluir a descrição da contribuição dos autores, conforme modelo:

“ Cada autor contribuiu individual e significantemente para o desenvolvimento deste artigo. MJ (0000 - 0000 - 0000 - 0000)*: redação do artigo, revisão e realização das cirurgias; CPV (0000 - 0002 - 3904 - 2836)*: cirurgias, análise dos dados e redação dos artigos; JVC (0000 - 0003 - 3910 - 714 x(0000 - 0000 - 0000 - 0000)*: análise estatística, cirurgias e revisão do artigo; OMA (0000 - 0000 - 0000 - 0000)*: análise das lâminas e revisão do artigo; MASP (0000 - 0000 - 0000 - 0000)*: redação e revisão do artigo e também em todo o conceito intelectual do artigo; ACA

(0000 - 0001 - 6891 - 5935)*: cirurgia, redação do artigo, análise estatística e conceito intelectual do artigo e confecção de todo o projeto de pesquisa. * Número ORCID (Open Researcher and Contributor ID).”

REFERÊNCIAS: Artigos originais podem incluir até cerca de 20 referências, restritas à bibliografia essencial ao conteúdo do artigo. Numerar as referências de forma consecutiva de acordo com a ordem em que forem mencionadas pela primeira vez no texto, utilizando- se números arábicos sobrescritos, no seguinte formato: (p. ex., Redução das funções da placa terminal. 1).

Os autores devem se certificar de que todas as referências são citadas no texto. Várias citações dentro de um único conjunto de parênteses devem ser separadas por vírgulas, sem espaço (1 , 5 , 7) . Onde há 3 ou mais citações sequenciais, utilizar um intervalo numérico (4 - 9) . Incluir os seis primeiros autores seguidos de et al.

Os t í tulos de periódicos deverão ser abreviados de acordo com o Index Medicus.

a) Artigo: Autor(es). Título do artigo. Título do Periódico. ano; volume: página inicial - f inal

Ex.: Campbell CJ. The healing of cartilage deffects. Clin Orthop Relat Res. 1969; (64) : 45- 63.

b) Livro: Autor(es) ou editor(es). Título do l ivro. Edição, se não for a primeira. Tradutor(es), se for o caso. Local de publicação: editora; ano. Ex.: Diener HC, Wilkinson M, editors. Drug- induced headache. 2nd ed. New York: Spriger- Verlag; 1996 .

c) Capítulo de l ivro: Autor(es) do capítulo. Título do capítulo Editor (es) do l ivro e demais dados sobre este, conforme o i tem anterior. Ex.: Chapman MW, Olson SA. Open f ractures. In: Rockwood CA, Green DP. Fractures in adults. 4 th ed. Philadelphia: Lippincott- Raven; 1996 . p. 305 -52.

d) Resumo: Autor(es). Título, seguido de [abstract]. Periódico ano; volume (suplemento e seu número, se for o caso): página(s) Ex.:

Enzensberger W, Fisher PA. Metronome in Parkinson's disease [abstract]. Lancet. 1996;34:1337.

e) Comunicações pessoais: só devem ser mencionadas no texto entre parênteses.

f) Tese: Autor, título nível (mestrado, doutorado etc.), cidade: instituição; ano. Ex.: Kaplan SJ. Post-hospital home health care: the elderly's access and utilization [dissertation]. St. Louis: Washington Univ.; 1995.

g) Material eletrônico: Autor(es). Título do artigo. Título do periódico abreviado [suporte]. Data de publicação [data de acesso com a expressão "acesso em"]; volume (número): páginas inicial-final ou [número de páginas aproximado]. Endereço eletrônico com a expressão "Disponível em:"

Exemplo: Pavezi N, Flores D, Perez CB. Proposição de um conjunto de metadados para descrição de arquivos fotográficos considerando a Nobrade e a Sepiades. Transinf. [Internet]. 2009 [acesso em 2010 nov 8];21(3):197-205. Disponível em:

TABELAS: As tabelas devem ser numeradas por ordem de aparecimento no texto com números arábicos. Cada tabela deve ter um título e, se necessário, uma legenda explicativa. Os quadros e tabelas deverão ser enviados através dos arquivos originais editáveis (Word, Excel) e não como imagem. Tabelas e quadros que ocupem mais de uma página devem ser evitados. Não usar elementos de imagem, caixas de texto, ou tabulações.

FIGURAS (FOTOGRAFIAS E ILUSTRAÇÕES): As figuras devem ser apresentadas em páginas separadas e numeradas sequencialmente, em algarismos arábicos, conforme a ordem de aparecimento no texto. Para evitar problemas que comprometam o padrão da revista, o envio do material deve obedecer aos seguintes parâmetros: todas as figuras, fotografias e ilustrações devem ter qualidade gráfica adequada (300 dpi de resolução) e apresentar título e legenda. Em todos os casos, os arquivos devem ter extensão .tif e/ou jpg. Também são aceitos arquivos com extensão .xls, .xlsx (Excel), .eps, .psd para ilustrações em curva (gráficos, desenhos e esquemas). As figuras incluem todas as ilustrações, tais como fotografias, desenhos, mapas, gráficos, etc. Figuras em preto e branco serão reproduzidas gratuitamente, mas o editor reserva o direito de estabelecer o limite razoável, quanto ao número delas ou cobrar do autor, a despesa decorrente do excesso. Fotos coloridas serão cobradas do autor.

Por favor, note que é de responsabilidade do autor (s) obter permissão do detentor dos direitos autorais para reproduzir figuras (ou tabelas) que tenham sido previamente publicados em outras fontes. Para todos os valores de acesso aberto, os autores devem ter permissão do detentor dos direitos, caso desejem incluir imagens que tenham sido publicados em outros periódicos de acesso não- aberto. A permissão deve ser indicada na legenda da figura, e a fonte original deve ser incluída na lista de referências.

LEGENDAS: Digitar as legendas usando espaço duplo, acompanhando as respectivas figuras (gráficos, fotos e ilustrações). Cada legenda deve ser numerada em algarismos arábicos, correspondendo a cada figura, e na ordem em que foram citadas no trabalho. Abreviaturas e siglas: Devem ser precedidas do nome completo quando citadas pela primeira vez no texto. No rodapé das figuras e tabelas deve ser discriminado o significado das abreviaturas, símbolos, outros sinais e informada fonte: local onde a pesquisa foi realizada. Se as ilustrações já tiverem sido publicadas, deverão vir acompanhadas de autorização por escrito do autor ou editor, constando a fonte de referência onde foi publicada.

SUBMISSÃO DE ARTIGOS: A partir de janeiro de 2008 a Acta Ortopédica Brasileira adota o Sistema SciELO de Publicação e Submissão online disponível. Os autores deverão seguir as instruções de cadastro e inclusão de artigo no próprio sistema.

Caso ocorra a necessidade de esclarecimentos adicionais, favor entrar em contato com a Atha Comunicação e Editora - Rua: Machado Bittencourt, 190 , 4º andar - Vila Mariana - São Paulo Capital CEP 04044 - 000 - E- mail: - telefone 55 - 11 - 5087 - 9502 com Ana Carolina de Assis/ Arthur T. Assis.

Instructions to Authors

The journal Acta Ortopédica Brasileira, official organ of the Department of Orthopedics and Traumatology, Faculdade de Medicina da Universidade de Sâo Paulo (DOT/ FMUSP), is published bimonthly in six issues per year (Jan/ Feb, Mar/ Apr, May/ Jun, Jul/ Aug, Sep/ Oct, and Nov/ Dec) with English version. The titles, abstracts and keywords are published in English and Portuguese. Acta is distributed to orthopedists and leading educational and research institutions in Brazil. The publication follows entirely the international standard of the International Committee of Medical Journal Editors (ICMJE) - Vancouver Convention - and its uniform requirements [http:// www. icmje. org/]. Submitted papers are sent for double- blind peer review evaluation to decide whether they should be published or not, suggesting improvements, asking the authors for clarification and making recommendations to the Editor- in Chief. The concepts and statements contained in the papers are the sole responsibility of the authors. We ask authors to observe the following instructions for publication.

ARTICLES FORMAT

Number of words recommended according to the publication type: The criteria specified below should be observed for each type of publication. The electronic counting of words should start at the Introduction and end at the Conclusion.

MANUSCRIPT PREPARATION: The journal Acta Ortopédica Brasileira receives the following types of contributions: Original Article, Update Article and Review Article. The Update and Review articles are only considered by invitation f rom the Editorial Board. Manuscripts should be sent in . txt or . doc f i les, double- spaced, with wide margins. Articles should be submitted ideally in English and Portuguese. Measures should be expressed in the International System (Système International, SI), available at and standard units, where applicable.
It is recommended that authors do not use abbreviations in the t i t le and l imit their use in the abstract and in the text. This journal adopts Writecheck plagiarism detection system, however all published content are the sole responsibility of the authors. The generic names should be used for all drugs. The drugs can be referred to by their t rade name, however, the manufacturer' s name, city and country or electronic address should be stated in brackets in the Materials and Methods section.

ABBREVIATIONS: The use of abbreviations should be minimized. Abbreviations should be defined at the t ime of i ts f i rst appearance in the abstract and also in the text. Non- standard abbreviations shall not be used, unless they appear at least three t imes in the text.
Measurement units (3 ml or 3 m L, but not 3 milliliters) or standard scientific symbols (chemical elements, for example, Na, and not sodium) are not considered abbreviations and, therefore, should not be defined. Authors should abbreviate long names of chemical substances and therapeutic combinations terms. Abbreviations in f igures and tables can be used for space reasons, but should be defined in the legend, even if they were defined in the article.

PRESENTATION LETTER: The cover letter accompanying the submission of the manuscript should be signed by the corresponding author and should include the following information: Title, names of all authors, text authorizing the publication of the article, stating that it has not being submitted simultaneously elsewhere and it has not been previously published (publication in another language is considered as the same article). Authors should make sure that the manuscript is entirely in accordance with the instructions.

CLINICAL TRIALS: The journal Acta Ortopédica Brasileira supports the Clinical Trials Registry policy of the World Health Organization (WHO) and the ICMJE, recognizing the importance of these initiatives for the registration and international dissemination of clinical studies in open access. Therefore, it will only accepted for publication articles involving clinical research that have received an identification number in one of the clinical t r ials registry platforms validated by WHO and ICMJE. The URLs of these registry platforms are available at the ICMJE page [http:// www. icmje. org/ about - icmje/ faqs/ clinical- t r ials-registration/].

CONFLICT OF INTERESTS: As recommended by the ICMJE and resolution of the Brazilian Federal Council of Medicine nº 1595 / 2000 , authors have the responsibility to recognize and declare any potential f inancial conflicts of interest, as well as conflicts of other nature (commercial, personal, political, etc.) involved in developing the work submitted for publication.

ACKNOWLEDGEMENTS: Authors can acknowledge f inancial support to the work in the form of research grants, scholarships and other, as well as professionals who do not qualify as co- authors of the article, but somehow contributed to i ts development.

CORRECTION OF GALLEY PROOFS: As soon as they are ready, the galley proofs in electronic form will be sent by e- mail to the corresponding author. Authors should return proofs, also by e-mail, with the necessary corrections within 48 hours maximum after its receipt. This aims to expedite the review process and publication of the article.

COPYRIGHT: All statements published in the articles are the authors' responsibility. However, all published material becomes the property of the publisher, which shall reserve the copyright. Therefore, no material published in Acta Ortopédica Brasileira can be marketed without the written permission of the publisher. All authors of articles submitted to Acta must sign a Copyright Transfer Agreement, which will take effect from the date of acceptance of the paper.

ORGANIZING THE ELECTRONIC FILE: All parts of the manuscript should be included in a single file. It should be formed by the cover page, then the text, references, figures (with their captions) and finally, tables and charts (with their respective captions).

COVERPAGE: The title page should contain:

a) The article category (original article, review article or update article);

b) The full title in Portuguese and English with up to 80 characters. The title should be concise, but informative;

c) The full name of each author (no abbreviations) and their affiliation (hierarchical units should be presented in descending order, for example, university, college/institute and department. The names of institutions and programs should be submitted preferably in full and in the original language of the institution or in the English version when writing is not Latin (e.g. Arabic, Mandarin, Greek);

d) The place where the work was performed;

e) Name, address, telephone number and e-mail of the corresponding author.

ABSTRACT: The abstract in Portuguese and in English should be structured in cases of original articles and shall present the study' s objectives clearly, methods, results and main conclusions and should not exceed 200 words (do not include any reference citations). Moreover, the abstract should include the level of evidence and the type of study, according to the classification table attached at the end of this text.

KEYWORDS: The article should include at least three and at most six descriptors in Portuguese and in English, based on the Descriptors of Health Sciences (De CS) or Medical Subject Headings (Me SH) of the National Library of Medicine.

INTRODUCTION: The introduction of the article shall present the matter and purpose of the study, including citations without, however, making an extensive review of the matter.

MATERIALS AND METHODS: This section should describe the experiments (quantitatively and qualitatively) and procedures in sufficient detail to allow other researchers to reproduce the results or provide continuity to the study.

When reporting experiments on humans or animals, authors should indicate whether the procedures followed the rules of the Ethics Committee on Human Trials of the institution in which the survey was conducted, and whether the procedures are in accordance with the 1995 Helsinki Declaration and the Ethics in Experimentation Animals, respectively. Authors should include a statement indicating that the protocol was approved by the Institutional Ethics Committee (affiliate institution of at least one of the authors), with i ts identification number. It should also include whether a Free and Informed Consent Term was signed by all participants.

