UNIVERSIDADE ESTADUAL DE CAMPINAS
INSTITUTO DE BIOLOGIA

REGIANE LUZ CARVALHO

Reajustes Posturais em Indivíduos Neurologicamente Normais e em Portadores da Síndrome de Down na gangorra: Efeito da manipulação sensorial

Dissertação apresentada ao Instituto de Biologia da ***Universidade Estadual de Campinas****, para obtenção do título de Doutor em Biologia Funcional e Molécula, Área de Fisiologia.*

Orientador: Prof. Dr. Gil Lúcio Almeida

CAMPINAS – SP
2006

Carvalho, Regiane Luz

C253r Reajustes posturais em indivíduos neurologicamente normais e em portadores da Síndrome de Down na gangorra: efeito da manipulação sensorial / Regiane Luz Carvalho. -- Campinas, SP: [s.n.], 2006.

Orientador: Gil Lúcio Almeida.
Dissertação (doutorado) – Universidade Estadual de Campinas, Instituto de Biologia.

1. Equilíbrio (Fisiologia). 2. Down, Síndrome de. 3. Gangorra. 4. Agentes do sistema sensorial. 5. Neurofisiologia. I. Almeida, Gil Lúcio. II. Universidade Estadual de Campinas. Instituto de Biologia. III. Título.

Data da Defesa: 20/02/2006

BANCA EXAMINADORA

Prof.Dr. GIL LÚCIO ALMEIDA (Orientador) ______________________ Assinatura

Profa.Dra. ELIZABETH MARIA APARECIDA BARASNEVIVIUS QUAGLIATO ______________________ Assinatura

Prof.Dr. FRANCESCO LANGONE ______________________ Assinatura

Profa.Dra. TANIA DE FÁTIMA SALVINI ______________________ Assinatura

Profa.Dra. HELENICE JANE COTE GIL COURY ______________________ Assinatura

Prof.Dr. MIGUEL ARCANJO ÁREAS ______________________ Assinatura

Profa.Dra. LUCIANA AUXILIADORA DE PAULA VASCONCELOS ______________________ Assinatura

Profa.Dra. ELAINE MINATEL ______________________ Assinatura

DEDICO

A minha família que me acompanhou nesta jornada, dando-me forças para prosseguir.

AGRADECIMENTOS

Ao Prof. Dr. Gil Lúcio Almeida pela orientação e ensinamentos.

Aos professores participantes da banca desta tese de doutorado.

Ao Marcos pelo carinho e paciência.

Aos meus pais, irmãos e avó pelo apoio.

Aos amigos do Laboratório de Pesquisas Clínicas em Fisioterapia, Nádia, Valdeci, Luciane, Rodrigo, Marcus e Juliano, pelo companheirismo, incentivo e agradável convívio.

Aos amigos, funcionários e professores do Curso de Fisioterapia da Universidade Católica de Minas Gerais- *Campus* Poços de Caldas pela ajuda.

Aos amigos, funcionários e professores do Departamento de Fisiologia e Biofísica da UNICAMP, especialmente a Andréia Vigilato.

A todas as instituições que trabalham com portadores da síndrome de Down e que nos ajudaram a recrutar voluntários para esta pesquisa.

A todos os voluntários que contribuíram conosco especialmente os portadores da síndrome de Down.

Resumo

Introdução: O objetivo deste estudo foi investigar o papel e a integração das informações sensoriais em indivíduos neurologicamente normais e portadores da síndrome de Down durante a manutenção do equilíbrio em condição de grande instabilidade. **Métodos:** Participaram deste estudo 8 sujeitos portadores da síndrome de Down (SD) pareados por sexo e idade com o grupo controle que balançaram em uma gangorra de 60cm de raio com combinação de 3 alturas (7,12 e 17cm). As informações sensoriais foram manipuladas pela oclusão da visão, aplicação da estimulação galvânica nos processos mastóideos e vibração no tendão de Aquiles. Os ângulos das articulações do quadril, joelho e tornozelo e a atividade eletromiográfica de alguns músculos da perna e do tronco foram registrados. **Resultados:** Na ausência de manipulação sensorial os dois grupos analisados mantiveram o equilíbrio na gangorra utilizando principalmente o deslocamento e contração dos músculos do tornozelo. Os indivíduos controle adotaram um padrão alternado de ativação muscular, sendo que a magnitude da resposta postural foi modulada com a altura da gangorra. Em contrapartida os indivíduos portadores da SD apresentaram um padrão generalizado de co-contração e não foram de capazes de modular sua resposta com a demanda mecânica da tarefa. No grupo controle a estimulação galvânica reduziu a magnitude da resposta muscular, mas não alterou o padrão alternado de contração. Já a vibração alterou este padrão de ativação, tornando-o de certa forma semelhante ao observado nos indivíduos portadores da SD. Nos indivíduos portadores da SD a estimulação galvânica reduziu significantemente a habilidade de manutenção do equilíbrio na gangorra, ao passo que a vibração não alterou nem o equilíbrio nem a estratégia postural. **Discussão.** Os indivíduos controle se adaptaram a redução de uma modalidade sensorial. A perda da modulação do

padrão alternado com a vibração indicou a grande importância da propriocepção na elaboração de respostas coordenadas ao nível do tornozelo. Por outro lado, os indivíduos portadores da SD apresentaram déficits na elaboração das respostas posturais. A perda do equilíbrio com a estimulação galvânica e a falta de efeito da vibração nos permite sugerir que, devido a déficits proprioceptivos a importância destas informações é reduzida acarretando em um aumento da importância das informações vestibulares durante o balanço na gangorra.

Abstract

Introduction: The main of this study was investigates the sensory integration and function in neurological (CG) and Down syndrome (DS) subjects during balance on unstable seesaw. Methods: Eight individuals with DS and eight CG were studied. Six balancing conditions were collected combining 3 seesaw heights and two manipulations: Galvanic Vestibular Stimulation (GVS) and Achilles tendon vibration. The angles and EMG activities of the some leg and trunk muscles were collected. Results: The CG adopted an alternated pattern of ankle muscle activation during balance and modulated the balance with the seesaw height. The individuals with DS showed the co-contraction muscle pattern during balance and were not able to modulate the muscle answer with the seesaw height. The GVS did not affect CG pattern of muscle contraction although the muscle activation has been partially inhibit. However the detriment of reciprocal pattern was observed due to vibration and under this perceptual condition the control subjects adopted a muscle pattern that remember the ones used by individuals with DS. On the other hand, individuals with DS lack the ability to keep balance during the vestibular manipulation and were no affected by vibration. Discussion: The CNS of CG rapidly assess and re-weigh available sensory inputs, assuring the balance success. On the other hand, individuals with DS showed a deficit in the mechanism responsible to elicit an appropriate postural response. They increased the postural response with GVS and decreased with vibration. This fact may indicate that because of proprioceptive dysfunctions the individuals with DS re-weigh the organization of sensory systems increasing the importance of vestibular system and decreasing the proprioceptive importance.

SUMÁRIO

I. Introdução

O estudo da regulação da postura constitui um tópico essencial do Controle Motor devido a sua importância universal. A manutenção da postura estática, assim como a estabilização durante a locomoção e execução de vários movimentos depende desta complexa regulação.

Estudos recentes têm fornecido uma nova visão sobre o controle postural. Anteriormente o equilíbrio era visto como resultado de um sistema de respostas reflexas desencadeadas por estímulos sensoriais. Atualmente o equilíbrio tem sido visto como uma habilidade que o sistema nervoso adquire utilizando múltiplos sistemas, incluindo elementos biomecânicos e estruturas cerebrais (Horak et al, 1997). Sendo assim, o equilíbrio não pode ser visto como uma simples resposta reativa a um estímulo sensorial.

Estudos têm mostrado que o controle do equilíbrio é bastante adaptativo e centralmente organizado baseado em experiência e intenção (Woollacott & Shumway-Cook, 2002). As informações sensoriais são organizadas seguindo uma ordem hierárquica que assegura a seleção da informação mais precisa e adequada durante a execução de uma tarefa. (Shumway-Cook & Woollacott, 1995). A função específica de cada sistema sensorial é bem conhecida e descrita em inúmeros trabalhos. No entanto, a interação e organização destas informações para a elaboração de ajustes posturais em diferentes contextos ambientais e em condições patológicas ainda não é totalmente compreendida.