Authors should precisely identify all drugs and chemicals used, including generic names, dosages and administration. Patients' names, initials, or hospital records should not be included. References regarding statistical procedures should be included.

RESULTS: Results should be present in logical sequence in the text, using tables and i l lustrations. Do not repeat in the text all the data in the tables and/ or i l lustrations but emphasize or summarize only the most relevant f indings.

DISCUSSION: Emphasize new and important aspects of the study and the conclusions that derive f rom i t , in the context of the best evidence available. Do not repeat in detail data or other information mentioned elsewhere in the manuscript, as in the Introduction or Results. For experimental studies it is recommended to start the discussion by briefly summarizing the main f indings, then explore possible mechanisms or explanations for these f indings, compare and contrast the results with other relevant studies, state the l imitations of the study and explore the implications of these results for future research and for clinical practice.
Link the conclusions with the goals of the study but avoid statements and conclusions that are not supported by the data, in particular the distinction between clinical and statistical relevance. Avoid making statements on economic benefits and costs, unless the manuscript includes data and appropriate economic analysis. Avoid priority claim (“ this is the f i rst study of . . . ”) or refer to work that has not yet been completed.

CONCLUSION: The conclusion should be clear and concise, establishing a l ink between the conclusion and the study objectives. Avoiding conclusions not based on data f rom the study in question is recommended, as well as avoiding suggest that studies with larger samples are needed to confirm the results of the work in question.

ACKNOWLEDGEMENTS: When applicable, briefly acknowledge the people who have contributed intellectually or technically to the study, but whose contribution does not justify co- authorship. The author must ensure that people agree to have their names and institutions disclosed. Financial support for the research and fellowships should be acknowledged in this section (funding agency and project number).

AUTHORS IDENTIFICATION: The ORCID (Open Researcher and Contributor ID, of each author should be informed in the authors' statement of contribution, according to the model below.

STATEMENT OF AUTHORS' CONTRIBUTION: The declaration of authors' contribution should be included at the end of the article, using minimum criteria for authorship, including:

• Substantial contribution in the work conception or design, or acquisition, analysis or interpretation of data to the study;
• Writing the article or critically reviewing i ts intellectual content;
• Approval of the f inal version of the manuscript to be submitted for publication;
• Agree to be responsible for all aspects of the work, to ensure that any matters regarding the completeness or accuracy of any of i ts parts are properly investigated and resolved;

All articles should include a description of the authors' contribution, as follows:

" Each individual author contributed individually and significantly to the development of this work. MJ (0000 - 0000 - 0000 - 0000)*: wrote and reviewed the and performed the surgeries; CPV (0000 - 0002 - 3904 - 2836)*: performed the surgeries, analyzed the data analysis and wrote the articles; JVC (0000-0003-3910-714x (0000-0000-0000-0000)*: performed statistical analysis, participated at the surgeries and reviewed the article; OMA (0000 - 0000 - 0000 - 0000)*: analyzed the slides and reviewed the article; MASP (0000 - 0000 - 0000 - 0000)*: drafted and reviewed the article and contributed to the intellectual concept of the study; ACA (0000 - 0001 - 6891 - 5935)*: performed the surgeries, wrote the article, performed statistical analysis and contributed to the intellectual concept of the study and the entire research project. * ORCID (Open Researcher and Contributor ID).”

REFERENCES: Original articles may include up to about 20 references, restricted to the essential bibliography to the article’s content. Number the references consecutively in the order in which they are first mentioned in the text, using superscript Arabic numerals in the following format: (e. g., Reduction of terminal plate functions. 1). Authors should make sure that all references are cited in the text. Several citations within a single set of parentheses should be separated by commas without space (1,5,7). Where there are 3 or more sequential citations, use a numeric range (4-9). Include the first six authors followed by et al.

The titles of journals should be abbreviated according to Index Medicus.

a) Article: Author (s). Article title. Journal title. Year; volume: initial page – final page.

Ex.: Campbell CJ. The healing of cartilage defects. Clin Orthop Relat Res. 1969;64:45-63.

b) Book: Author(s) or editor (s). Book title. Edition, if it is not the first. Translator (s), if it applies. Publication place: publisher; year.

Ex.: Diener HC, Wilkinson M, editors. Drug- induced headache. 2nd ed. New York: Spriger- Verlag; 1996.

c) Book chapter: Chapter author (s). Chapter title. Book Editor (s) and supplementary data, likewise the previous item.

Ex.: Chapman MW, Olson SA. Open fractures. In: Rockwood CA, Green DP. Fractures in adults. 4th ed. Philadelphia: Lippincott- Raven; 1996. p.305-52.

d) Abstract: Author(s). Title followed by [abstract]. Journal. Year; volume (supplement and its number, if it applies): page (s).

Ex.: Enzensberger W, Fisher PA. Metronome in Parkinson’s disease [abstract]. Lancet.1996;34:1337.

e) Personal communications: should only be mentioned in the text, between parentheses.

f) Thesis: Author, title, level (Master, Ph D, etc.), city: institution; year. Ex.: Kaplan SJ. Post- hospital home health care: the elderly' s access and utilization [dissertation]. St. Louis: Washington Univ.; 1995 .

g) Electronic material: Author (s). Article title. Abbreviated Journal title [medium]. Publication date [access date followed by the expression "accessed on"]; volume (number): initial page- final page or [approximate number of pages]. URL followed by the expression "Available from:"

Ex.: Pavezi N, Flores D, Perez CB. Proposição de um conjunto de metadados para descrição de arquivos fotográficos considerando a Nobrade e a Sepiades. Transinf. [Internet]. 2009 [acesso em 2010 nov 8];21(3):197-205. Available from:

TABLES: Tables should be numbered in order of appearance in the text with Arabic numerals. Each table should have a title and, when necessary, an explanatory caption. Charts and tables should be sent in editable source files (Word, Excel) and not as images. Tables and charts covering more than one page should be avoided. Do not use image elements, text boxes, or tabs.

FIGURES (ILLUSTRATIONS AND PHOTOS): Figures should be submitted on separate pages and numbered sequentially in Arabic numerals, according to the order of appearance in the text. To avoid issues that compromise the journal pattern, all material sent shall comply with the following parameters: all graphics, photographs and illustrations should have adequate graphic quality (300 dpi resolution) and present title and caption. In all cases, the files must have .tif or .jpg extensions. Files with extension .xls, .xlsx (Excel), .eps or .psd to curve illustrations (graphics, drawings and diagrams) shall also be accepted. Figures include all illustrations such as photographs, drawings, maps, graphs, etc. Black and white figures will be freely reproduced, but the editor reserves the right to set a reasonable limit on their number or charge the author the expense resulting from excesses. Color photos will be charged to the author.

Please note that it is the authors' responsibility to obtain permission from the copyright holder to reproduce figures (or tables) that have been previously published elsewhere. Authors must have permission from the copyright owner, if they wish to include images that have been published in other non- open access journals. Permission shall be indicated in the figure legend, and the original source must be included in the reference list.

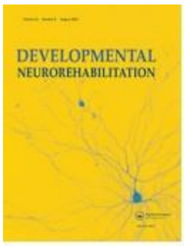
LEGENDS TO FIGURES: Type the legends using double space, following the respective figures (graphics, photos and illustrations). Each legend must be numbered in Arabic numerals corresponding to each illustration and in the order that they are mentioned in the text. Abbreviations and acronyms should be preceded by the full name when cited for the first time in the text. At the bottom of figures and tables discriminate the meaning of abbreviations, symbols, signs and other informed source. If the illustrations have already been published, they shall be accompanied by written consent of the author or editor, stating the reference source where it was originally published.

PAPER SUBMISSION: From January 2008 Acta Ortopédica Brasileira adopts the SciELO Publication and Submission System available online at Authors should follow the registration and article inclusion instructions available at the website.

For further information please contact Atha Comunicação e Editora, Rua Machado Bittencourt 190, 4° floor. Vila Mariana, 04044 - 000 São Paulo, SP, Brazil. actaortopedicabrasileira@uol.com.br.
Tel. + 55 11 5087 - 9502 c/ o Ana Carolina de Assis/ Arthur T. Assis.

ANEXO D: Normas de formatação do periódico Developmental Neurorehabilitation.

Instructions for authors



Taylor & Francis

Developmental Neurorehabilitation

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ipdr20

AUTHOR SERVICES
Supporting Taylor & Francis authors

For general guidance on every stage of the publication process, please visit our Author Services website.

EDITING SERVICES
Supporting Taylor & Francis authors

For editing support, including translation and language polishing, explore our Editing Services website

SCHOLARONE MANUSCRIPTS™

This journal uses ScholarOne Manuscripts (previously Manuscript Central) to peer review manuscript submissions. Please read the guide for ScholarOne authors before making a submission. Complete guidelines for preparing and submitting your manuscript to this journal are provided below.

Contents

About the Journal

Developmental Neurorehabilitation is an international, peer-reviewed journal publishing high-quality, original research. Please see the journal's Aims & Scope for information about its focus and peer-review policy.

Please note that this journal only publishes manuscripts in English.

Developmental Neurorehabilitation accepts the following types of article:

- Subject Reviews
- Peer Commentary
- Original Scientific Papers
- Brief Reports

Open Access

You have the option to publish open access in this journal via our Open Select publishing program. Publishing open access means that your article will be free to access online immediately on publication, increasing the visibility, readership and impact of your research. Articles published Open Select with Taylor & Francis typically receive 32% more citations* and over 6 times as many downloads** compared to those that are not published Open Select.

Your research funder or your institution may require you to publish your article open access. Visit our Author Services website to find out more about open access policies and how you can comply with these.

You will be asked to pay an article publishing charge (APC) to make your article open access and this cost can often be covered by your institution or funder. Use our APC finder to view the APC for this journal.

Please visit our Author Services website or contact openaccess@tandf.co.uk if you would like more information about our Open Select Program.

*Citations received up to Jan 31st 2020 for articles published in 2015-2019 in journals listed in Web of Science®.
**Usage in 2017-2019 for articles published in 2015-2019.

Peer Review and Ethics

Taylor & Francis is committed to peer-review integrity and upholding the highest standards of review. Once your paper has been assessed for suitability by the editor, it will then be double blind peer reviewed by independent, anonymous expert referees. Find out more about what to expect during peer review and read our guidance on publishing ethics.

Preparing Your Paper

All authors submitting to medicine, biomedicine, health sciences, and allied and public health journals should conform to the Uniform Requirements for Manuscripts Submitted to Biomedical Journals, prepared by the International Committee of Medical Journal Editors (ICMJE).

Subject Reviews

- Should be written with the following elements in the following order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figures; figure captions (as a list)

Peer Commentary

- Should be written with the following elements in the following order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figures; figure captions (as a list)

Original Scientific Papers

- Should be written with the following elements in the following order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figures; figure captions (as a list)

Brief Reports

- Should be written with the following elements in the following order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figures; figure captions (as a list)

- This submission format is appropriate for pilot and preliminary findings as well direct replications of research findings. Papers submitted as brief reports must be less than 10 pages inclusive of abstract and references and are limited to no more than two tables or figures. The Results and Discussion sections should be combined under a single heading "Results and Discussion". The Results and Discussion section should be limited to the presentation and summary of results, brief discussion of the implications of the findings, acknowledgement of the limitations, and a suggested area for future research. The title of the paper must end with "Brief Report."

Style Guidelines

Please refer to these quick style guidelines when preparing your paper, rather than any published articles or a sample copy.

Please use American spelling style consistently throughout your manuscript.

Please use double quotation marks, except where "a quotation is 'within' a quotation". Please note that long quotations should be indented without quotation marks.

All authors are asked to take account of the diverse audience of Developmental Neurorehabilitation. Clearly explain or avoid the use of terms that might be meaningful only to a local or national audience. Some specific points of style for the text of original papers, reviews, and case studies follow: • Developmental Neurorehabilitation prefers US to 'American', USA to 'United States', and UK to 'United Kingdom'. • Developmental Neurorehabilitation uses conservative British, not US, spelling, i.e. colour not color; behaviour (behavioural) not behavior; [school] programme not program; [he] practises not practices; centre not center; organization not organisation; analyse not analyze, etc. • Single 'quotes' are used for quotations rather than double "quotes", unless the 'quote is "within" another quote'. • Punctuation should follow the British style, e.g. 'quotes precede punctuation'. • Punctuation of common abbreviations should follow the following conventions: e.g. i.e. cf. • Note that such abbreviations are not followed by a comma or a (double) point/period. • Dashes (M-dash) should be clearly indicated in manuscripts by way of either a clear dash (-) or a double hyphen (- -). • Developmental

Neurorehabilitation is sparing in its use of the upper case in headings and references, e.g. only the first word in paper titles and all subheads is in upper case; titles of papers from journals in the references and other places are not in upper case. • Apostrophes should be used sparingly. Thus, decades should be referred to as follows: 'The 1980s [not the 1980's] saw ...'. Possessives associated with acronyms (e.g. APU), should be written as follows: 'The APU's findings that ...', but, NB, the plural is APUs. • All acronyms for national agencies, examinations, etc., should be spelled out the first time they are introduced in text or references. Thereafter the acronym can be used if appropriate, e.g. 'The work of the Assessment of Performance Unit (APU) in the early 1980s ...'. Subsequently, 'The APU studies of achievement ...', in a reference ... (Department of Education and Science [DES] 1989a). • Brief biographical details of significant national figures should be outlined in the text unless it is quite clear that the person concerned would be known internationally. Some suggested editorial emendations to a typical text are indicated in the following with square brackets: 'From the time of H. E. Armstrong [in the 19th century] to the curriculum development work associated with the Nuffield Foundation [in the 1960s], there has been a shift from heurism to constructivism in the design of [British] science courses'. • The preferred local (national) usage for ethnic and other minorities should be used in all papers. For the USA, African-American, Hispanic, and Native American are used, e.g. 'The • African American presidential candidate, Jesse Jackson...' For the UK, African-Caribbean (not 'West Indian'), etc. • Material to be emphasized (italicized in the printed version) should be underlined in the typescript rather than italicized. Please use such emphasis sparingly. n (not N), % (not per cent) should be used in typescripts. • Numbers in text should take the following forms: 300, 3000, 30 000. Spell out numbers under 10 unless used with a unit of measure, e.g. nine pupils but 9 mm (do not introduce periods with measure). For decimals, use the form 0.05 (not .05).

Formatting and Templates

Papers may be submitted in Word or LaTeX formats. Figures should be saved separately from the text. To assist you in preparing your paper, we provide formatting template(s).

Word templates are available for this journal. Please save the template to your hard drive, ready for use.

If you are not able to use the template via the links (or if you have any other template queries) please contact us here.

Figures should be saved separately from the text. The main document should be double-spaced, with one-inch margins on all sides, and all pages should be numbered consecutively. Text should appear in 12-point Times New Roman or others common 12-point font. Authors should not include their names, telephone numbers, fax numbers or e-mail addresses inside the body of the manuscript or on any figures or tables. The text should be divided into numbered sections. Use person-first language throughout the manuscript (i.e., persons with brain injury rather than brain injured persons).

References

Please use this reference guide when preparing your paper.

Taylor & Francis Editing Services

To help you improve your manuscript and prepare it for submission, Taylor & Francis provides a range of editing services. Choose from options such as English Language Editing, which will ensure that your article is free of spelling and grammar errors, Translation, and Artwork Preparation. For more information, including pricing, visit this website.

Checklist: What to Include

1. Author details. Please ensure everyone meeting the International Committee of Medical Journal Editors (ICMJE) requirements for authorship is included as an author of your paper. All authors of a manuscript should include their full name and affiliation on the cover page of the manuscript. Where available, please also include ORCiDs and social media handles (Facebook, Twitter or LinkedIn). One author will need to be identified as the corresponding author, with their email address normally displayed in the article PDF (depending on the journal) and the online article. Authors' affiliations

are the affiliations where the research was conducted. If any of the named co-authors moves affiliation during the peer-review process, the new affiliation can be given as a footnote. Please note that no changes to affiliation can be made after your paper is accepted. Read more on authorship.

2. You can opt to include a video abstract with your article. Find out how these can help your work reach a wider audience, and what to think about when filming.
3. Funding details. Please supply all details required by your funding and grant-awarding bodies as follows:
   For single agency grants
   This work was supported by the [Funding Agency] under Grant [number xxxx].
   For multiple agency grants
   This work was supported by the [Funding Agency #1] under Grant [number xxxx]; [Funding Agency #2] under Grant [number xxxx]; and [Funding Agency #3] under Grant [number xxxx].
4. Disclosure statement. This is to acknowledge any financial interest or benefit that has arisen from the direct applications of your research. Further guidance on what is a conflict of interest and how to disclose it.
5. Data availability statement. If there is a data set associated with the paper, please provide information about where the data supporting the results or analyses presented in the paper can be found. Where applicable, this should include the hyperlink, DOI or other persistent identifier associated with the data set(s). Templates are also available to support authors.
6. Data deposition. If you choose to share or make the data underlying the study open, please deposit your data in a recognized data repository prior to or at the time of submission. You will be asked to provide the DOI, pre-reserved DOI, or other persistent identifier for the data set.
7. Supplemental online material. Supplemental material can be a video, dataset, fileset, sound file or anything which supports (and is pertinent to) your paper. We publish supplemental material online via Figshare. Find out more about supplemental material and how to submit it with your article.
8. Figures. Figures should be high quality (1200 dpi for line art, 600 dpi for grayscale and 300 dpi for color, at the correct size). Figures should be supplied in one of our preferred file formats: EPS, PDF, PS, JPEG, TIFF, or Microsoft Word (DOC or DOCX) files are

acceptable for figures that have been drawn in Word. For information relating to other file types, please consult our Submission of electronic artwork document.

9. Tables. Tables should present new information rather than duplicating what is in the text. Readers should be able to interpret the table without reference to the text. Please supply editable files.
10. Equations. If you are submitting your manuscript as a Word document, please ensure that equations are editable. More information about mathematical symbols and equations.
11. Units. Please use SI units (non-italicized).

Using Third-Party Material in your Paper

You must obtain the necessary permission to reuse third-party material in your article. The use of short extracts of text and some other types of material is usually permitted, on a limited basis, for the purposes of criticism and review without securing formal permission. If you wish to include any material in your paper for which you do not hold copyright, and which is not covered by this informal agreement, you will need to obtain written permission from the copyright owner prior to submission. More information on requesting permission to reproduce work(s) under copyright.

Disclosure Statement

Please include a disclosure statement, using the subheading “Disclosure of interest.” If you have no interests to declare, please state this (suggested wording: *The authors report no conflict of interest*). For all NIH/Wellcome-funded papers, the grant number(s) must be included in the declaration of interest statement. Read more on declaring conflicts of interest.

Clinical Trials Registry

In order to be published in a Taylor & Francis journal, all clinical trials must have been registered in a public repository at the beginning of the research process (prior to patient enrolment). Trial registration numbers should be included in the abstract, with full details in the methods section. The registry should be publicly accessible (at no charge), open to all prospective registrants, and managed by a not-for-profit organization. For a list of registries that meet these requirements, please visit the WHO International Clinical Trials Registry Platform (ICTRP). The registration of all clinical trials facilitates the sharing of information among clinicians, researchers, and patients, enhances public confidence in research, and is in accordance with the ICMJE guidelines.

Complying With Ethics of Experimentation

Please ensure that all research reported in submitted papers has been conducted in an ethical and responsible manner and is in full compliance with all relevant codes of experimentation and legislation. All papers which report in vivo experiments or clinical trials on humans or animals must include a written statement in the Methods section. This should explain that all work was conducted with the formal approval of the local human subject or animal care committees (institutional and national), and that clinical trials have been registered as legislation requires. Authors who do not have formal ethics review committees should include a statement that their study follows the principles of the Declaration of Helsinki.

Consent

All authors are required to follow the ICMJE requirements on privacy and informed consent from patients and study participants. Please confirm that any patient, service user, or participant (or that person's parent or legal guardian) in any research, experiment, or clinical trial described in your paper has given written consent to the inclusion of material pertaining to themselves, that they acknowledge that they cannot be identified via the paper; and that you have fully anonymized them. Where someone is deceased, please ensure you have written consent from the family or estate. Authors may use this Patient Consent Form, which should be completed, saved, and sent to the journal if requested.

Health and Safety

Please confirm that all mandatory laboratory health and safety procedures have been complied with in the course of conducting any experimental work reported in your paper. Please ensure your paper contains all appropriate warnings on any hazards that may be involved in carrying out the experiments or procedures you have described, or that may be involved in instructions, materials, or formulae.

Please include all relevant safety precautions; and cite any accepted standard or code of practice. Authors working in animal science may find it useful to consult the International Association of Veterinary Editors' Consensus Author Guidelines on Animal Ethics and Welfare and Guidelines for the Treatment of Animals in Behavioural Research and Teaching. When a product has not yet been approved by an appropriate regulatory body for the use described in your paper, please specify this, or that the product is still investigational.

Submitting Your Paper

This journal uses ScholarOne Manuscripts to manage the peer-review process. If you haven't submitted a paper to this journal before, you will need to create an account in ScholarOne. Please read the guidelines above and then submit your paper in the relevant Author Center, where you will find user guides and a helpdesk.

If you are submitting in LaTeX, please convert the files to PDF beforehand (you will also need to upload your LaTeX source files with the PDF).

Please note that *Developmental Neurorehabilitation* uses Crossref™ to screen papers for unoriginal material. By submitting your paper to *Developmental Neurorehabilitation* you are agreeing to originality checks during the peer-review and production processes.

On acceptance, we recommend that you keep a copy of your Accepted Manuscript. Find out more about sharing your work.

Data Sharing Policy

This journal applies the Taylor & Francis Basic Data Sharing Policy. Authors are encouraged to share or make open the data supporting the results or analyses presented in their paper where this does not violate the protection of human subjects or other valid privacy or security concerns.

Authors are encouraged to deposit the dataset(s) in a recognized data repository that can mint a persistent digital identifier, preferably a digital object identifier (DOI) and recognizes a long-term preservation plan. If you are uncertain about where to deposit your data, please see this information regarding repositories.

Authors are further encouraged to cite any data sets referenced in the article and provide a Data Availability Statement.

At the point of submission, you will be asked if there is a data set associated with the paper. If you reply yes, you will be asked to provide the DOI, pre-registered DOI, hyperlink, or other persistent identifier associated with the data set(s). If you have selected to provide a pre-registered DOI, please be prepared to share the reviewer URL associated with your data deposit, upon request by reviewers.

Where one or multiple data sets are associated with a manuscript, these are not formally peer reviewed as a part of the journal submission process. It is the author's responsibility to ensure the soundness of data. Any errors in the data rest solely with the producers of the data set(s).

Publication Charges

There are no submission fees, publication fees or page charges for this journal.

Color figures will be reproduced in color in your online article free of charge. If it is necessary for the figures to be reproduced in color in the print version, a charge will apply.

Charges for color figures in print are $400 per figure (£300; $500 Australian Dollars; €350). For more than 4 color figures, figures 5 and above will be charged at $75 per figure (£50; $100 Australian Dollars; €65). Depending on your location, these charges may be subject to local taxes.

Copyright Options

Copyright allows you to protect your original material, and stop others from using your work without your permission. Taylor & Francis offers a number of different license and reuse options, including Creative Commons licenses when publishing open access. Read more on publishing agreements.

Complying with Funding Agencies

We will deposit all National Institutes of Health or Wellcome Trust-funded papers into PubMedCentral on behalf of authors, meeting the requirements of their respective open access policies. If this applies to you, please tell our production team when you receive your article proofs, so we can do this for you. Check funders' open access policy mandates here. Find out more about sharing your work.

My Authored Works

On publication, you will be able to view, download and check your article's metrics (downloads, citations and Altmetric data) via My Authored Works on Taylor & Francis Online. This is where you can access every article you have published with us, as well as your free eprints link, so you can quickly and easily share your work with friends and colleagues.

We are committed to promoting and increasing the visibility of your article. Here are some tips and ideas on how you can work with us to promote your research.

Article Reprints

You will be sent a link to order article reprints via your account in our production system. For enquiries about reprints, please contact Taylor & Francis at reprints@taylorandfrancis.com. You can also order print copies of the journal issue in which your article appears.

Queries

Should you have any queries, please visit our Author Services website or contact us here.

Updated 22-04-2020

ANEXO E: Normas de formatação do periódico Journal of the American Academy of Orthopaedic Surgeons (JAAOS).

Instructions for Authors

TABLE OF CONTENTS

The mission of the *Journal of the American Academy of Orthopaedic Surgeons (JAAOS)* is dissemination of knowledge to improve the care of orthopaedic patients.

MANUSCRIPT AND AUTHORSHIP POLICY

• Presubmission approval of a proposal is required for review manuscripts (the Standard Review, Orthopaedic Advances, and Surgical Techniques article types). See page 2. Invited authors and research manuscripts do not need a presubmission proposal.

• *JAAOS* uses Editorial Manager® (www.editorialmanager.com/jaaos) for all proposal and manuscript submissions.

• Note: Please submit your fully written research manuscripts (the esearch article type) directly to Editorial Manager. A proposal is not required. Case Reports should be submitted to *JAAOS Global Research & Reviews* (http://www.editorialmanager.com/jaaosglobal/default.aspx).

• Invited authors: Please log in to the Editorial Manager website, click "My New Invitations" in your author main menu, click "Agree to Submit," and follow the on-screen directions.

• Video: You are encouraged to submit video with audio to accompany your manuscript. See tables 1 through 3 below and the section on videos in the Checklists (page 9).

• Authorship: We require that the senior author take an active role in manuscript preparation and development. *Standard Review, Orthopaedic Advances, and Surgical Techniques manuscripts are limited to 4 authors.*

• If a contributor to your manuscript does not meet the criteria for authorship listed below, that author should be credited in an acknowledgment.

• No simultaneous submissions (to more than one publisher) or multi-part articles will be considered.

Authorship policy: Research (the Research Section of the *Journal* and *JAAOS Global Research & Reviews*) and Case Report (*JAAOS Global Research & Reviews*)

(No limit to the number of authors, and authorship restrictions do not apply)

Order of Authors	MD *(or equivalent / above, eg, DO, MBBS, PhD)*	Resident or in Fellowship Training[a]	Post- Residency Fellow of the AAOS	Other

First/Lead Author[a] 2nd etc., Author Senior Author Corresponding Author[a] We do not permit dual first-author status.

Authorship policy: Standard Review, Orthopaedic Advances, and Surgical Techniques (the Review Section of the *Journal*)

(The number of authors is limited to no more than four, and authorship restrictions apply)

Order of Authors	MD *(or equivalent/ above, eg, DO, MBBS, PhD)*	Resident or in Fellowship Training[a]	Post- Residency Fellow of the AAOS	Other

First/Lead Author [a] 2nd, 3rd, 4th Author Senior Author Corresponding Author [a] We do not permit dual first-author status.

♣ Authors who will complete residency or training fellowship within 6 months following submission may serve as corresponding authors and first authors.