Visando compreender os mecanismos envolvidos no Controle Postural, propusemos analisar os ajustes posturais durante a manutenção do equilíbrio em condição de grande instabilidade como o balanço em gangorra. A fim de entender o papel das informações sensoriais na elaboração das respostas posturais na gangorra as mesmas foram manipuladas.

Nós avaliamos a importância das informações vestibulares pela aplicação da estimulação galvânica e análise de seu efeito nas repostas posturais durante o balanço na gangorra.

Aprimorando a investigação do papel das informações sensoriais na gangorra utilizamos a vibração do tendão de Aquiles para avaliar o impacto da redução da propriocepção no equilíbrio.

O interesse pelos indivíduos portadores da síndrome de Down se explica pelos déficits posturais freqüentemente descritos nesta população. Estes déficits têm sido relacionados a problemas na seleção das informações sensoriais (Shumway-Cook & Woollacott, 1985), disfunção de integração sensorial (Uyanik et al., 2003), assim como alterações na estrutura neural e biomecânica.

O entendimento das estratégias de reajuste postural utilizadas em uma situação de desequilíbrio pode contribuir na elaboração de novas condutas terapêuticas visando à prevenção da queda que é uma das principais causas de traumatísmo do ser humano.

Apresentaremos a seguir a revisão de literatura em forma de dois artigos nos quais discutiremos os mecanismos envolvidos no controle postural normal "Controle postural: perspectivas atuais" e de indivíduos portadores da SD "Controle Postural em indivíduos portadores da síndrome de Down". Os resultados serão apresentados em capítulos compostos por artigos desenvolvidos ao longo do trabalho sendo que o primeiro intitulado "Vestibular evoked postural response on a seesaw" foi escrito baseado nos resultados obtidos da análise dos dados de indivíduos neurologicamente normais. O segundo artigo intitulado "The effect of Galvanic Vestibular Stimulation on postural response of individuals with Down syndrome on seesaw" foi escrito baseado nos resultados da estimulação vestibular em indivíduos portadores da síndrome de Down e o terceiro intitulado “The effect of ankle tendon vibration on seesaw balance in individuals with and without Down syndrome” elaborado a partir dos dados da vibração do tendão de Aquiles em indivíduos normais e portadores da SD.

Na parte final da tese apresentamos uma conclusão geral.

II. Capítulo 1: Artigo de Revisão

Controle Postural: Perspectivas atuais.

Carvalho RL, Almeida GL.

Na última década o controle da postura tem sido visto sob nova perspectiva. As definições têm se alterado com a evolução do conhecimento acerca dos mecanismos neurais envolvidos neste controle. A teoria de que a postura e o equilíbrio resultam de uma resposta reflexa hierarquicamente organizada tem cedido lugar a uma visão sistêmica que enfatiza a múltipla organização e interação neural (Horak, 1992). Estudos recentes têm indicado que o controle do equilíbrio não pode ser visto como simples resposta reativa a um estímulo sensorial, mas sim como habilidade baseada na experiência, intenção e com capacidade adaptativa. Para Lackner & DiZio (2005) o controle e a percepção da orientação corpórea dependem desde mecanismos periféricos relativamente simples, a mecanismos complexos envolvendo altos níveis de função cognitiva e integração sensório-motora.

O eficiente controle postural é fundamental para o sucesso de grande parte das tarefas diárias. O melhor conhecimento dos mecanismos envolvidos neste controle tem implicações para a prática fisioterapêutica. As novas perspectivas abrem o leque de atuação, possibilitando a aplicação de conceitos já estabelecidos de aprendizado motor como treino, "feedback" e atenção na reabilitação de desordens do equilíbrio.

De uma forma global duas funções principais podem ser atribuídas à postura. A primeira é a função antigravitaria na qual os segmentos corporais superimpostos resistem as forças da gravidade. A segunda é de servir como interface com o exterior para a interpretação sensorial e orientação espacial (Massion 1992).

A manutenção da postura envolve a orientação ativa de um ou vários segmentos contra forças desestabilizadoras geradas pelo ambiente ou por outros segmentos corporais. O equilíbrio entre as forças atuantes no corpo é denominado de estabilidade postural. Nesta condição o centro de massa é controlado em relação à base de suporte tanto em uma posição estática como durante o movimento (Horak et al. 1997). A estabilidade é dependente de controles antecipatórios (proativos) e compensatórios (reativos) (Mochizuki et al. 2004).

O controle antecipatório está relacionado à correção de distúrbios gerados por movimentos voluntários (focais) nas articulações não focais. As respostas antecipatórias são caracterizadas pela ativação da musculatura postural antes do início do movimento de forma a minimizar o distúrbio. O fato das reações antecipatórias serem observadas também em indivíduos deaferentados mostra que elas são elicitadas por um mecanismo “feedforward” (Forget & Lamarre 1990).

O controle compensatório está relacionado à correção de distúrbios posturais gerados pela interação com o ambiente (força de gravidade, choques mecânicos) ou pelo próprio movimento (Oddsson 1990). Estas reações são disparadas por informações aferentes na forma de um “feedback” sensorial.

Estudos das respostas posturais desencadeadas por distúrbios ambientais têm levado a noção de sinergias e estratégias (Macpherson 1991). As sinergias são definidas como modelos de ativação muscular centralmente organizados. O conhecimento desta organização facilita a compreensão da coordenação motora normal e anormal em caso de lesões cerebrais (Horak et al. 1997). Para Krishnamoorthy et al. (2003) as estratégias posturais representam soluções sensório-motoras para o controle da postura incluindo não apenas sinergias musculares, mas também padrões de movimentos articulares, torques e forças de contato.

As estratégias são limitadas por fatores externos (impostos pelo ambiente e tarefa) e internos. Os fatores internos envolvem os aspectos biomecânicos e neurais. Os aspectos biomecânicos são caracterizados pelas propriedades visco-elásticas dos músculos, ligamentos, a configuração anatômica dos ossos, músculos, articulações e a maquinaria contrátil. Os fatores neurais envolvem a seleção e processamento das informações sensoriais, elaboração de sinergias coordenadas, atenção na tarefa, experiência dentre outros (Horak et al. 1997). As informações de múltiplos sistemas sensoriais incluindo o somatosensorial, visual e vestibular são integradas pelo sistema de controle motor para orientar e alinhar a posição entre os segmentos corpóreos e a sua localização em relação ao meio externo (Bacsi & Colebatcg 2005). A interação multisensorial para o controle do equilíbrio não resulta de uma simples convergência das informações sensórias, mas sim de transformações apropriadas e coordenadas. Cada canal sensorial tem qualidades diferentes em termos de resolução e importância sendo que a fidedignidade de uma informação pode alterar a confiabilidade em outras (Lackner & DiZio 2005).

O estudo da organização sensorial tem possibilitado uma melhor compreensão do controle postural normal e anormal. Um dos métodos clássicos para o estudo da organização sensorial é a manipulação das informações sensoriais durante a aplicação de um distúrbio postural.

Informações visuais

As informações visuais orientam a posição e movimento da cabeça em relação ao ambiente sendo que, os múltiplos graus de movimento da cabeça facilitam a exploração ambiental.

Em condições estáticas as aferências visuais reduzem a oscilação corpórea em aproximadamente 50% (Sasaki et al. 2002). Para (Allun et al. 1998) as informações visuais tem um papel mais importante na estabilização tardia das correções posturais. Já Vallis et al. (2001) mostraram que elas podem ser utilizadas no planejamento de reações antecipatórias

Lishman & Lee (1973) observaram um aumento da importância das informações visuais durante o aprendizado de uma nova tarefa. Estes autores sugerem que com a automatização da tarefa a dependência das informações visuais diminui e das somatosensoriais aumenta.

Pozzo et al. (1995) têm sugerido que em superfícies instáveis o papel das informações visuais aumenta devido à desorganização das informações somatosensoriais. O aumento da importância visual também tem sido observado em pacientes com desordens vestibulares (Redfern et al. 2001).