- ♣ No more than one resident can serve as coauthor, and medical students are not allowed as coauthors.
- ♣ No more than two accepted proposals or manuscripts within a 1-year period will be allowed from any author.

• *JAAOS* requires all authors to meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship: http://www.icmje.org/icmje-recommendations.pdf

• The lead author (listed first) may claim 10 *AMA PRA Category 1 Credit*s directly from the American Medical Association (AMA) for publishing an article in *JAAOS*. The AMA requires a copy of a page from the published article that shows the name of the author listed first, the name of the journal, and the date published: www.ama-assn.org/education/claim-cme-credit-ama

PRESUBMISSION APPROVAL

Authors of Research manuscripts may submit fully written manuscripts at any time, without an invitation. Prospective authors of Standard Review, Orthopaedic Advances, and Surgical Techniques manuscripts *must* first submit a proposal, which will be reviewed by the *JAAOS* Editorial Board. If your proposal is approved, you will receive an invitation to submit the *blinded* manuscript. Acceptance of your proposal DOES NOT guarantee acceptance of your manuscript. It means only that your manuscript will be reviewed.

Submit all proposals for Standard Review, Orthopaedic Advances, or Surgical Techniques manuscripts to the *JAAOS* Editorial Manager website at www.editorialmanager.com/jaaos by following these steps:

1. Prepare your proposal on the topic using this template.

2. Register in Editorial Manager or log in to your existing author account and click "Submit New Manuscript."

Please see Presubmission Approval Instructions for complete directions.

ONLINE EXCLUSIVE PUBLICATION

Publication of your manuscript as an Online Exclusive means that the full text of your article will appear online- only at www.jaaos.org, rather than in print:

OPEN ACCESS PUBLICATION

Compliance with NIH and Other Research Funding Agency Accessibility Requirements

A number of research funding agencies require or request authors to submit the post-print (the article after peer review and acceptance but not the final published article) to a repository that is accessible online by all without charge. As a service to our authors, the Academy's publishing partner, Wolters Kluwer Health, Inc. (WKH) will identify to the National Library of Medicine (NLM) articles that require deposit and will transmit the post-print of an article based on research funded in whole or in part by the National Institutes of Health, Wellcome Trust, or Howard Hughes Medical Institute, to PubMed Central. Authors may indicate such funding when submitting their manuscripts into Editorial Manager, during the Funding Information step.

Choosing Open Access Publication

Authors of accepted peer-reviewed articles have the option to pay an article processing charge (APC) to allow perpetual unrestricted online access to their published article to readers globally, immediately upon publication. These articles are subject to the standard peer-review process and will be accepted or rejected based on their own merit. Authors may opt for the open access option after manuscript acceptance; this choice has no influence on the peer review and acceptance process. Authors who initially decline the open access option may change that decision for up to 2 years from initial acceptance.

The APC is charged on acceptance of the article and should be paid within 30 days by the author, funding agency, or institution. Payment must be processed for the article to be published open access. For a list of journals and pricing, please visit the Wolters Kluwer Open Health Journals page.

Benefits of Open Access Publication

- Authors Retain Copyright: readers can disseminate and reuse the article without modifying individual elements of the work (such as figures, tables, etc.). Any modification in the creation of derivative works requires specific permission from the author.
- Authors can fulfill a grant obligation and meet applicable license requirements with Creative Commons licenses. For more information visit: http://wkauthorservices.editage.com/open-access/.
- Quick global access to your article.

3. From the Article Type drop-down menu, select “Manuscript Proposal” and proceed through the remaining screens.

The online version of *JAAOS* is the official version of publication record.

- The online version of your article appears in the same format as that of the print version of *JAAOS* typically months before it would appear in print.
- The *JAAOS* journal cover, Table of Contents, and social media promotion all remain the same.

Authors who have questions about open access are welcome to consult the Wolters Kluwer Open Health site: http://www.wkopenhealth.com/openaccessfaq.php.

MANUSCRIPT SPECIFICATIONS AND COMPONENTS

IMPORTANT NOTE: All manuscripts submitted to *JAAOS* will undergo double-blind peer review. Please prepare your manuscript in a way that conceals the identities and affiliations of all contributing authors. Failure to submit an appropriately blinded manuscript will result in your manuscript being returned to you for correction. To assist in this process, please ensure the following:

- Remove any identifying information, including author names, from file names. If you are using Office 2007 or later, please use the Document Inspector Tool to remove only the document properties and personal information from the manuscript prior to submission. This process ensures that the document properties have been anonymized.

- Do not include any identifying information, including author names and affiliations in the body of the text.
- Remove references to funding sources from the body of the text.
- Do not include clinical trial or Institutional Review Board numbers in the body of the text.
- Remove any affiliation related identifier from all figures and tables.

If you have received an invitation to submit a manuscript, the correct article type will be indicated when your manuscript is submitted. If your proposal has been accepted, you will receive an email with instructions for submitting your full manuscript.

If you have not received an invitation, select the article type most appropriate for your content.

All manuscript submissions must include a Title Page, uploaded to Editorial Manager as a separate file. The Title Page should not be included in the word count. The title page should include the following information:

• Title of paper including a description of the type of study conducted.

• Full name of each author (first name, middle initial and last name) followed by each author's highest academic degree(s). Name of department(s) and institution(s) with which each author is affiliated and to which work should be attributed.

• Name, address, telephone number, fax number, and E-mail (if available) of author responsible for correspondence concerning the manuscript.

• Name, address, and telephone number of authors to who requests for reprints should be addressed, or a statement that reprints will not be available from the author(s).

• Cite all sources of support for the work being reported, including grants, equipment, and drugs.
• A short running head of no more than 40 characters, including spaces, placed at the bottom of the title page.

Manuscripts that do not meet the specifications outlined in Table 1 will be returned to the corresponding author through Editorial Manager for changes.

Table 1: Manuscript Specifications

Article Type	Description	Abstract Word Limit	Text Word Limit[a]	Illustrative Material Limit[b]	Reference Limit	Format
Research Section: Manuscript	Present retrospective or prospective studies that are clinical observational, interventional, or experimental. Format: Introduction, Methods, Results, Discussion	300	4,000	16 panels	40	Keywords (list 5 to 8) Title page[c] Abstract (use structured headings: Introduction, Methods, Results, Discussion, Data Availability and Trial Registration numbers) Text with headings: Introduction, Methods, Results, Discussion References Figures and Figure legends (if

						applicable) Tables (if applicable) Video (if applicable)
Review Section: Standard Review	Present a balanced approach to the current state of knowledge on a topic of interest to the practicing orthopaedic surgeon	200	4,000	16 panels	40 (≥25% from past 5 years)	Keywords Title page[c] Abstract Text (including Introduction and Summary) References Figures Figure legends (if applicable) Tables (if applicable) Video (if applicable)
Review Section: Orthopaedic Advances	Provide current information on recent developments in orthopaedic surgery, technology, pharmacotherapeutics, and diagnostic modalities. Topics are not yet well represented in the literature.	150	2,250	6 panels	20	Keywords Title page[c] Abstract Text References Figures and Figure legends (if applicable) Tables (if applicable) Video (if applicable)

Review Section: Surgical Techniques	Provide step-by-step details of new/innovative surgical procedures or substantial modifications of	150	4,000	8 panels	30	Keywords Title page[c] Abstract Text (Use headings: Introduction, Indications, Contraindications, Pearls, Pitfalls, Summary)

previously reported techniques. Provide video with audio to demonstrate specific steps.	References Figures and Figure legends (if applicable) Table (if applicable) Video

[a] Excludes abstract, references, and figure legend [b] Add the number of figure and table panels together to get the total. Count each multi-part figure separately, and multiply number of tables by 2 (eg, Figure 1A and 1B = 2 panels; one table = 2 panels; count appendices as tables). Note that a single illustration would not be broken up into multiple panels. [c] Upload as a separate file. The Title Page should not be included in the word count. The title page should contain the following information:

Title of paper including a description of the type of study conducted. Full name of each author (first name, middle initial and last name) followed by each author's highest academic degree(s). Name of department(s) and institution(s) with which each author is affiliated and to which work should be attributed. Name, address, telephone number, fax number, and E-mail (if available) of author responsible for correspondence concerning the manuscript. Name, address, and telephone number of author to who requests for reprints should be addressed, or a statement that reprints will not be available from the author(s). Cite all sources of support for the work being reported, including grants, equipment, and drugs. A short running head of no more than 40 characters, including spaces, placed at the bottom of the title page.

Table 2: Parts of a Manuscript: Research

Article
Type Abstract Introduction

Figures, Tables, Body, References Videos

Research Section: Manuscript	State essential principles and information Provide facts, conclusions, and outcomes; avoid “we discuss” Be certain data agree with numbers and values in the text Use structured headings:	State hypothesis and purpose of study, setting, population, and primary outcome measure Any clinical study in which patients are randomized into two treatment groups or are followed prospectively to compare two different treatments must have been registered in a public trial registry, eg, www.clinicaltrials.gov (approved registries for clinical trials need to meet all of ICJME guidelines: http://www.icmje.org/recommendations/browse/publishing-and-	Use structured headings: Introduction, Methods, Results, Discussion Include approval for human studies by IRB or animal utilization study committee In the Discussion, note whether hypothesis was validated or refuted, and discuss	Figures Line drawings, radiographs/other imaging scans, photos, algorithms A succinct legend is required for each figure panel Number each figure in order of citation in text Include signed photo consent or remove/blur patient faces, names, institution identifiers, and manufacturer logos Authors must obtain permission

	Introduction, Methods, Results, Discussion	editorial- issues/clinical- trial- registration.html)	relative significance, strengths, and limitations of your study Limit 40 references Include levels of evidence[a]	to reuse published figures and tables. Digital manipulation must not result in misrepresentation of the original image Preferred image file formats: TIFF, EPS, or MS Office (DOC, PPT, XLS) files. High resolution PDF files are also acceptable. Include a title for each table and a heading for each column If possible, use no more than 6 columns and 10 rows per table. Larger tables will be placed online as supplemental material.

				Place each table on a separate page in Word or Excel Tables

Videos Include as appropriate Preferred video format: .mp4. For SDC, video over 10 MB (up to 100MB): .wmv, .swf, .flv, mpg., .mpeg, m4v, .mov, .mp4. For video up to 10 MB.qt and .avi will also be accepted.

[a] Level I. Diagnostic study = randomized controlled trial; testing of previously developed diagnostic criteria. Prognostic study = inception cohort study. Therapeutic study = randomized controlled trial. Economic study = computer simulation model. Level II. Diagnostic study = prospective cohort study; development of diagnostic criteria. Prognostic study = prospective cohort study; control arm of randomized trial. Therapeutic study = prospective cohort study; observational study with dramatic effect. Economic study = computer simulation model. Level III. Diagnostic study = retrospective cohort study; case-control study; nonconsecutive patients; no consistently applied reference standard. Prognostic study = retrospective cohort study; case-control study. Therapeutic study = retrospective cohort study; case-control study. Economic study = computer simulation model. Level IV. Diagnostic study = case series; poor or nonindependent reference standard. Prognostic study = case series. Therapeutic study = case series; historically controlled study. Economic study = decision tree over the short time horizon with input data from original level II and III studies and uncertainty examined by univariate sensitivity analyses. Level V. Diagnostic, prognostic, and therapeutic studies = mechanism- based reasoning. Economic study = decision tree over the short time horizon with input data informed by

prior economic evaluation and uncertainty examined by univariate sensitivity analyses.

Table 3: Parts of a Manuscript: Standard Review, Orthopaedic Advances, Surgical Techniques

Article
Type Abstract Introduction

Body, References Figures, Tables, Videos

Review Section: Standard Review	Reflect essential principles and information Provide facts, conclusions, and outcomes; avoid “we discuss” Be certain data agree with numbers and values in the text	Present brief overview, background information, statistics, and history Include rationale for importance, main points, information deficiencies, and/or differences of opinion	Review pertinent literature Use section headings (eg, Indications, Contraindications) Include, as applicable: controversy, treatment methods, basic science, authors’ preferred treatment, complications Use generic names for drugs and devices Include *P* values and correlation coefficients	Figures Line drawings, radiographs/ other imaging scans, photos, algorithms A succinct legend is required for each figure panel Number each figure in order of citation in text Include signed photo consent or remove/blur patient faces, institution identifiers, and manufacturer logos Authors must obtain permission to reuse

			Reiterate nature of problem, provide clear conclusion based on literature and author experience, suggest role for ongoing study and future directions Limit 40 references (≥25% published within past 5 years) Include levels of evidence[a]	published figures and tables. Digital manipulation must not result in misrepresentation of the original image Preferred image file TIFF, EPS, or MS Office (DOC, PPT, XLS) files. High-resolution PDF files are also acceptable. Tables Include a title for each table and a heading for each column Use no more than 6 columns and 10 rows per table Place each table on a separate page in Word formats: or Excel Videos

				Include as appropriate Preferred video format: .mp4 For SDC video over 10 MB (up to 100MB): .wmv, .swf, .flv, mpg., .mpeg, .m4v, .mov, .mp4. For video up to 10 MB, .qt and .avi will also be accepted.

Review Section: Orthopaedic Advances	See above	Present objective appraisals of recent or controversial techniques and new developments in orthopaedic surgery Address current trends or advances of brief clinical experience and few documented studies	See above Limit 20 references Include levels of evidence[a]	See above
Review Section:	None	Present brief overview, background	Use headings: Introduction, Indications, Contraindications, Surgical	See above

Surgical Techniques		information, statistics, and history Include rationale for importance, main points, information deficiencies, and/or differences of opinion, surgical technique	Technique, Pearls and Pitfalls, Outcomes In the Surgical Technique section, use subheads Setup, Exposure/Approach, Technique, Closure, Postoperative Care/Considerations Discuss anatomic and biomechanical considerations Provide pearls and pitfalls in two bulleted lists Limit 30 references Include levels of evidence[a]	Video is strongly recommended Describe indications and contraindications of technique No more than 5 to 10 minutes Audio narration is required Include title screen without identifying author, patient, or institution Adhere to safety precautions and FDA guidelines for off-label use

[a] Level I. Diagnostic study = randomized controlled trial; testing of previously developed diagnostic criteria. Prognostic study = inception cohort study. Therapeutic study = randomized controlled trial. Economic study = computer simulation model. Level II. Diagnostic study = prospective cohort study; development of diagnostic criteria. Prognostic study = prospective cohort study; control arm of randomized trial. Therapeutic study = prospective cohort study; observational study with dramatic effect. Economic study = computer simulation model. Level III. Diagnostic study = retrospective cohort study; case-control study; nonconsecutive patients; no consistently applied reference standard. Prognostic study = retrospective cohort study; case-control study. Therapeutic study = retrospective cohort study; case-control study. Economic study = computer simulation model. Level IV. Diagnostic study = case

series; poor or nonindependent reference standard. Prognostic study = case series. Therapeutic study = case series; historically controlled study. Economic study = decision tree over the short time horizon with input data from original level II and III studies and uncertainty examined by univariate sensitivity analyses. Level V. Diagnostic, prognostic, and therapeutic studies = mechanism- based reasoning. Economic study = decision tree over the short time horizon with input data informed by prior economic evaluation and uncertainty examined by univariate sensitivity analyses.

MANUSCRIPT SUBMISSION

If you received an invitation from Editorial Manager to submit a manuscript, follow these steps:

1. Go to www.editorialmanager.com/jaaos, enter your username and password, and click "Author Login." (If you have misplaced your login information, click the "Send Login Details" link on the Editorial Manager home page.)
2. From your Author Main Menu, click "My Accepted Invitations" and "Submit Invited Manuscript." Proceed through the remaining screens, attaching your text/references/figure legends, figures, tables, videos, and author forms as separate files. All figures must be submitted as image files. Please do not embed figures in the body of your text or in a separate Word document.
3. 3. When the PDF of your submission is ready, click "View Submission" and then "Approve Submission."

If you have *not* received an invitation to submit a manuscript and wish to submit a Research manuscript, follow these steps:

1. Go to www.editorialmanager.com/jaaos

2. Register in Editorial Manager or log in using your existing author account and click "Submit New Manuscript."

3. From the Article Type drop-down menu, select "Research Section: Manuscript" and proceed through the remaining screens.

If you have any questions about the proposal or manuscript submission process, please contact Kyle Overturf at Kyle.Overturf@wolterskluwer.com.

POLICIES AND GUIDELINES

Authors must read the Academy's guidelines and policies on:

AAOS Clinical Practice Guidelines AAOS Appropriate Use Criteria

Table 4: Intellectual Property, Public Funding, and *JAAOS* Article Citation Topic Description

Duplicative publishing and copyright	Text *JAAOS* uses iThenticate® to detect matching text across published works. If the similarity percentage of your manuscript is excessive, it will be returned to you. Images and Tables Provide complete bibliographic information for any previously published material you are submitting. Authors are responsible for obtaining permission to use previously published material. Be aware that images contained in a "free use" database may be copyrighted. When your material is published in *JAAOS*, it becomes the copyrighted property of the AAOS. You may still use this material for certain purposes. Please see the Rights and Permissions link on the online version of your article for more information.
Intellectual property	Prior to submitting your paper, see copyright resources from the U.S. Copyright Office here: https://www.copyright.gov/learning-engine/ The AAOS is currently updating a comprehensive Intellectual Property Primer with Intellectual Property Learning Modules. Links will be added here as soon as these become available.

Funding from public entities	NIH The corresponding author of a study prepared with funding from the National Institutes of Health is responsible for submitting the final peer-reviewed manuscript to the digital archive PubMed Central upon acceptance for publication. Such manuscripts are to be made accessible to the public on PubMed Central no more than 12 months after publication.
JAAOS article citation	To cite an article that you have published in *JAAOS*, use the format below: Last name + initials: Title. *J Am Acad Orthop Surg* Year;Volume(Issue):starting page no. - ending page no.

Figures

CHECKLISTS

Figures must meet the professional standards of the journal (ie, sufficient resolution and appropriate file format).

Acceptable formats are .tif, .eps, .jpg, .pdf, .ppt. Word (.doc) files are also acceptable.

Line art must be vector or have a resolution of at least 1200 dpi (dots per inch), and electronic photographs- radiographs, CT scans, and so on-and scanned images must have a resolution of at least 300 dpi. Photographs containing text must have a resolution of at least 600 dpi. If fonts are used in the artwork, they must be converted to paths or outlines or they must be embedded in the files. Cite figures consecutively on the site, and number them in the order in which they are discussed.

For additional assistance, please refer to the journal's Creating Digital Artwork file. Each figure should be uploaded into Editorial Manager as a separate item, one file per figure. Do not embed

figures in the manuscript. Color figures are encouraged and are published at no charge to the author.

A Figure Legend should be included in the manuscript, beginning on a new page after the References. Cover the following in the figure legend:

- Identification: Clearly convey what each figure depicts. Explain clearly in the legend any symbols, arrows, numbers, or letters used to identify parts of the figure. Identify the method of staining in photomicrographs and provide their magnifications.
- Abbreviations: Define all abbreviations used in each figure/illustration. Number figures consecutively in the order cited in the text, using Arabic numerals (eg, Fig. 1, Fig 2). If a figure

  contains more than one part, each part must be labeled alphabetically (eg, Fig. 3A, Fig 3B).

  If a figure contains a human subject that is identifiable, written consent from the patient or guardian must accompany the submission.

  If a figure or its data is reproduced from another source, the author is responsible for securing permission for both print and electronic rights from the original publisher and is responsible for paying any permission fees. Cite the original source of previously published material following the wording specified in the publisher's permission letter. Copies of permissions to publish material from another source must be included when submitting your manuscript for review.

Figure Legends

Provide brief legends for each figure. Symbols, abbreviations, and inset images must be defined in the figure or its legend. Incorporate figure keys into the legend rather than including them as part of the figure whenever possible. Please include a description for each panel (using A, B, C, etc) in the figure legend. If the figure is reprinted/adapted from another source, please provide a permission letter and include the source in the legend. If no language is provided in the permission letter, use the following sample: “(Reproduced/adapted with permission from Jones AB, Smith CD, Wilson EF: How to write a credit line. *Journal of Figure Legends* 2017;1[2]:5-12.)

Lettering

Lettering should be the same font throughout all figures in the manuscript in the sans-serif typeface Helvetica, Medium, 8pt, sharp. Units, capitalization, etc, should follow *JAAOS* style (see www.jaaos.org) and refer to issues of the *Journal* published in 2015 through 2017. Arrows, arrowheads, and other symbols should be black or white, depending which is most visible against the image in question and sized to be visible but not to obscure or overwhelm the image. Leaders and rules should be 2.25 px.

Avoid headings on the figure. Heading information should appear in the figure legend. Label units of measure consistently with the text and legend. Follow the *AMA Manual of Style* for unit abbreviations.

For multi-panel figures, submit each part individually (eg, Figure 1A, Figure 1B, Figure 1C, Figure 1D), rather than as one block (eg, Figure 1ABCD). Similar panels should be consistent in size and uniformly set.

Supply a scale bar with photomicrographs.

Authors are responsible for obtaining from the copyright holder permission to reproduce previously published artwork.

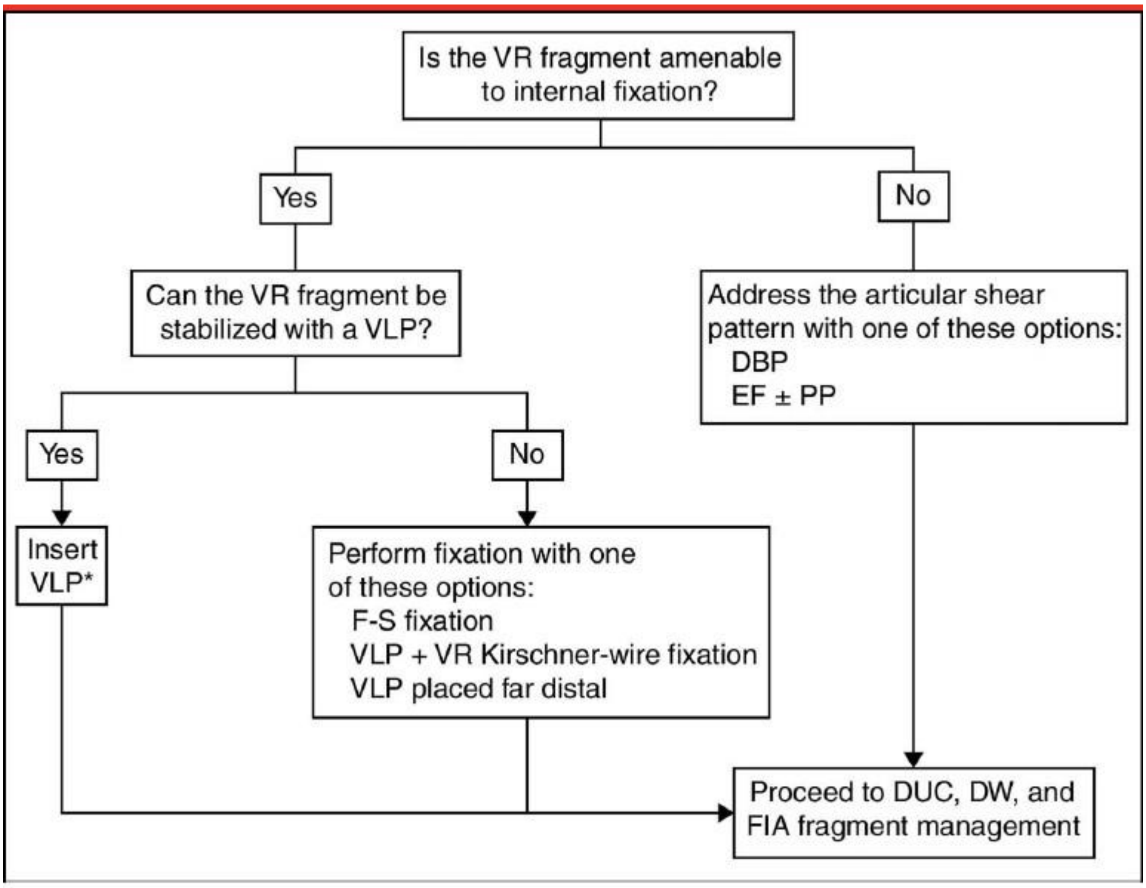
Algorithms

The flow should be logical and complete. Text is centered in boxes with one idea or point. Hanging indents are used for boxes with more than one idea or option (eg, treatment option).

Label leaders and algorithm leaders (rules) to boxes should be 10 px when the document DPI is 1200. Arrowheads are inserted only when a rule leads to a box with an action, such as a surgical procedure. Arrowheads for algorithm rules are to be created with 800% width, 650% length at 10 px. If a need arises to have an "algorithm box" in an image at 300 DPI the box should be created with a 3 px contraction in Photoshop. Label leaders (rules) should be 2.25 at 300 DPI.

Example: Figure 5 from Rhee PC, Medoff RJ, Shin AY: Complex distal radius fractures: An anatomic algorithm for surgical management. *J Am Acad Orthop Surg*2017;25(2):77-88. https://journals.lww.com/jaaos/Fulltext/2017/02000/Complex_Distal_Radius_Fractures___An_Anatomic.1.aspx

1. Data should neither be added to, nor removed from, an image by digital manipulation. Images gathered at different times or from different locations should not be combined into a single image, unless it is stated that the resultant image is a product of time-averaged data or a time-lapse sequence. Figures assembled from multiple images must indicate the separation of the parts by lines and described in the legend.
2. The use of touch-up tools, such as cloning and healing tools in Photoshop, or any feature that deliberately obscures manipulations, is unacceptable.



Algorithm depicting the management of a volar rim (VR) fragment. The asterisk (*) indicates insertion of distal locking screws through the volar locking plate (VLP) into the intermediate column only (not the radial column). DBP = distraction bridge plate, DUC = dorsal ulnar corner, DW = dorsal wall, EF ± PP = external fixation with or without percutaneous pins, FIA = free intra-articular, F-S = fragment-specific

The use of digital media for image acquisition and processing introduces the potential for inadvertent distortion of data. To prevent such distortion, the following guiding principles should be used:

3. Linear adjustment of contrast, brightness or color must be applied equally to controls and all parts of an entire image. Contrast should not be adjusted so that data disappear. Excessive manipulations, such as processing to emphasize one region in the image at the expense of others (e.g. through the use of a biased choice of threshold settings), is unacceptable, as is emphasizing experimental data relative to the control.
4. When submitting revised final figures upon conditional acceptance, authors may be asked to submit original, unprocessed images.

5. All image acquisition tools and image processing software packages used should be listed. Deviations from the above, including nonlinear adjustments, must be indicated in the figure legend along with a description of the processing software used.

Tables

Numbering: Number tables consecutively in the order cited in the text using Arabic numerals (eg, Table 1, Table 2).

Formatting: Each table should begin on a new page. Supply a brief, descriptive title for each table. Provide each column with a short or abbreviated heading. Tables submitted as photographs are not acceptable. Do not repeat information in a table if data are already provided in the text. Do not prepare a table if your data can be reported in the text in one or two sentences.