As informações visuais podem ser manipuladas pela movimentação do cenário em relação ao sujeito pela oclusão da visão ou por estímulos optocinéticos (Kuo et al. 1998; Lee& Aronson 1974). Movimentos angulares ou lineares do campo de visão geram uma oscilação corporal na mesma direção do estímulo visual. Estímulos optocinéticos criam um conflito sensorial aumentando a dependência no sistema vestibular e proprioceptivo (Sasaki et al. 2002)

Informações Proprioceptivas

A importância da propriocepção para a manutenção da postura fica evidente pelas conseqüências clínicas decorrentes da deficiência destas informações (Allum et al. 1998). Apesar de numerosos estudos, o papel da propriocepção no controle postural não é completamente compreendido. Para Massion (1992) a representação da geometria estática e dinâmica do corpo se baseia amplamente na propriocepção muscular que informa continuamente ao SNC a posição de cada segmento corpóreo em relação ao outro.

Existem evidências de que as informações propriocepivas são mais importantes para a orientação postural durante a manutenção do equilíbrio em superfície fixa (Horak & Macpherson 1996). A amplitude e velocidade da oscilação aumentam significantemente quando as informações somatosensoriais dos membros inferiores são reduzidas por isquemia ou em pacientes com neuropatia periférica. O risco de queda é vinte e três vezes maior nos portadores de neuropatia periférica (Richardson & Hurvitz 1995).

Segundo o modelo de Mergner (1997) as informações proprioceptivas estão envolvidas na estabilização do corpo em relação à base de suporte e são primariamente utilizadas quando o SNC interpreta a superfície de suporte como estável. Para Mergner o controle pelas informações proprioceptivas ocorre no sentido dos pés para a cabeça ao passo que o controle pelas informações vestibulares ocorre de uma maneira crânio-caudal de forma a estabilizar o tronco no espaço. O SN compara as informações proprioceptivas e vestibulares. Se o resultado da comparação sugerir que a superfície é estável a importância das informações proprioceptivas aumenta, mas se a comparação sugerir que a superfície é instável, a influência vestibular torna-se mais importante. Corroborando com o modelo de Mergner, Allun et al. (1998) mostraram que indivíduos com neuropatia periférica apresentam respostas posturais alteradas nos membros inferiores mas não no tronco.

A propriocepção pode ser manipulada em indivíduos normais por várias técnicas como bloqueio isquêmico dos músculos, anestesia local (Mauritz & Dietz 1980) e vibração dos tendões musculares (Wierzbicka, et al. 1998; Ivanenko et al. 199, Hatzitaki et al. 2004). A utilização limitada da isquemia e anestesia se deve ao efeito não seletivo e de curta duração. A vibração muscular altera a orientação postural por ativar as aferências fusais produzindo uma situação de ilusão da posição do membro (De Nunzio 2005). Como resultado da ativação fusal observa-se a contração muscular. Por exemplo, a vibração do músculo tibial anterior resulta em inclinação anterior e do tríceps sural em inclinação posterior. A vibração induz não apenas reações locais, mas reações globais relacionadas a alteração de toda posição corporal (Ivanenko et al. 1999).

A influência da vibração nos músculos do tornozelo tem sido diminuída quando associada a informações proprioceptivas dinâmicas como a permanência em superfície instável (Ivanenko et al. 1999; Hatzitaki et al. 2004). Estes autores sugerem que a associação da vibração à instabilidade da superfície leva a redução da importância das informações proprioceptivas do tornozelo para o controle postural e aumento da importância das informações vestibulares e sua interação com a superfície de suporte.

1.3- Informações vestibulares

O sistema vestibular consiste em dois sensores de movimento, os canais semicirculares que detectam o movimento rotacional da cabeça e os órgãos otolíticos que detectam a aceleração linear. O papel das informações vestibulares no controle das respostas posturais geradas por distúrbios externos tem sido debatido. Entretanto, alguns estudos mostram que o sistema vestibular tem um papel importante na manutenção do equilíbrio corporal tônico (Hlavacka et al.1999).

Relatos têm mostrado que as informações vestibulares desempenham um menor papel na manutenção de posturas fixas (Day et al. 1997). Por outro lado à redução destas aferências leva a importantes déficits no controle de tarefas complexas com natureza dinâmica como a locomoção (Inglis & Macpherson 1995). Buchanan & Horak (2002) mostraram que a perda das informações vestibulares prejudica o controle do tronco e da cabeça em uma plataforma móvel sinusoidal. Peruch et al. (1999) examinaram a trajetória da locomoção em indivíduos com vestibulopatia crônica e observaram grande dificuldade na manutenção de uma trajetória linear de marcha. Para Mergner. (1997) as informações vestibulares controlam primariamente a orientação do tronco no espaço sendo que a deficiência das informações vestibulares compromete a estratégia do quadril e não a do tornozelo.

As informações vestibulares podem ser manipuladas pela aplicação de estimulação galvânica (EGV). A aplicação de corrente galvânica nos processos mastóideos despolariza o nervo vestibular e aumenta a freqüência de disparo dos aferentes vestibulares do lado do cátodo e diminui do lado do ânodo (Fitzpatrick & Day 2004). Esta aplicação resulta em uma oscilação corporal para o lado do ânodo. Este comportamento é semelhante ao observado em indivíduos com desordens no sistema vestibular. Estudos utilizando esta técnica mostram que a estimulação vestibular iniciada 0.5s antes do início da translação da plataforma altera o deslocamento do centro de pressão (Hlavacka et al.1999). A estimulação galvânica permite avaliar os efeitos primários das informações vestibulares na postura já que outras técnicas como a oscilação da cabeça ativam simultaneamente as aferências proprioceptivas cervicais.

A oscilação decorrente da EGV é menor quando as informações visuais estão disponíveis. A mesma estimulação vestibular resulta em respostas posturais diferentes de acordo com o estado do sistema somatosensorial indicando a interação entre estes sistemas. (Bacsi & Colebatcg, 2004; Mergner et al. 1997).A permanência em uma superfície de espuma (Horak & Hlavacka, 2001) ou plataforma de translação (Fitzpatrick & Day 2004) aumenta a magnitude da oscilação devido a EGV.

Estratégias Posturais

Como descrito anteriormente o SN utiliza as informações sensoriais na elaboração das estratégias. A implementação de várias estratégias normais e patológicas tem sido bem caracterizada na literatura. Em superfície fixa e estável o corpo se mantém ao redor do eixo do tornozelo como um pêndulo invertido. O torque do tornozelo necessário para o controle da postura nesta situação é gerado por componentes passivos (rigidez ou viscosidade produzido por músculos e tecidos ao redor como ligamentos e tendões) e ativos (contração muscular regulada pelo sistema nervoso central) (Masani et al. 2006).

Em plataforma de translação Horak & Nashner (1986) descreveram a estratégia do tornozelo e do quadril. A estratégia do tornozelo é caracterizada pela ativação estereotipada da musculatura no sentido distal para proximal e a estratégia do quadril pela ativação precoce da musculatura proximal do tronco e quadril. A estratégia do quadril é utilizada quando a base de suporte se torna menor e mais instável. Uma terceira estratégia é a do passo utilizada em grandes perturbações para evitar a queda, sendo caracterizada pela ativação inicial dos abdutores do quadril e co-contração do tornozelo (Horak & Nashner 1986) Em plataforma de rotação como a gangorra, a estratégia adotada é a contração alternada dos músculos agonistas e antagonistas do tornozelo (Almeida et al. 2006).

O conhecimento dos aspectos específicos das estratégias como latência das respostas, coordenação espaço-temporal, modulação da força e adaptação podem ajudar na compreensão do equilíbrio assim como do desequilíbrio. Por exemplo, o aumento da latência das respostas posturais tem sido observado em portadores de neuropatias periféricas (Inglis et al. 1994) e da síndrome de Down (Aruin & Almeida 1997). Coordenação espaço-temporal anormal tem sido comum em pacientes com comprometimentos neurológicos (Horak et al. 1997). A falta de modulação da resposta postural automática com a magnitude do desequilíbrio foi observada em pacientes com disfunção cerebelar (Horak & Diener. 1994). Idosos apresentaram grande redução da estabilidade postural com a execução de uma segunda tarefa associada à manutenção do equilíbrio indicando uma grande dependência da atenção para o sucesso do equilíbrio (Woollacott & Shumway-Cook 2002).