References cited in tables: All references cited in tables must be included in the References list. References are numbered consecutively throughout the manuscript, *including in tables*. For example, if references 1 through 10 have been cited in the body of the manuscript and then Table 1, which has five not-yet-cited references, is called out in text, then those references in Table 1 should be numbered 11, 12, 13, 14, and 15. The next new reference cited in text after the Table 1 callout would be reference 16.

Footnotes: Place explanatory matter in footnotes rather than in the table title or column heading. Please define all abbreviations used in the table in the footnotes. If italics are used, specify the meaning of the italics in the footnotes.

SUPPLEMENTAL DIGITAL CONTENT (SDC)

Authors may submit supplemental digital content to be considered for online-only posting to enhance their article's text. Supplemental digital content may include the following types of content: text documents, graphs, tables, figures, graphics, illustrations, audio, and video.

SDC - Text Citations Cite all supplemental digital content consecutively in the text. Citations should include the type of material submitted, should be clearly labeled as "Supplemental Digital Content," should include a sequential number, and should provide a brief description of the supplemental content.

SDC – Legends Provide legends for supplemental digital content at the end of the text, listing each legend in the order in which the material is cited in the text. The legends must be numbered to match the citations from the text. Include a title and a brief summary of the content. For audio and video files, also include the author name, videographer, participants, length (minutes), and size (MB).

Size and File Type Requirements To ensure a quality experience for those viewing supplemental digital content, it is suggested that authors submit digital files no larger than 10 MB each. Documents, graphs, and tables may be presented in any format. Figures, graphics, and illustrations should be submitted with the following file extensions: .tif, .eps, .ppt, .jpg, .pdf, .gif. Audio files should be submitted with the following file extensions: .mp3, .wma. Video files should be submitted with the following file extensions: .wmv, .mov, .qt, .mpg, .mpeg, .mp4. Video files should also be formatted with a 320 X 240 pixels minimum screen size. For more information, please review the publisher's requirements for submitting supplemental digital content at http://links.lww.com/A142.

Videos

Surgical Techniques manuscripts require supplemental video (either surgical video or Sawbones/cadaver demonstrations). For other articles, authors' video demonstrations, particularly of a procedure or to show functional outcomes, range of motion, or other patient activities, are welcome and encouraged. Video should be no more than 5 to 10 minutes. DO NOT include any author information, identifiable patients, patient information, hospital/institution names, or corporate logos in your video or audio. Videos without audio narration will not be accepted. Please consider the following:

- Title: Does the video begin with a descriptive title frame?

- Indications/Contraindications: Does the video describe the indications and contraindications for the technique and the patient case illustrated?
- FDA Devices: Was the “off-label” use of any pharmaceuticals and/or medical devices disclosed?
- Universal Precautions: Were universal precautions observed, most noticeably protective eyewear?
- Preoperative and Postoperative Images: Preoperative and postoperative images are important to illustrate the patient’s condition before and after treatment and to confirm the results achieved. Does the video contain the appropriate images?
- Narration: Is the narration clear and easy to understand?
- Safety and Efficacy: Is the video consistent with generally acceptable orthopaedic practice?

Preferred video format: .mp4 *Note:* For SDC video over 10 MB (up to 100MB): .wmv, .swf, .flv, .mpg, .mpeg, .m4v, .mov, .mp4. For SDC video up to 10 MB, .qt and .avi will also be accepted.

Reference Citation and Examples

- References must be in-press or published.
- List all references in numeric order at the end of your text.
- Cite references in the text in numeric order, including those cited in a table or figure at the first mention of the table or figure.
- List all author names up to six and list the first three plus et al when there are seven or more authors.
- Do not use programs that automatically generate reference numbers.

Manuscripts submitted with references that are not listed in numeric order or generated with an incompatible bibliographic software program will be returned to the author for correction.

Journal Reference Example

Sonnadara RR, Van Vliet A, Safir O, et al: Orthopedic boot camp: Examining the effectiveness of an intensive surgical skills course. *Surgery* 2011;149(6):745-749.

Book Chapter Reference Example

Henry MH: Hand fractures and dislocations, in Court-Brown CM, Heckman JD, McQueen MM, Ricci WM, Tornetta III P, McKee M, eds: *Rockwood and Green's Fractures in Adults*, ed 8. Philadelphia, PA, Wolters Kluwer Health/Lippincott Williams & Wilkins, 2014, vol 1, pp 915-990.

Online Resource Reference Example

The American Board of Surgery: ABS to require ACLS, ATLS and FLS for general surgery certification. https://www.absurgery.org/default.jsp?news_newreqs. Accessed April 7, 2016.

Required Author Forms/Disclosures

Required from each author:

- ⎫ Electronic Transfer of Rights: A copy of the form is made available to the submitting author within the Editorial Manager submission process. Co-authors will automatically receive an Email with instructions on completing the form upon submission.
- ⎫ Read the Intellectual Property Learning Modules. Note: this is currently being updated. Links to follow (Nothing to be turned in)

Required from only one author per submission:

⎫ A permission grant from the publisher(s), for art you wish to borrow from a published source (Apply for permission at www.copyright.com)

⎫ Research manuscript: Upload an Institutional Review Board (IRB) approval letter for your study if IRB approval is required.

Required only in special circumstances, if requested by *JAAOS* Editorial Office:

⎫ Authorization to Change Authorship Form.

Requested only if an author is added or removed from a manuscript after the initial submission. of an author is removed, include language to acknowledge his/her contribution.

⎫Talent Release.

Required if someone other than an author of your manuscript is narrating in or appears in a video that accompanies your manuscript.

⎫ Patient Consent Form.

Maybe requested for patients presented in Review manuscripts.

EDITORIAL EXPECTATIONS

Please keep in mind that if our requirements are not met, we will return your manuscript to you through Editorial Manager and will ask you to make the changes necessary to proceed to our peer review process.

Possible consequences of not adhering to *JAAOS* requirements include: •
Return of your manuscript for further work
• Delayed peer review
• Delayed publication

• Rejection of your manuscript

Editorial Timeline

This process might take 30 days or more. After you submit your manuscript, it will be processed and sent to the appropriate *JAAOS* Deputy Editor, who will determine whether to invite peer reviewers to assess your work. The reviewers are asked to focus on the medical and scientific accuracy, clarity, and comprehensive quality of the content. After required reviews are complete, the

Deputy Editor will submit a decision and comments, in light of the peer reviewer comments. The Editor-in-Chief (for review manuscripts) or Editor of Research (for research manuscripts) will then make a final decision, and you will receive a decision letter e- mail from Editorial Manager. Following peer review in some cases, the Deputy Editor may make tracked changes to your document, which will be made available to you through Editorial Manager. You are encouraged to use the Deputy Editor's version as the basis of your revision.

Revision Process for Articles

This process usually takes about 30 to 45 days. If the Deputy Editor determines that your manuscript should be revised, you will be given a timeframe of up to 45 days to submit your revised manuscript through Editorial Manager (this varies with the article type). A point-by-point response to the peer reviewer and/or Deputy Editor comments on your original version is required with your revised version. Once your revision is processed, it will be routed to the Deputy Editor and then the Editor-in-Chief or Editor of Research for a decision. The Deputy Editor may decide to invite peer reviewers to evaluate your revision.

Professional Editorial Services

Your manuscript may be provisionally accepted pending use of a professional editorial service. See the following page for a list of professional editorial services: https://journals.lww.com/jaaos/Pages/editorialservices.aspx. These services are merely suggestions; you may use the editorial service of your choice. None of the services listed on the *JAAOS* website is endorsed by *JAAOS*. Any expenses for editing services are the responsibility of the author. Use of an editing service does not guarantee final acceptance and subsequent publication.

Acceptance for Publication and Author Review

Once your manuscript has been accepted for publication in *JAAOS*, you will receive a final decision letter e- mail through Editorial Manager. For Standard Review, Orthopaedic Advances, and Surgical Techniques articles, you will be offered the option of Online Exclusive publication. Your manuscript will be edited and proofread, and you will receive copyedited page proofs to review prior to publication. All decisions regarding rejection for publication are final.

Letters to the Editor Readers are welcome to submit Letters to the Editor on articles published in the *Journal of the American Academy of Orthopaedic Surgeons*. All letters are reviewed by the *JAAOS* Editor-in-Chief, and approved letters are forwarded to the authors of the published article for their response. Letters are to address one specific article, limited to 500 words.

Please submit all Letters to the Editor using the *JAAOS* Editorial Manager website at www.editorialmanager.com/jaaos by following the steps below:

- Prepare your Letter. It should include the title, authors, and publication month/year of the article you are writing about.
- Register in Editorial Manager or log in to your existing author account and click "Submit New Manuscript."
- From the Article Type drop-down, select "Review Section: Letter to the Editor" (for review articles) or "Research Section: Letter to the Editor" (for research articles) and proceed through the remaining screens.

TIPS FOR SEARCH ENGINE OPTIMIZATION

Search engine optimization (SEO) is the process of affecting the visibility of a website or web page on a search engine's results page. Authors can play a decisive role in optimizing search results to make their articles more discoverable online.

Below are some useful writing tips to ensure that your article is visible and high-ranking in the search results of Google and other engines.

1. Make the title of your article SEO-friendly

The title of your article should be descriptive of its content and include keywords. Because only the first 65 characters (including spaces) are shown in Google search results, it is important to put your keywords within the first 65 characters of the title.

2. Use headings

Headings help readers as well as search engines like Google to better understand the structure and organization of your article. Be sure to include keywords and phrases in section headings where appropriate.

3. Choose good keywords

Appropriate keywords will help improve the visibility of your article via search engines. Keywords should accurately reflect the content of the paper. In crafting good keywords, think about your audience. Which words or phrases might a reader use to find the information in your article online using a search engine? You might also consider using sites such as Google Trends or Google Adwords to find out which search terms are most popular.

4. Optimize the abstract

In most cases, only the abstract of the paper will be “visible” to search engines. It is therefore important that the abstract accurately reflect the content of the entire paper by incorporating appropriate keywords and phrases throughout in a natural, contextual way.

5. Stay consistent in your language

In writing your paper, be sure to use terms and keywords in a consistent manner. Wherever possible, try to refer to these key terms in the same way they’ve been referred to in past online publications.

6. Cite previous publications

When appropriate, cite your own or your co-authors’ previous publications. Such citations will factor into how search engines will rank your current and future work.

7. Promote your article through social media

Another important way to ensure that your article is visible and discoverable online is to promote it through academic and social networking sites. Google and other search engines regard links as “votes” for web pages. Therefore, by creating inbound and outbound links to your article, you can help improve the ranking of your article in the search results. Recommended academic and social networking platforms include:

• LinkedIn, •Facebook. •Twitter, • Mendeley, If you are interested in promoting your article via Twitter or Facebook, you will have the opportunity to enter your Twitter handle and/or your Facebook username when you complete the author questionnaire during the submission process.

ANEXO F: Normas de formatação do periódico Gait and Posture.

GAIT & POSTURE

Official Journal of: Gait and Clinical Movement Analysis Society (GCMAS), European Society of Movement Analysis in Adults and Children (ESMAC), Società Italiana di Analisi del Movimento in Clinica (SIAMOC), and the International Society for Posture and Gait Research (ISPGR)

AUTHOR INFORMATION PACK

TABLE OF CONTENTS

ISSN: 0966-6362

DESCRIPTION

.

Gait & Posture is a vehicle for the publication of up-to-date basic and clinical research on all aspects of locomotion and balance. The topics covered include: Techniques for the measurement of gait and posture, and the standardization of results presentation; Studies of normal and pathological gait; Treatment of gait and postural abnormalities; Biomechanical and theoretical approaches to gait and posture; Mathematical models of joint and muscle mechanics; Neurological and musculoskeletal function in gait and posture; The evolution of upright posture and bipedal locomotion; Adaptations of carrying loads, walking on uneven surfaces, climbing stairs etc; spinal biomechanics only if they are directly related to gait and/or posture and are of general interest to our readers; The effect of aging and development on gait and posture; Psychological and cultural aspects of gait; Patient education.

Index bound in last issue of year.
For details of the GCMAS, ESMAC, SIAMOC, ISPGR please visit their web sites throughthese links.

AUDIENCE
Orthopaedic surgeons, neurologists, rheumatologists, podiatrists/chiropodists, physiatrists, physical and occupational therapists, research professionals, psychologists, physiologists, bioengineers, kinesiologists, ergonomists and those with an interest in elite performance.

IMPACT FACTOR
2018: 2.414 © Clarivate Analytics Journal Citation Reports 2019
AUTHOR INFORMATION PACK 25 Oct 2019 www.elsevier.com/locate/gaitpost 2
ABSTRACTING AND INDEXING

OT Bibsys (The Reliable SOURCE)
PubMed/Medline
Embase
Current Contents - Clinical Medicine
Journal of Rehabilitation Research and Development
Scopus

AUTHOR INFORMATION PACK

25 Oct 2019 www.elsevier.com/locate/gaitpost 4

GUIDE FOR AUTHORS.

JOURNAL DESCRIPTION

Gait and Posture publishes new and innovative basic and clinical research on all aspects of human movement, locomotion and balance.

The topics covered include: Techniques for the measurement of gait and posture, and the standardization of results presentation; Studies of normal and pathological gait; Treatment of gait and postural abnormalities; Biomechanical and theoretical approaches to gait and posture; Mathematical models of joint and muscle mechanics; Neurological and musculoskeletal function in gait and posture; The evolution of upright posture and bipedal locomotion; Adaptations of carrying loads, walking on uneven surfaces, climbing stairs, running and performing other movements. Spinal biomechanics only if they are directly related to gait and/or posture and are of general interest to our readers; The effect of aging and development on gait and posture; Psychological and cultural aspects of gait; Patient education.