Implicações práticas

A implementação de várias estratégias posturais assim como a descrição da organização neural do sistema de controle postural é muito importante para uma avaliação precisa e intervenção mais eficaz.

Aspectos como o tempo de reação, coordenação das respostas musculares e da organização sensorial devem ser levados em consideração durante a avaliação do equilíbrio, assim como fatores relacionados à experiência, expectativa e atenção.

A identificação dos déficits posturais norteia o tratamento. Por exemplo, Hu & Woollacott (1994) mostraram uma redução do tempo da resposta postural em idosos após o treino, que consistiu de manutenção do equilíbrio em diferentes superfícies associado a alteração da disponibilidade visual. Di Fabio et al. (1990) observaram uma melhora na ordem de recrutamento muscular em pacientes com seqüela de AVE depois do tratamento com a utilização de feedback.

Considerações Finais

O controle da postura depende de uma complexa interação do sistema neural e músculo-esquelético com as forças internas e externas que atuam deslocando o centro de massa corporal. O sistema nervoso utiliza as informações aferentes na elaboração dos comandos que são enviados aos neurônios motores de forma a gerar uma força muscular que recupere o equilíbrio. Estes comandos são modulados pelas características sensoriais e também por mecanismos relacionados à atenção, experiência, contexto, bem como a modelos pré-programados de atividade muscular, denominados de estratégias (Horak et al. 1997). O sucesso do controle depende da flexibilidade do sistema e capacidade de adaptação da organização sensorial e das estratégias de manutenção do equilíbrio. A visão mais atual de controle postural e o melhor conhecimento dos sistemas envolvidos no controle normal e anormal do equilíbrio embasaram o avanço da reabilitação das desordens de equilíbrio.

Referências Bibliográficas

Almeida GL, Carvalho RL, Talis VL. Postural strategy to keep balance on the seesaw. Gait and Posture 23: 17-21, 2006

Allun JHJ, Bloem BR, Carpenter MG, Hulliger M, Hadders-Algra M. Proprioceptive control of posture: a review of new concepts. Gait and Posture 214-242, 1998.

Bacsi AM, Colebatch JG. Evidence for reflex and perceptual vestibular contributions to postural control. Exp. Brain Res160(1): 22-8, 2005.

Buchanan JJ, Horak FB. Role of vestibular and visual system controlling head and trunk position in space. Soc Neirosc 24-153, 1998

Day BL, Cauquil A, Bartolomei L, Pastor MA & Lyon IN Human body segment tilts induced by galvanic stimulation: a vestibularly driven balance protection mechanism. JPhysiol 500: 601-672, 1997.

De Nunzio AM, Schieppati. Head stabilization on continuously oscillating platform: the effect of a proprioceptive disturbance on the balance strategy. Exp Brain Research 165: 261- 272 , 2005

Di Fabio RP, Badke MB, MaEoy A, Ogden E. Kinematic properties of voluntary sway in patients with unilateral primary hemispheric lesions. Exp Brain 5(13): 248-245, 1990.

Fitzpatrick RC, Day BL. Probing the human vestibular system with galvanic stimulation. J Appl Physiol 96: 2301-2316, 2004.

Forget, R., Lamarre, Y. Antecipatory postural adjustment in the absence of normal peripheral feedback. Brain Research, 508: 176-179, 1990.

Hatzitaki V, Pavlou M, Bronstein AM. The integration of multiple proprioceptive information: effect of ankle tendon vibration on postural responses to platform tilt. Exp Brain Res. 154(3):345-54. 2004

Hlavack F, Shupert LC, Horak FB. The timing of galvanic vestibular stimulation affects responses to platform translation. Brain research, 821: 8-16, 1999.

Horak FB. Motor Control Models underlying neurologic rehabilitation posture in children. Medicine and Sport Science, 1992.

Horak FB, Hlavacka F. Somatosensory loss increases vestibulospinal sensitivity. J Neurophysiol 86: 575-585, 2001.

Horak FB, Nashner LM. Central program of postural movements: Adaptation to altered support-surface configurations. Journal of Neurophysiology 55:13691381, 1986.

Horak FB, Henry SM, Shumway-Cook A. Postural perturbations: new insights for treatment of balance disorders. Phys Ther. 77(5):517-33, 1997.

Horak FB, Diener HC. Cerebellar control of postural scaling and central set in stance J Neurophysiol 72: 479-49,1994.

Hu M, Woollacott MH. Multisensory training of standing balance in older adults, Kinematic and electromyographic postural responses. J Gerontol 49:1994

Inglis JT, Horak FB, Shupert CL, Jones-Rycewicz C. The importance of somatosensory information in triggering and scaling automatic postural responses in humans.

Exp Brain Res. 101(1):159-64, 1994.

Inglis JT, Macpherson JM. Bilateral labyrinthectomy in the cat: effects on the postural response to translation. J Neurophysiol. 73(3):1181-91, 1995.

Ivanenko, YP, Talis, VL, Kazennikov OV. Support stability influences postural responses to muscle vibration in humans. European Journal of Neuroscience, 11: 647-654, 1999.

Krishnamoorthy V, Latash ML, Scholz, JP, Zatsiorsky VM. Muscle synergies during shifts of the center of pressure by standing persons. Exp Brain Res 152: 281-292, 2003

Kuo AD, Speers RA, Peterka RJ, Horak FB. Effect of altered sensory conditions on multivariate descriptors of human postural sway. Exp Brain Res. 122(2):185-95, 1998.

Lackner JR, DiZio P Vestibular, proprioceptive, and haptic contributions to spatial orientation. Annu Rev Psychol.56:115-47, 2005.

Lee DN, Aronson E. Visual proprioceptive control of standing in human infants. Perceptual Psychophysiology.15: 529-532,1974.

Macpherson JM. How flexible are muscle synergies? Motor Control: Concepts and Issus. 33-47, 1991

Masani, K, Vette AH, Popovic MR. Controlling balance during quiet standing: Proportional and derivative controller generates preceding motor command to body sway position observed in experiments. Gait and Posture 23: 164-172, 2006.

Massion J. Movement posture and equilibrium: Interaction and coordination. Program Neurobiology. 38:35-36,1992

Mauritz KH, Dietz V. Characteristics of postural instability induced by ischemic blocking of leg afferents. Exp Brain Res.38(1):117-9, 1980.

Mergner T, Huber W, Becker. Vestibular Neck interaction and transformation of sensory coordinates. Journal of vestibular research. 7: 347-367, 1997.

Mochizuki G, Ivanova TD, Garland, SJ. Postural muscle activity during bilateral and unilateral arm movements at different speeds. Exp Brain Res. 155: 352:361,2004.

Oddsson LI Control of voluntary trunk movements in man. Mechanisms for postural equilibrium during standing. Acta Physiol Scand Suppl.;595:1-60, 1990.

Peruch P, Borel L, Gaunet F, Thinus-Blanc G, Magnan J, Lacour M. Spatial performance of unilateral vestibular defective patients in nonvisual versus visual navigation.

J Vestib Res 9(1):37-47, 1999.

Pozzo T, Levik Y, Berthoz A. Head and trunk movements in the frontal plane during complex dynamic equilibrium tasks in humans. Exp Brain Res.;106(2):327-38, 1995

Redfern MS, Yardly L, Bronstein PA. Visual influences on balance. J Anxiety Disord 15:81-94, 2001.

Richardson JK , Hurvitz EA. Peripheral neuropathy: a true risk factor for falls J Am Geriatr Soc 40: 1008-1012, 1992

Sasaki O, Usami S, Gagey P, Martinerie J, Quyen M, Arranz P. Role of visual input in nonlinear postural control system. Exp Brain Res 147:1-7, 2002.

Vallis LA, Patla AE, Adkin AL. Control of steering in the presence of unexpected head yaw movements Exp Brain Res 138:128-134, 2001.

Wierzbicka, M. M., Gilhodes, J. C. & Roll, J. P. Vibration-induced postural post effects. Journal Neurophysiology, 79: 143-150, 1998 .

Woollacott Marjorie, Shumway-Cook Anne. Attention and the control of posture and gait: a review of an emerging area of research. Gait and Posture 16: 1-14, 2002.

III. Capítulo 2. Artigo de Revisão

Controle Postural em indivíduos portadores da síndrome de Down

Carvalho RL, Almeida GL.

A síndrome de Down é a mais freqüente anormalidade cromossômica associada ao retardo mental com incidência aproximada de 1 em cada 700 nascidos vivos. Ela se deve a trissomia (92-95%), mosaico (2-4%) e translocação (3 a 4%) (Malini 2006) do cromossomo 21. O número e localização exata dos genes envolvidos assim como a patogênese permanece indeterminada, sendo que o gene DCR-1 tem sido estudado como um candidato (Rachidi 2005). Os fatores mais aceitos como predisponentes são exposição a radiações, infecções e idade materna (Malini 2006).

O fenótipo é variável afetando diferentes órgãos e tecidos, incluindo a musculatura esquelética e o cérebro (Rachidi 2005). As alterações músculo-esqueléticas incluem baixa estatura, frouxidão ligamentar, (Stein et al. 1991). Apresentam menor volume total do cérebro, principalmente do cerebelo, alterações celulares na região do hipocampo, redução das sinapses no córtex temporal (Saran et al. 2003). Evidências neuropatológicas sugerem que as diferenças na estrutura cerebral não estão presentes no útero, mas emergem durante o desenvolvimento, devido a padrões retardados de crescimento (Raz et al. 1995). Uma característica do desenvolvimento neural é o atraso na mielinização.

Alterações motoras e perceptivas que afetam o controle postural são freqüentes nessa população (Babul & Bown 2004). Os padrões eletromiográficos são caracterizados por uma co-activação, com acentuada diminuição da quantidade de atividade muscular, gerando uma redução dos torques e movimentos lentos, pouco suaves e mais variáveis do que os da população em geral (Almeida et al. 2000).

Em relação ao desenvolvimento motor apresentam uma defasagem cronológica, embora a sequência deste desenvolvimento se assemelhe à observada nos indivíduos neurologicamente normais (Block 1991). Rauh et al. (1991) observaram que tarefas motoras com alta dependência do equilíbrio, como a marcha, desenvolvem-se mais lentamente e de uma forma muito variável. Carr (1970) relatou o atraso de cerca de 10 meses na manutenção do equilíbrio sem apoio nos portadores da síndrome de Down. Haley (1986) descreveu a defasagem na aquisição das reações de equilíbrio e a utilização de reações de proteção como mecanismo compensatório.

Shumway-Cook & Woollacott (1985) analisaram as respostas posturais automáticas em crianças portadoras da síndrome de Down de 4 a 6 anos, durante perturbações geradas por plataforma móvel. Padrões normais de respostas posturais ao distúrbio externo foram observados, entretanto a latência para o início da resposta foi muito grande, resultando em aumento da oscilação corporal e em algumas vezes perda do equilíbrio. Outras alterações foram déficits de adaptação ao longo das tentativas e de utilização de reações antecipatórias.

Problemas na seleção das informações sensoriais também têm sido descritos. O estudo de Shumway-Cook & Woollacott (1985) com alteração das condições sensoriais demonstrou que crianças portadoras da síndrome de Down têm grande dificuldade em manter o equilíbrio, na presença de informações sensoriais incongruentes sendo que o efeito da movimentação do campo visual no deslocamento postural é consideravelmente maior nas crianças portadoras da síndrome de Down . Este resultado indica que aos 10 anos de idade os portadores dessa síndrome dependem muito da visão, ao passo que as outras crianças apresentam um controle multimodal. Estes estudos não determinam se o desenvolvimento do processo de organização de conflito sensorial está ausente, ou simplesmente atrasado, nessas crianças, já que este processo se desenvolve normalmente dos 7 aos 10 anos .

Para Ulrich et al. (1997), o atraso do desenvolvimento postural de crianças portadoras da síndrome de Down pode ser explicado pela dificuldade da percepção das respostas posturais, prejudicando a sensação do movimento e de suas conseqüências. Corroborando com esta idéia, Uyanik et al. (2003) sugerem a disfunção de integração sensorial como resultado da limitada experiência sensorial nesses indivíduos.

As dificuldades motoras e os déficits posturais parecem persistir ao longo da vida dos portadores da síndrome de Down (Almeida et al 200; Aruin & Almeida 1997). Aruin & Almeida, (1997) analisaram as respostas posturais geradas por movimentos rápidos de flexão e extensão bilateral dos ombros em adultos com e sem síndrome de Down. Modelos diferentes de repostas posturais antecipatórias, precedendo movimentos voluntários foram observados. Jovem adultos portadores da síndrome de Down, apresentaram grande deslocamento do centro de pressão sem correlação com o distúrbio e um padrão de co-ativação muscular. A estratégia adotada pelos portadores da síndrome de Down em reação ao distúrbio foi de flexão do quadril e extensão do joelho, oposta a estratégia adotada pelo indivíduos neurologicamente normais que estenderam o quadril e flexionaram o joelho. Os portadores da síndrome de Down conseguiram manter o equilíbrio usando uma estratégia menos universal e de menor eficiência em relação ao gasto energético.

Os estudos sobre a manutenção da postura em superfície estável mostram uma maior velocidade de oscilação postural tanto em adultos (Webber et al. 2004) quanto em adolescentes portadores da síndrome de Down (Vuillerme 2001). O aumento da oscilação parece ser uma característica geral da postura desses indivíduos, da infância à vida adulta. Com o aumento da oscilação, os movimentos realizados sobre uma base de suporte mais instável são mais difíceis de serem controlados (Vuillerme et l. 2001).

Além do aumento da oscilação postural, Webber et al. (2004) observaram um padrão de co-contração muscular nessa população. Este padrão também foi observado por Ulrich et al. (2004) durante caminhada em uma esteira de baixa e alta velocidade. A co-contração tem sido uma característica dos portadores da síndrome de Down em movimentos uni-articulares (Aruin & Almeida 1997) e bi-articulares (Latash 1993), nos músculos posturais em antecipação a perturbações posturais (Aruin & Almeida 1997) e em reações preprogramadas (Latash 1992). Vários autores tentam explicar este padrão de co-activação. Para Virji-Babaul (2002) a co-contração se deve à dificuldade de gerar forças adequadas. Ele se baseia no fato de que atividade eletromiográfica durante a extensão do joelho estar diminuída nesta população. Ulrich et al (2004) propõe que a co-contração é utilizada para compensar a frouxidão ligamentar e otimizar a estabilidade.

Latash (2000) tem proposto que a co-contração é uma característica geral dos movimentos dos SD utilizada em situações inesperadas para otimizar a segurança e a estabilidade. De acordo com Latash & Anson (1996), se uma resposta preprogramada de padrão recíproco for ativada de forma errônea ela acentuará o distúrbio. Por outro lado, o padrão de co-contração é mais universal, e, neste sentido, atenua os efeitos da perturbação, independentemente da direção do distúrbio. Portanto, a estratégia de co-contração seria aparentemente conseqüência de desordens neurológicas provocadas pela síndrome, já que com a prática extensiva esses indivíduos são capazes de adotar um padrão trifásico de ativação (Almeida et al, 1994). Latash & Anson (1996) sugerem que a co-contração é uma escolha feita pelo sistema nervoso tendo em vista sua flexibilidade e adaptabilidade.

Embora seja uma escolha mecanicamente sub-ótima, a co-ativação oferece mais segurança e reflete a insegurança do sistema em gerar reações posturais corretas.

Adolescentes portadores da síndrome de Down que são caracterizados por baixo tônus e baixa capacidade de gerar força, mostraram altos níveis de co-contração em superfície rígida (Webber et al. 2004) e durante a marcha em esteira (Ulrich et al. 2004). Existe portanto uma inconsistência entre a avaliação clínica do tônus nesta população e os achados acima citados, permanecendo a relação entre hipotonia (baixa rigidez) e co-contração pouco compreendida. Weber et al. (2004) sugerem que a avaliação do tônus sobre condições passivas pode fornecer informações limitadas sobre as estratégias utilizadas pelo SNC.