Submission checklist

You can use this list to carry out a final check of your submission before you send it to the journal for review. Please check the relevant section in this Guide for Authors for more details.

Ensure that the following items are present: One author has been designated as the corresponding author with contact details: E-mail address

Full postal address

All necessary files have been uploaded:

Manuscript: Include 3-5 keywords Include a structured abstract (see below for format) All figures (include relevant captions) All tables (including titles, description, footnotes) Ensure all figure and table citations in the text match the files provided Indicate clearly if color should be used for any figures in print Graphical Abstracts / Highlights files (where applicable) Supplemental files (where applicable)

Further considerations Manuscript has been 'spell checked' and 'grammar checked' All references mentioned in the Reference List are cited in the text, and vice versa

Permission has been obtained for use of copyrighted material from other sources (including the Internet) A competing interests statement is provided, even if the authors have no competing interests to declare Journal policies detailed in this guide have been reviewed Referee suggestions and contact details provided, Based on journal requirements For further information, visit our Support Center Support Center.

BEFORE YOU BEGIN

Ethics in publishing

Please see our information pages on Ethics in publishing and Ethical guidelines for journal publication.

Declaration of interest

All authors must disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of potential competing interests include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding. Authors must disclose any interests in two places: 1. A summary declaration of interest statement in the title page file (if double-blind) or the manuscript file (if single-blind). If there are no interests to declare then please state this: 'Declarations of interest: none'. This summary statement will be ultimately published if the article is accepted. 2. Detailed disclosures as part of a separate Declaration of Interest form, which forms part of the journal's official records. It is important for potential interests to be declared in both places and that the information matches. More information.

Submission declaration and verification

Submission of an article implies that the work described has not been published previously (except in the form of an abstract, a published lecture or academic thesis, see 'Multiple, redundant or concurrent publication' for more information), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in AUTHOR INFORMATION PACK 25 Oct 2019 www.elsevier.com/locate/gaitpost 5 English or in any other language, including electronically without the written consent of the copy right holder. To verify originality, your article may be checked by the originality detection service Cross ref Similarity Check.

Preprints

Please note that preprints can be shared anywhere at any time, in line with Elsevier's sharing policy.

Sharing your preprints e.g. on a preprint server will not count as prior publication (see 'Multiple, redundant or concurrent publication' for more information).

Use of inclusive language

Inclusive language acknowledges diversity, conveys respect to all people, is sensitive to differences, and promotes equal opportunities. Articles should make no assumptions about the beliefs or commitments of any reader, should contain nothing which might imply that one individual is superior to another on the grounds of race, sex, culture or any other characteristic, and should use inclusive language throughout. Authors should ensure that writing is free from bias, for instance by using 'he or she', 'his/her' instead of 'he' or 'his', and by making use of job titles that are free of stereotyping (e.g. 'chairperson' instead of 'chairman' and 'flight attendant' instead of 'stewardess').

Author contributions

For transparency, we encourage authors to submit an author statement file outlining their individual contributions to the paper using the relevant CRediT roles: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Roles/Writing - original draft; Writing - review & editing. Authorship statements should be formatted with the names of authors first and CRediT role(s) following. More details and an example.

Authorship

All authors should have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

Changes to authorship

Authors are expected to consider carefully the list and order of authors before submitting their manuscript and provide the definitive list of authors at the time of the original submission. Any addition, deletion or rearrangement of author names in the authorship list should be made only before the manuscript has been accepted and only if approved by the journal Editor. To request such a change, the Editor must receive the following from the corresponding author: (a) the reason for the change in author list and (b) written confirmation (e-mail, letter) from all authors that they agree with the addition, removal or rearrangement. In the case of addition or removal of authors, this includes confirmation from the author being added or removed.

Only in exceptional circumstances will the Editor consider the addition, deletion or rearrangement of authors after the manuscript has been accepted. While the Editor considers the request, publication of the manuscript will be suspended. If the manuscript has already been published in an online issue, any requests approved by the Editor will result in a corrigendum.

Clinical trial results

In line with the position of the International Committee of Medical Journal Editors, the journal will not consider results posted in the same clinical trials registry in which primary registration resides to be prior publication if the results posted are presented in the form of a brief structured (less than 500 words) abstract or table. However, divulging results in other circumstances (e.g., investors' meetings) is discouraged and may jeopardize consideration of the manuscript. Authors should fully disclose all posting in registries of results of the same or closely related work.

Article transfer service

This journal is part of our Article Transfer Service. This means that if the Editor feels your article is more suitable in one of our other participating journals, then you may be asked to consider transferring the article to one of those. If you agree, your article will be transferred automatically on your behalf with no need to reformat. Please note that your article will be reviewed again by the new journal. More information.

AUTHOR INFORMATION PACK 25 Oct 2019 www.elsevier.com/locate/gaitpost 6

Copyright

Upon acceptance of an article, authors will be asked to complete a 'Journal Publishing Agreement' (see more information on this). An e-mail will be sent to the corresponding author confirming receipt of the manuscript together with a 'Journal Publishing Agreement' form or a link to the online version of this agreement. Subscribers may reproduce tables of contents or prepare lists of articles including abstracts for internal circulation within their institutions. Permission of the Publisher is required for resale or distribution outside the institution and for all other derivative works, including compilations and translations. If excerpts from other copyrighted works are included, the author(s) must obtain written permission from the copyright owners and credit the source(s) in the article. Elsevier has preprinted forms for use by authors in these cases. For gold open access articles: Upon acceptance of an article, authors will be asked to complete an 'Exclusive License Agreement' (more information). Permitted third party reuse of gold open access articles is determined by the author's choice of user license.

Author rights

As an author you (or your employer or institution) have certain rights to reuse your work. More information.

Elsevier supports responsible sharing

Find out how you can share your research published in Elsevier journals.

Role of the funding source

You are requested to identify who provided financial support for the conduct of the research and/or preparation of the article and to briefly describe the role of the sponsor(s), if any, in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. If the funding source(s) had no such involvement then this should be stated.

Funding body agreements and policies

Elsevier has established a number of agreements with funding bodies which allow authors to comply with their funder's open access policies. Some funding bodies will reimburse the author for the gold open access publication fee. Details of existing agreements are available online.

After acceptance, open access papers will be published under a noncommercial license. For authors requiring a commercial CC BY license, you can apply after your manuscript is accepted for publication.

Open access

This journal offers authors a choice in publishing their research:

Subscription

• Articles are made available to subscribers as well as developing countries and patient groups through

our universal access programs.

• No open access publication fee payable by authors.

• The Author is entitled to post the accepted manuscript in their institution's repository and make this public after an embargo period (known as green Open Access). The published journal article cannot be shared publicly, for example on ResearchGate or Academia.edu, to ensure the sustainability of peer reviewed research in journal publications. The embargo period for this journal can be found below.

Gold open access

• Articles are freely available to both subscribers and the wider public with permitted reuse.

• A gold open access publication fee is payable by authors or on their behalf, e.g. by their research funder or institution.

Regardless of how you choose to publish your article, the journal will apply the same peer review criteria and acceptance standards.

For gold open access articles, permitted third party (re)use is defined by the following Creative Commons user licenses:

AUTHOR INFORMATION PACK 25 Oct 2019 www.elsevier.com/locate/gaitpost 7

Creative Commons Attribution-Non Commercial-No Derivs (CC BY-NC-ND)

For non-commercial purposes, lets others distribute and copy the article, and to include in a collective work (such as an anthology), as long as they credit the author(s) and provided they do not alter or modify the article.

The gold open access publication fee for this journal is **USD 3500**, excluding taxes. Learn more about

Elsevier's pricing policy: https://www.elsevier.com/openaccesspricing.

Green open access

Authors can share their research in a variety of different ways and Elsevier has a number of green open access options available. We recommend authors see our open access page for further information.

Authors can also self-archive their manuscripts immediately and enable public access from their institution's repository after an embargo period. This is the version that has been accepted for publication and which typically includes author-incorporated changes suggested during submission, peer review and in editor-author communications. Embargo period: For subscription articles, an appropriate amount of time is needed for journals to deliver value to subscribing customers before an article becomes freely available to the public. This is the embargo period and it begins from the date the article is formally published online in its final and fully citable form. Find out more.

This journal has an embargo period of 12 months.

Elsevier Researcher Academy

Researcher Academy is a free e-learning platform designed to support early and mid-career researchers throughout their research journey. The "Learn" environment at Researcher Academy offers several interactive modules, webinars, downloadable guides and resources to guide you through the process of writing for research and going through peer review. Feel free to use these free resources to improve your submission and navigate the publication process with ease.

Language (usage and editing services)

Please write your text in good English (American or British usage is accepted, but not a mixture of these). Authors who feel their English language manuscript may require editing to eliminate possible grammatical or spelling errors and to conform to correct scientific English may wish to use the English Language Editing service available from Elsevier's Author Services.

Submission

Our online submission system guides you stepwise through the process of entering your article details and uploading your files. The system converts your article files to a single PDF file used in the peer-review process. Editable files (e.g., Word, LaTeX) are required to typeset your article for final publication. All correspondence, including notification of the Editor's decision and requests for revision, is sent by e-mail.

Submit your article

Please submit your article via https://www.evise.com/profile/api/navigate/GAIPOS.

PREPARATION

Peer review

This journal operates a single blind review process. All contributions will be initially assessed by the editor for suitability for the journal. Papers deemed suitable are then typically sent to a minimum of two independent expert reviewers to assess the scientific quality of the paper. The Editor is responsible for the final decision regarding acceptance or rejection of articles. The Editor's decision is final. More information on types of peer review.

Introduction

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

1. Article types accepted are: Original Article (Full Paper or Short Communication), Review Article,

Book Review. Word limits are as follows: Full Paper 3,000 words plus no more than 6 figures/ tables in total; Short Communication 1,200 words plus no more than 3 figures/tables in total. The recommended word limit for Review Papers is 6,000 words. The word limits are non-inclusive of figures, tables, references, and abstracts. If the Editor feels that a paper submitted as a Full Paper would be more appropriate for the Short Communications section, then a shortened version will be requested. References should be limited to 30 for Full Papers; and 15 for Short Papers; there is no limit for review articles. A structured abstract of no more than 300 words should appear at the beginning of each Article. Authors must state the number of words when submitting.

AUTHOR INFORMATION PACK 25 Oct 2019 www.elsevier.com/locate/gaitpost 8

Short Communications are intended to introduce new techniques that improve the analysis and evaluation of human movement. This article type is not for preliminary or case studies, and such submissions will be rejected without review. Authors submitting a Short Communication should justify why it is a Short Communication rather than a Full Paper in their cover letter. Gait and Posture does not accept case reports.

All papers should contribute to improved understanding of human movement, particularly in clinical populations, and must therefore include a statement of significance in both the structured abstract and the main text. The contribution may be methodological; however, articles that simply validate existing methods or technologies are discouraged. Validation of methodology should instead be included within a larger study in which the methodology is used to answer a clinically relevant question.

2. All publications will be in English. Authors whose 'first' language is not English should arrange for their manuscripts to be written in idiomatic English **before** submission. A concise style avoiding jargon is preferred.

3. Authors should supply up to five keywords that may be modified by the Editors.

4. Authors should include a structured abstract of no more than 300 words including the following headings: Background, Research question, Methods, Results and Significance. The scientific and clinical background should be explained in 1-2

sentences. One clear scientifically relevant question should be derived from the background which represents the principle research question of the paper.

This should be framed specifically as a question not simply as a description. The Methods section should summarize the core study methodology including the type of study (prospective/retrospective, intervention etc), procedures, number of participants and statistical methods. The Results section should summarize the study's main findings. The Significance section should place the results into context. Furthermore, this section should highlight the clinical and/or scientific importance of the work, answering the question "so what?" This section should not simply repeat the study results or conclusions.

5. Acknowledgements should be included in the title page. Include external sources of support.

6. The text should be ready for setting in type and should be carefully checked for errors. Scripts should be typed double-spaced on one side of the paper only. Please do not underline anything, leave wide margins and number every sheet.

7. All illustrations should accompany the typescript, but not be inserted in the text. Refer to photographs, charts, and diagrams as 'figures' and number consecutively in order of appearance in the text. Substantive captions for each figure explaining the major point or points should be typed on a separate sheet.

8. Tables should be presented on separate sheets of paper and labelled consecutively but the captions should accompany the tables.

9. Authors should also note that files containing text, figures, tables or multimedia data can be placed in a supplementary datafile which will be accessible via ScienceDirect (see later section for further details).

What information to include with the manuscript

Having read the criteria for submissions, authors should specify in their letter of transmittal whether they are submitting their work as an Original Article (Full Paper or Short Communication), Review Article, or Book Review. Emphasis will be placed upon originality of concept and execution. Only papers not previously published will be accepted. Comments regarding articles published in the Journal are solicited and should be sent as "Letter to the Editor". Such Letters are subject to editorial review.

They should be brief and succinct. When a published article is subjected to comment or criticism, the authors of that article will be invited to write a letter or reply.

A letter of transmittal must include the statement, "Each of the authors has read and concurs with the content in the final manuscript. The material within has not been and will not be submitted for publication elsewhere except as an abstract." The letter of transmittal must be from all co-authors.