A maior oscilação postural, as anormalidades no tempo de ativação muscular, o padrão de co-contração e a dificuldade de se adaptar as alterações do ambiente podem estar relacionados aos movimentos desajeitados e instáveis. Embora existam teorias que justifiquem o padrão de co-contração, as razões específicas das alterações motoras observadas nos portadores da SD não foram totalmente identificadas.

Alguns aspectos dos déficits de controle postural podem ser explicados pelas alterações biomecânicas, como diferença na densidade óssea, hipoplasia da cartilagem, alterações nas propriedades dos ligamentos (Stein et al. 1991). Estas alterações podem influenciar a habilidade de gerar torque articular já que eles apresentam reduzidos níveis de força em contrações isocinéticas (Cioni at al. 1994). Para Shields & Dodd (2004) a fraqueza muscular também pode influenciar na habilidade de realizar tarefas diárias, como a manutenção do equilíbrio e a marcha.

As alterações neurobiológicas são de grande importância para a compreensão dos distúrbios. Ao nível central, o cerebelo seria um bom candidato devido a seu papel na coordenação muscular (Houk et al. 1996) e seu peso ser menor em indivíduos portadores da Síndrome de Down (Bellugi et al. 1990). Segundo Latash (2000), o cerebelo tem um papel importante na formação de comandos coordenados a vários músculos, articulações ou membros. Déficits cerebelares levam a dificuldade de ativação sinérgica dos músculos contribuindo também para a lentidão dos movimentos. Finalmente, os portadores da síndrome de Down apresentam um padrão motor semelhante ao observado em portadores de disfunção cerebelar durante a marcha em esteira (Rand et al. 1997).

Ao nível periférico, o candidato seria distúrbio no mecanismo proprioceptivo. Brandt (1995) mostrou baixa amplitude do potencial de ação devido à estimulação do polegar, sugerindo função somatosensorial deficitária. Cole et al. (1988) observaram falhas na modulação da força de preensão sobre objetos de diferentes superfícies. Entretanto, Shumway-Cook, & Woollacott (1985) mostraram latências normais dos reflexos de estiramento monossinápticos durante perturbações geradas por plataforma de força. Além de reflexos normais, o padrão adotado durante movimentos planares dos braços diferiu do observado em indivíduos com neuropatia periférica (Sainburg et al. 1995). No entanto, acreditamos que os déficits observados nos portadores da síndrome de Down estejam mais relacionados a comprometimentos em níveis centrais do que periféricos, corroborando com a idéia de Courage et al. (1997) os quais sugerem a disfunção de integração sensorial.

Porém, as alterações do sistema nervoso não podem ser consideradas como os únicos fatores responsáveis pelas alterações da performance motora. Características como contexto ambiental e experiência tem grande influência.

De uma forma geral os estudos de controle motor em portadores da SD indicam déficits nos mecanismos envolvidos no controle postural. A aquisição deste controle é atrasada e os mecanismos posturais parecem estar organizados de forma a maximizar a estabilidade, como uma adaptação ao longo tempo de reação e pobre interação com as alterações imprevisíveis do ambiente. A conseqüência funcional deste princípio é a redução da velocidade e coordenação dos movimentos que se tornam desajeitados.

Implicações práticas

O melhor conhecimento sobre os aspectos biomecânicos, neurológicos e ambientais envolvidos no controle postural, assim como as adaptações observadas em várias situações facilitam a compreensão dos déficits de equilíbrio possibilitando uma intervenção mais específica.

Estudos em condições de laboratório mostram que com o treino, os portadores da síndrome de Down trocam o padrão de co-activação por um padrão recíproco e trifásico, melhorando a performance motora (Almeida et al. 1994). Similarmente Webber et al.(2004) mostrou uma melhora na manutenção da postura estática com a prática. Entretanto ainda existem dúvidas sobre a capacidade de transferência deste aprendizado para situações cotidianas.

Tem sido debatido na literatura se a reabilitação deve enfatizar a alteração das estratégias (caracterizadas como sub-ótimas) utilizadas pelos portadores da síndrome de Down, já que a escolha pela utilização destas parece ser uma adaptação aos déficits nos mecanismos de controle postural (Latash & Anson 1996).

Sobre o nosso ponto de vista, e de acordo com Aruin & Almeida (1997), a reabilitação deve enfatizar a função e não o padrão motor já que o SNC pode adotar inúmeros padrões motores capazes de acompanhar com sucesso as tarefas motoras (variabilidade normal).

Referências Bibliográficas

Almeida GL, Tortoza, C, Ferreira, SMS. Marconi, NF, Corcos, DM, & Gottlieb, LG, Motor control in individuals with Down Syndrome: comparison with normals. In *Perceptual-motor behavior in Down syndrome*. Human Kineticss, 2000; 151-174.

Almeida GL, Corcos DM, Latash ML. Practice and transfer effects during fast single-joint elbow movements in individuals with Down syndrome. *Physical Therapy* 1994; 74, 11: 1000-1016.

Aruin AS, Almeida GL. A. coactivation strategy in anticipatory postural adjustments in person with Down Syndrome. *Motor Control* 1997; 1: 178-191.

Bellugi U, Bihrle A, Jernigan T, Trauner D, & Doherty S, Neuropsychological, neurological, and neuroanatomical profile of Williams syndrome. *American Journal of Medical Genetics* 1990; 6: 115-125.

Block ME, Motor development in children with Down syndrome. A review of the literature. *Adapted Physical activity Quarterly* 1991; 8: 179-209.

Brandt BR, Rosen I, Impaired Peripheral Somatosensory Function in children with Down syndrome. *Neuropediatrics* 1995; 26: 310-312

Carr, J. Mental and motor development in Young mongol children. Journal of Mental Deficiency Research 1970;14: 205-218,.

Cioni M, Cocilovo A, Di Pasquale F, Rillo Araujo MB, Rodrigues Suqueira C, Bianco M. Strength deficit of knee extensor muscles of individuals with Down syndrome from childhood to adolescence. *Am J Ment Retard* 1994; 99: 166-174.

Cole, KJ, Abbs, JH, & Turner, GS, (1988). Deficits in the production of grip force in Down syndrome. *Developmental Medicine and Child Neurology*, 30:752-758.

Courage, ML, Adams RJ, Hall EJ. Contrast sensitivity in infants and children with DS. *Vision Res* 1997; 37: 1545-55.

Haley SM. Postural reactions in infants with Down syndrome: Relationship to motor milestone development and age. *Physical Therapy* 1986; 66:17-22.

Houk, JC, Buckingham, JT, & Barto, AG, Models of the cerebellum and motor learning. *Behavioral and Brain Sciences*, 1996; 19: 368-383.

Latash ML. Motor Control in Down Syndrome: The role of adaptation and practice. J. *of Developmental and Phys. Disab* 1992; 3: 227-261.

Latash ML. Motor coordination in Down syndrome: The role of adaptive changes In: Perceptual-motor behavior in Down syndrome, *Human Kineticss*, 2000; 151-174.

Latash ML. Almeida GL, Corcos DM, Preprogrammed reactions in individuals with Down syndrome: The effects of instruction and predictability of perturbation. Archives of *Physical Medicine and Rehabilitation*, 1993; 73: 391-399.

Latash ML, Anson JG. What are normal movements in atypical populations? *Behavioral and Brain Sciences*. 1996; 19: 55-68.

Malini SS, Ramachandra NB.Influence of advanced age of maternal grandmothers on Down syndrome. *Med Genet* 2006; 14: 7-1-4

Mazzone L, Mugno D, Mazzone D The General Movements in children with Down syndrome.*Early Hum Dev*. 2004; Sep;79(2):119-30.

Raz N, Torres IJ, Briggs SD, Spencer WD, Thornton AE, Loken WJ, Gunning FM, Mac quain JD, Driesen NR, Acker JD. Selective neuroanatomic abnormalities in Down´s syndrome and their cognitive correlates. *Neurology* 1995; 45: 356-366.

Rachidi M, Lopes C, Costantine M, Delabar JM.C21orf5, a new member of dopey family involved in morphogenesis, could participate in neurological alterations and mental retardation in down syndrome. *DNA Res.* 2005; 12(3): 203-10.

Rand MK, Wunderlich DA, Martin PE, Stelmach GE, Bloedel JR. Adaptive changes in responses to repeated locomotor perturbations in cerebellar patients 1997; 43: 122-131

Rauh H, Rudinger G, Bowman T, Berry P, Gunn P, Hayes A 1991. *The development of Down syndrome children.* In M.Lamb, H.Keller, Infant development (329-355) Hillsdale NJ, Erlbaum

Sainburg RL, Ghilardi MF, Poizner H, Chez C. Control of limb dynamics in normal subjects and patients without proprioception. *J. of Neurophysiology*,1995; 73: 820-835

Saran NG, Pletcher MT, Natale JE, Cheng Y, Reeves R Global disruption of the cerebellar transcriptome in a Down syndrome. *Hum. Mol. Genetics* 2003; 2013-2019

Shields N, Dodd KA, systematic review on the effects of exercise programms designed to improve strength for people with Down syndrome. *Phys Therapy Reviews* 2004; 9: 109-115.

Shumway Cook A, Woollacott M.Postural control in the Down´s syndrome child. *Phy Ther* 1985; 9: 211-235 .

Shumway-Cook A, Woollacott MJ. Dynamics of postural control in the child with Down syndrome. *Physical Therapy* 1985; 65(9): 1315-1322.

Stein SM, Kirchner SG, Horev G, Hernanz-Schulman M. Atlanto-occipital subluxation in Down syndrome. *Ped Radiol*, 1991; 21:121-124.

Ulrich BD, Ulrich DA, Chapman DD. Sensitivity of infants with and without Down syndrome to produce treadmill steps. *Physical Therapy* 1997;75: 14-23.

Ulrich BD, Haehl V, Buzzi UH, Kubo M, Holt KG. Modeling dynamic resource utilization in populations with unique constrains: preadolescents with and without Down syndrome. *Hum. Mov Sci* 2004 23(2): 133-56

Uyanik M, Bumin G, Kayihan H. Comparison of different therapy approaches in children with Down syndrome. *Pediatrics International* 2003; 45: 68-73.

Virji- Babul N,V. Brown M. Stepping over obstacles:antecipatory modifications in children with and without Down syndrome. *Exp Brain Research*, 2004, 159(4):487-90

Vuillerme N, Marin L, Debu B, Assessment of Static Postural Control in teenagers with Down syndrome.*Adapted Physical activity Quarterly*, 2001;18: 417-431.

Webber, A Babul V, Edwards R. Stiffness and postural stability in adults with Down syndrome. *Exp Brain research* 2004; 155:450-458

IV. Capítulo 3.

Vestibular-evoked postural response on the seesaw.

Carvalho RL, Almeida G.L

ABSTRACT

The purpose of this experiment was to investigate the ways in which sensory channels interact to control balance on seesaws using Galvanic Vestibular Stimulation (GVS) and blindfolding to partially block the vestibular and visual feedback. Subjects stood on seesaws of different heights during two sensory conditions (1) with GVS of 1.5mA applied over the mastoid processes (2) without stimulation. The movement of hip, knee and ankle were reconstructed using a 3-D motion analysis system, and the electromyography activities of selected ankle, knee, and hip muscles were recorded. Three important results were observed: GVS increases the ankle displacement due to a decrease of ankle muscle activation and the alternated pattern of contraction on the seesaw was not affected. The evidence presented here suggests that the effect of GVS was quantitative and not qualitative. This may explain the fact that, despite these changes, all subjects were able to keep their balance on the seesaw with GVS. Then, seesaw postural responses (in the absence of visual information) are evoked by interaction of vestibular input with support-surface information and the postural responses to the concurrent application of different stimuli depend upon the ability of the central nervous system to rapidly assess and re-weigh available sensory inputs. The flexible reweighing of the sensory information from the sensory systems seems to be essential to the success of postural control.

Key words: Galvanic Vestibular Stimulation, seesaw, posture

INTRODUCTION

The control and perception of body orientation and motion are subserved by multiple sensory and motor mechanisms, ranging from relatively simple, peripheral mechanisms to complex ones involving the highest levels of cognitive function and sensory-motor integration (Lackner & DiZio, 2005). Each sensory channel has different qualities in terms of resolution, bandwidth, and importance for the whole body and segmental balance, and the availability and sensitivity of one input can alter the confidence placed on the others. For example, some reports have shown that the identical vestibular stimulus results in different postural responses, depending on the state of the somatosensory system, producing the most convincing evidence of vestibulo-somatosensorial interaction (Bacsi & Colebatcg, 2004; Creath et al. 2002; Mergner et al. 1997).

Standing on compliant surfaces, such as a piece of foam rubber (Horak & Hlavacka, 2001) or translation surfaces (Fitzpatrick et al. 1994) increased the size of the sway response due to vestibular manipulation using GVS. Like those unstable surfaces, the seesaw requires an integration of the vestibular and somatosensorial information for the success of balance. Indeed, we have shown that on a seesaw with blindfolded vision, the balance is done mainly at the ankle joint. The EMG patterns of the gastrocnemius and anterior tibialis alternated between agonist and antagonist bursts with the agonist burst starting before the end of the lengthening phase and being prolonged until the end of the shortening phase (Almeida et al. 2006).

We cannot define the exact contribution of vestibular and somatosensorial information to the maintenance of equilibrium on the seesaw. Here we explore the effect of the manipulation of vestibular information during balance on the seesaw using GVS and blindfolding to respectively prevent the vestibular and visual feedback.

Our first hypothesis is that the joint displacements, mainly at the ankle, would increase with GVS, providing evidence for an increase in the sensitivity of the vestibular-evoked responses. This increase is expected since studies using the same GVS showed greater body oscillation in individuals with loss of somatosensorial information, such as with hypothermic anesthesia of the feet (Magnusson et al. 1990) and peripheral neuropathy (Horak & Hlavacka, 2001) and in studies in which somatosensorial input was not accurate such as on an unstable support surface (Fitzpatrick et al. 1994) and foam (Wardman et al. 2003).

The second hypothesis is that GVS will increase the muscle activation. This increase has been described on a rigid platform, a translation surface and on compliant foam (Fitzpatrick et al. 1994; Wardman et al. 2003). Apart from muscle increase, we did not expect to see the effect of GVS on joint coupling nor on muscle activity patterns since the subjects with vestibular loss lack the hip strategy but show normal ankle strategy (Horak et al. 1990; Popov 1990).

METHODS

Eight individuals (4 male, 4 female, average age 27 years) were studied after they had signed an institutional (UNICAMP) term of informed consent. Six balancing conditions were collected combining 3 seesaw heights (7,12 and 17cm) to provide an index of difficulty, and two GVS conditions (with and without stimulation).

Kinematic data

The X, Y and Z coordinates Light Emitting Diodes (LED) marks were recorded using a 3D-motion- analysis system (OPTOTRAK 3020). The LED marks were attached on the left side of the shoulder (lateral aspect of the humerus), hip (between the greater trochanter and superior iliac crest), knee (lateral condyle), ankle (external malleolus), foot (head of the 5th metatarsal), and on the seesaw. The (LED) coordinates were recorded at 100 Hz and used to calculate the ankle, knee, and hip angular displacements.

EMG activities

The activities of the gastrocnemius medialis (GM), tibialis anterior (TA), biceps femoris (BF), rectus femoris (RF), erector spinae (ES) at the L4 level, and the rectus abdominis (RA) were recorded using bipolar surface EMG electrodes (DeLSys). All data were band pass filtered (45-450 Hz), amplified (x 2000) and digitized at 1000 Hz. The EMG signals were rectified and smoothed using a second order Butterworth filter with 10 Hz. cutoff frequencies.

Procedure

Initially, the individual was blindfolded with a mask, than the researcher helped him/her to stand on seesaw keeping the feet at the center. From this position, the individual could start balancing with or without GVS. GVS of 1.5mA was applied via 2.5cm carbon-rubber electrodes placed behind the subject's ears over the mastoid processes. The anode was placed on the right ear. The balance began after 2s of stimulation and lasted for 10s. During the balance, the individual held each shoulder with the opposite hand, keeping the upper limbs crossed and in contact with the chest.