AUTHOR INFORMATION PACK 25 Oct 2019 www.elsevier.com/locate/gaitpost 9 All authors should have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

All contributors who do not meet the criteria for authorship as defined above should be listed in an acknowledgements section. Examples of those who might be acknowledged include a person who provided purely technical help, writing assistance, or a department chair who provided only general support. Authors should disclose whether they had any writing assistance and identify the entity that paid for this assistance.

Work on human beings that is submitted to *Gait & Posture* should comply with the principles laid down in the Declaration of Helsinki; Recommendations guiding physicians in biomedical research involving human subjects. Adopted by the 18th World Medical Assembly, Helsinki, Finland, June 1964, amended by the 29th World Medical Assembly, Tokyo, Japan, October 1975, the 35th World Medical Assembly, Venice, Italy, October 1983, and the 41st World Medical Assembly, Hong Kong, September 1989. The manuscript should contain a statement that the work has been approved by the appropriate ethical committees related to the institution(s) in which it was performed and that subjects gave informed consent to the work. Studies involving experiments with animals must state that their care was in accordance with institution guidelines. Patients' and volunteers' names, initials, and hospital numbers should not be used.

All Articles should include a justification of their sample size. While there is no set requirement for minimum sample size, studies considered to have too small a sample size to answer the research question will be rejected.

At the end of the text, under a subheading "Conflict of interest statement" all authors must disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/ registrations, and grants or other funding.

All sources of funding should be declared as an acknowledgement. Authors should declare the role of study sponsors, if any, in the study design, in the collection, analysis and interpretation of data; in the writing of the manuscript; and in the decision to submit the manuscript for publication. If the study sponsors had no such involvement, the authors should so state.

Authors are encouraged to suggest referees although the choice is left to the Editors. If you do, please supply their postal address and email address, if known to you.

Please note that papers are subject to single-blind review whereby authors are blinded to reviewers.

Randomised controlled trials

All randomised controlled trials submitted for publication in *Gait & Posture* should include a completed Consolidated Standards of Reporting Trials (CONSORT) flow chart. Please refer to the CONSORT statement website at http://www.consort-statement.org for more information. The Journal has adopted the proposal from the International Committee of Medical Journal Editors (ICMJE) which require, as a condition of consideration for publication of clinical trials, registration in a public trials registry. Trials must register at or before the onset of patient enrolment. The clinical trial registration number should be included at the end of the abstract of the article. For this purpose, a clinical trial is defined as any research project that prospectively assigns human subjects to intervention or comparison groups to study the cause-and-effect relationship between a medical intervention and a health outcome. Studies designed for other purposes, such as to study pharmaco kinetics or major toxicity (e.g. phase I trials) would be exempt. Further information can be found at http://www.icmje.org.

Review and Publication Process

1. You will receive an acknowledgement of receipt of the manuscript by the Editorial Office before the manuscript is sent to referees. Please contact the Editorial Office if you do not receive an acknowledgement.

AUTHOR INFORMATION PACK 25 Oct 2019 www.elsevier.com/locate/gaitpost 10

Following assessment one of the following will happen:

A: The paper will be accepted directly. The corresponding author will be notified of acceptance by email or letter. The Editor will send the accepted paper to Elsevier for publication.

B: The paper will be accepted subject to minor amendments. The corrections should be made and the paper returned to the Editor for checking. Once the paper is accepted it will be sent to production.

C: The paper will be rejected outright as being unsuitable for publication in *Gait and Posture*. By submitting a manuscript, the authors agree that the copyright for their article is transferred to the publisher if and when the article is accepted for publication. (https://www.elsevier.com/copyright). 3. Page proofs will be sent to the corresponding author for correction, although at this stage any changes should be restricted to typographical errors. Other than these, any substantial alterations may be charged to the authors. Proofs will be sent preferably by e-mail as a PDF file (although they can be sent by overland post) and must be rapidly checked and returned. Please ensure that all corrections are sent back in one communication. Subsequent corrections will not be possible.

4. An order form for reprints will accompany the proofs.

Essential title page information

• ***Title.*** Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.

• ***Author names and affiliations.*** Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. You can add your name between parentheses in your own script behind the English transliteration. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lowercase superscript letter immediately after the author's name and in front of the appropriate address.

Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.

• ***Corresponding author.*** Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. This responsibility includes answering any future queries about Methodology and Materials. **Ensure that the e-mail address is given and that contact details are kept up to date by the corresponding author.**

• ***Present/permanent address.*** If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.

Highlights

Highlights are optional yet highly encouraged for this journal, as they increase the discoverability of your article via search engines. They consist of a short collection of bullet points that capture the novel results of your research as well as new methods that were used during the study (if any). Please have a look at the examples here: example Highlights.

Highlights should be submitted in a separate editable file in the online submission system. Please use 'Highlights' in the file name and include 3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point).

Keywords

Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

Formatting of funding sources

List funding sources in this standard way to facilitate compliance to funder's requirements: Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa].

AUTHOR INFORMATION PACK 25 Oct 2019 www.elsevier.com/locate/gaitpost 11 It is not necessary to include detailed descriptions on the program or type of grants and awards. When funding is from a block grant or other resources available to a university, college, or other research institution, submit the name of the institute or organization that provided the funding. If no funding has been provided for the research, please include the following sentence: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Artwork

Electronic artwork

General points Make sure you use uniform lettering and sizing of your original artwork. Embed the used fonts if the application provides that option. Aim to use the following fonts in your illustrations:

Arial, Courier, Times New Roman, Symbol, or use fonts that look similar. Number the illustrations according to their sequence in the text. Use a logical naming convention for your artwork files. Provide captions to illustrations separately. Size the illustrations close to the desired dimensions of the printed version. Submit each illustration as a separate file. A detailed guide on electronic artwork is available. **You are urged to visit this site; some excerpts from the detailed information are given here.**

Formats

If your electronic artwork is created in a Microsoft Office application (Word, PowerPoint, Excel) then please supply 'as is' in the native document format. Regardless of the application used other than Microsoft Office, when your electronic artwork is finalized, please 'Save as' or convert the images to

one of the following formats (note the resolution requirements for line drawings, halftones, and line/halftone combinations given below):

EPS (or PDF): Vector drawings, embed all used fonts.

TIFF (or JPEG): Color or grayscale photographs (halftones), keep to a minimum of 300 dpi.

TIFF (or JPEG): Bitmapped (pure black & white pixels) line drawings, keep to a minimum of 1000 dpi.

TIFF (or JPEG): Combinations bitmapped line/half-tone (color or grayscale), keep to a minimum of 500 dpi.

Please do not: Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG); these typically have a low number of pixels and limited set of colors; Supply files that are too low in resolution; Submit graphics that are disproportionately large for the content; Supply more than 6 figures per manuscript.

References

All author names should be listed unless there are more than 6 authors, in which case the first 6 names should be listed followed by et al.

Data references

This journal encourages you to cite underlying or relevant datasets in your manuscript by citing them in your text and including a data reference in your Reference List. Data references should include the following elements: author name(s), dataset title, data repository, version (where available), year, and global persistent identifier. Add [dataset] immediately before the reference so we can properly identify it as a data reference. The [dataset] identifier will not appear in your published article.

Reference management software

Most Elsevier journals have their reference template available in many of the most popular reference management software products. These include all products that support Citation Style Language styles, such as Mendeley. Using citation plug-ins from these products, authors only need to select the appropriate journal template when preparing their article, after which citations and bibliographies will be automatically formatted in the journal's style. If no template is yet available for this journal, please follow the format of the sample references and citations as shown in this Guide. If you use reference management software, please ensure that you remove all field codes before submitting the electronic manuscript. More information on how to remove field codes from different reference management software.

AUTHOR INFORMATION PACK 25 Oct 2019 www.elsevier.com/locate/gaitpost 12

Reference style

Text: Indicate references by number(s) in square brackets in line with the text. The actual authors can be referred to, but the reference number(s) must always be given. Example: '. as demonstrated [3,6]. Barnaby and Jones [8] obtained a different result ....' *List:* Number the references (numbers in square brackets) in the list in the order in which they appear in the text.

Examples:

Reference to a journal publication:

[1] J. van der Geer, J.A.J. Hanraads, R.A. Lupton, The art of writing a scientific article, J. Sci. Commun. 163 (2010) 51–59. https://doi.org/10.1016/j.Sc.2010.00372.

Reference to a journal publication with an article number: [2] J. van der Geer, J.A.J. Hanraads, R.A. Lupton, 2018. The art of writing a scientific article. Heliyon. 19, e00205. https://doi.org/10.1016/j.heliyon 2018.e00205.

Reference to a book: [3] W. Strunk Jr., E.B. White, The Elements of Style, fourth ed., Longman, New York, 2000.

Reference to a chapter in an edited book: [4] G.R. Mettam, L.B. Adams, How to prepare an electronic version of your article, in: B.S. Jones, R.Z. Smith (Eds.), Introduction to the Electronic Age, E-Publishing Inc., New York, 2009, pp. 281–304.

Reference to a website: [5] Cancer Research UK, Cancer statistics reports for the UK. http://www.cancerresearchuk.org/ aboutcancer/statistics/cancerstatsreport/, 2003 (accessed 13 March 2003).

Reference to a dataset:

[dataset] [6] M. Oguro, S. Imahiro, S. Saito, T. Nakashizuka, Mortality data for Japanese oak wilt disease and surrounding forest compositions, Mendeley Data, v1, 2015. https://doi.org/10.17632/xwj98nb39r.1.

Data visualization

Include interactive data visualizations in your publication and let your readers interact and engage more closely with your research. Follow the instructions here to find out about available data visualization options and how to include them with your article.

Supplementary material

Supplementary material such as applications, images and sound clips, can be published with your article to enhance it. Submitted supplementary items are published exactly as they are received (Excel or PowerPoint files will appear as such online). Please submit your material together with the article and supply a concise, descriptive caption for each supplementary file. If you wish to make changes to supplementary material during any stage of the process, please make sure to provide an updated file. Do not annotate any corrections on a previous version. Please switch off the 'Track Changes' option in Microsoft Office files as these will appear in the published version.

Research data

This journal encourages and enables you to share data that supports your research publication where appropriate and enables you to interlink the data with your published articles. Research data refers to the results of observations or experimentation that validate research findings. To facilitate reproducibility and data reuse, this journal also encourages you to share your software, code, models, algorithms, protocols, methods and other useful materials related to the project.

Below are a number of ways in which you can associate data with your article or make a statement about the availability of your data when submitting your manuscript. If you are sharing data in one of these ways, you are encouraged to cite the data in your manuscript and reference list. Please refer to the "References" section for more information about data citation. For more information on depositing, sharing and using research data and other relevant research materials, visit the research data page.

Data linking

If you have made your research data available in a data repository, you can link your article directly to the dataset. Elsevier collaborates with a number of repositories to link articles on ScienceDirect with relevant repositories, giving readers access to underlying data that gives them a better understanding of the research described. There are different ways to link your datasets to your article. When available, you can directly link your dataset to your article by providing the relevant information in the submission system. For more information, visit the database linking page.

For supported data repositories a repository banner will automatically appear next to your published article on ScienceDirect.

In addition, you can link to relevant data or entities through identifiers within the text of your manuscript, using the following format: Database: xxxx (e.g., TAIR: AT1G01020; CCDC: 734053; PDB: 1XFN).

Mendeley Data

This journal supports Mendeley Data, enabling you to deposit any research data (including raw and processed data, video, code, software, algorithms, protocols, and methods) associated with your manuscript in a free-to-use, open access repository. During the submission process, after uploading your manuscript, you will have the opportunity to upload your relevant datasets directly to *Mendeley Data*. The datasets will be listed and directly accessible to readers next to your published article online.

For more information, visit the Mendeley Data for journals page.

Data statement

To foster transparency, we encourage you to state the availability of your data in your submission. This may be a requirement of your funding body or institution. If your data is unavailable to access or unsuitable to post, you will have the opportunity to indicate why during the submission process, for example by stating that the research data is confidential. The statement will appear with your published article on ScienceDirect. For more information, visit the Data Statement page.

AFTER ACCEPTANCE

Online proof correction

Corresponding authors will receive an e-mail with a link to our online proofing system, allowing annotation and correction of proofs online. The environment is similar to MS Word: in addition to editing text, you can also comment on figures/tables and answer questions from the Copy Editor. Web-based proofing provides a faster and less error-prone process by allowing you to directly type your corrections, eliminating the potential introduction of errors.

If preferred, you can still choose to annotate and upload your edits on the PDF version. All instructions for proofing will be given in the e-mail we send to authors, including alternative methods to the online version and PDF.

We will do everything possible to get your article published quickly and accurately. Please use this proof only for checking the typesetting, editing, completeness and correctness of the text, tables and figures. Significant changes to the article as accepted for publication will only be considered at this stage with permission from the Editor. It is important to ensure that all corrections are sent back to us in one communication. Please check carefully before replying, as inclusion of any subsequent corrections cannot be guaranteed. Proofreading is solely your responsibility.

Offprints

The corresponding author will, at no cost, receive a customized Share Link providing 50 days free access to the final published version of the article on ScienceDirect. The Share Link can be used for sharing the article via any communication channel, including email and social media. For an extra charge, paper offprints can be ordered via the offprint order form which is sent once the article is accepted for publication. Both corresponding and co-authors may order offprints at any time via Elsevier's Author Services. Corresponding authors who have published their article gold open access do not receive a Share Link as their final published version of the article is available open access on ScienceDirect and can be shared through the article DOI link.

AUTHOR INQUIRIES

Visit the Elsevier Support Center to find the answers you need. Here you will find everything from Frequently Asked Questions to ways to get in touch.

You can also check the status of your submitted article or find out when your accepted article will be published.