All trials were 10s in duration. The trials were recorded for a rigid floor (for control) and for each seesaw, with and without GVS. All subjects completed two trials in each condition.

Data quantification

The Matlab program was used to calculate the maximum plantar and dorsal ankle flexion and the corresponding angular displacement of the hip and knee joints during this time. The activities of the six muscles cited above were integrated during 50 milliseconds, just before and 50 milliseconds after the maximum dorsal and plantar flexion time. The EMG values were normalized to the values obtained during stationary standing condition.

All EMG and kinematic variables were studied using ANOVA ($p<0,05$) with one factor (GVS) when standing still on rigid platform and two factors (GVS and ID) on seesaw. The effect of GVS and index of difficulty was evaluated separately for the groups and for the movement directions.

RESULTS

Figure 1 depicts the muscle activation patterns and ankle-joint displacement during the balance of a representative individual on a seesaw 12cm high.

Insert here figure 1

It is interesting to observe that GVS did not alter the pattern of muscle activation during the balance. In both conditions, the individuals kept balance by alternating the activation of the TA and the GM muscles. The activation of the GM started before the ankle moved from dorsal to plantar flexion and remained until the ankle shifted again into dorsal flexion. The same occur with the TA when the ankle shifted into dorsal flexion.

The effect of GVS on EMG and Kinematics strategy

Insert here figure 2

Figure 2 illustrates the joint displacements and muscle activities at maximal plantar flexion (PF) and dorsal flexion (DF) on a rigid platform (RP) and on seesaws with different indexes of difficulties. On a rigid platform, the displacement of ankle and hip increase with GVS (See Table 1). On the seesaw, with or without GVS, the balance was kept mainly at the ankle joint, which increased with the index of difficulty (seesaw heights) for both directions (PF and DF). The maximal knee and hip displacement were very small and this displacement was not modulated by the index of difficulty. GVS increased the ankle sway and changed the direction of knee displacement, although the magnitude of this displacement was less than 1 degree (Fig 2 and Table 1).

On a rigid platform, the activity of all muscles studied increased with GVS excepted for the ES (Table 1). On the seesaw, we observed a decrease of TA and GM activity when it functioned as the agonist of the movement, or else, TA for dorsal flexion and GM for plantar flexion. Despite the decrease of muscle activity, the pattern of activation was not affected. With or without GVS, the TA muscle was more active during DF and the GM during PF. The ability of modulating the TA and GM responses with the index of difficulty of the seesaw was not affected by GVS but this modulation was less evident during stimulation (Table 1 and Fig 2).

In general, the GVS condition inhibits BF, RF, RA and ES activation during balance on a seesaw, although these values were only statistically significant for ES. The ability of the RA and ES to modulate the activation with the index of difficulty was not affected by GVS.

DISCUSSION

The present data replicate previous studies showing that, on a rigid platform, GVS increases the body oscillation and the muscle activities (Day et al. 1997).

As predicted by our first hypothesize, on a seesaw, the ankle-joint displacement increases due to GVS. Increase in sway responses due to GVS on unstable supports have been reported by Horak & Hlavacka, (2001) and Fitzpatrick et al. (1994). However, contrary to our second hypothesize, the maximal activation of ankle muscles was inhibited with GVS. These unexpected findings are in disaccord with support-surface translation studies that show an increase in ankle EMG response with GVS (Inglis et al. 1995; Horak & Hlavacka, 2001).

Despite the increment in joint displacement associated with decrement in muscle activation, all subjects were able to keep balance without falling, using an alternated pattern between the anterior and posterior muscle activation and balancing mainly at the ankle joint.

With the reduction of available vestibular and visual inputs, can be suggested that the proprioception was enough to assure the equilibrium and balance strategy. Our data do not fully support this view, since GVS associated with the sway on the seesaw provoked additional changes in the muscle activities and in the amount of balance. Thus, it is clear that GVS has a marked influence on the modulation of the motor neuron pool on the seesaw. However, one must consider that the changes in the EMG and kinematic strategy were quantitative and not qualitative. This may explain the fact that, despite these changes, all subjects were able to keep the balance on the seesaw with GVS.

One can explain the quantitative effect of GVS on the seesaw-sway strategy through the Mergner model in which the proprioceptive information is important to stabilize the body motion relative to the support surface in a bottom up manner (Mergner & Rosemeier, 1998). Thus, according to our data, the proprioceptive information from the ankle joint prevails over the vestibular information. Also, based on this model, the vestibular information would help to stabilize the trunk in space in a bottom down way. In this sense, our data also support the observation that individuals with vestibular lesion are able to keep balance on translation platforms, which requires the ankle strategy. (Horak et al. 1990; Popov et al. 1999).

On a seesaw, postural responses (in the absence of visual information) are evoked by interaction of vestibular input with support surface information (Ivanenko et al. 1999). These two sensory systems converge anatomically, physiologically and functionally in the vestibular nuclei, cerebellum, cortex, thalamus, brain stem and spinal cord, allowing opportunities for many types of interactions (Wilson, 1995). The data presented here suggest that postural responses to the concurrent application of different stimuli depend upon the ability of the central nervous system to rapidly assess and re-weigh available sensory inputs. The flexible reweighing of the sensory information from the sensory systems seems essential to the success of postural control.

REFERENCES

Almeida GL, Carvalho RL, Talis VL (2006). Postural strategy to keep balance on the seesaw. *Gait and Posture* 23, 17-21.

Bacsi AM & Colebatcg JC (2004). Evidence for reflex and perceptual vestibular contributions to postural control. *Exp Brain Research* 160(1), 22-8

Creath R, Kiemel T, Horak F & Jeka J (2002). Limited control strategies with the loss of vestibular function. Experimental Brain research 145(3) 323-33

Day BL, Cauquil A, Bartolomei L, Pastor MA & Lyon IN (1997). Human body segment tilts induced by galvanic stimulation: a vestibularly driven balance protection mechanism. *J Physiol* 500, 601-672

Fitzpatrick RC, Burke D & Gandevia SC (1994). Task-dependent reflex responses and movement illusions evoked by galvanic vestibular stimulation in standing humans. *J Physiol* 478, 363-372

Fitzpatrick RC & Day BL (2004) Probing the human vestibular system with galvanic stimulation. J Appl Physiol 96, 2301-2316

Inglis JT, Shupert CL, Hlavacka F & Horak FB (1995) Effect of galvanic vestibular stimulation on human postural responses during support surface translations. *J Neurophysiol* 73, 896-901

Lackner JR & DiZio P (2005) Vestibular, Proprioceptive, and haptic contributions to spatial orientation. *Annu Rev Psychol* 56,115-47

Horak FB & Hlavacka F (2001) Somatosensory loss increases vestibulospinal sensitivity. *J Neurophysiol* 86, 575-585

Horak FB Nashner LM & Diener HC (1990) Postural strategies associated with somatosensory and vestibular loss. *Experimental Brain Research* 82, 167-177

Ivanenko YP, Talis VL & Kazennikov OV (1999) Support stability influences postural responses to muscle vibration in humans. *Eur J. Neurosci* 11, 647-54

Magnusson M, Enbom H, Johansson R & Wiklund J (1990) Significance of pressor input from the human feet in lateral postural control. The effect of hypothermia on galvanically induced body-sway. *Acta Otolaryngol* 110, 321-327.

Mergner T, Huber W & Becker W (1997) Vestibular Neck interaction and transformation of sensory coordinates. *Journal of vestibular research* 7, 347-367.

Mergner T & Rosemeier (1998) T. Interaction of vestibular, somatosensory and visual signals for postural control and motion perception under terrestrial and microgravity conditions: a conceptual model. *Brain Research Reviews* 28, 118-135.

Pavlik A, Inglis JT, Lauk M, Oddsson L & Collins JJ (1999) The effects of stochastic galvanic vestibular stimulation on human postural sway. Exp Brain Res 124, 273-280

Popov KE, Kozhina BN, Smetanin, Shlikov (1999). Postural responses to combined vestibular and hip proprioceptive stimulation in man. *European Journal of Neuroscience* 11, 3307-3311.

Wardman DL, Taylor JL & Fitzpatrick RC (2003) Effects of galvanic vestibular stimulation on human posture and perception while standing. *J.Physiol* 551, 1033-1042

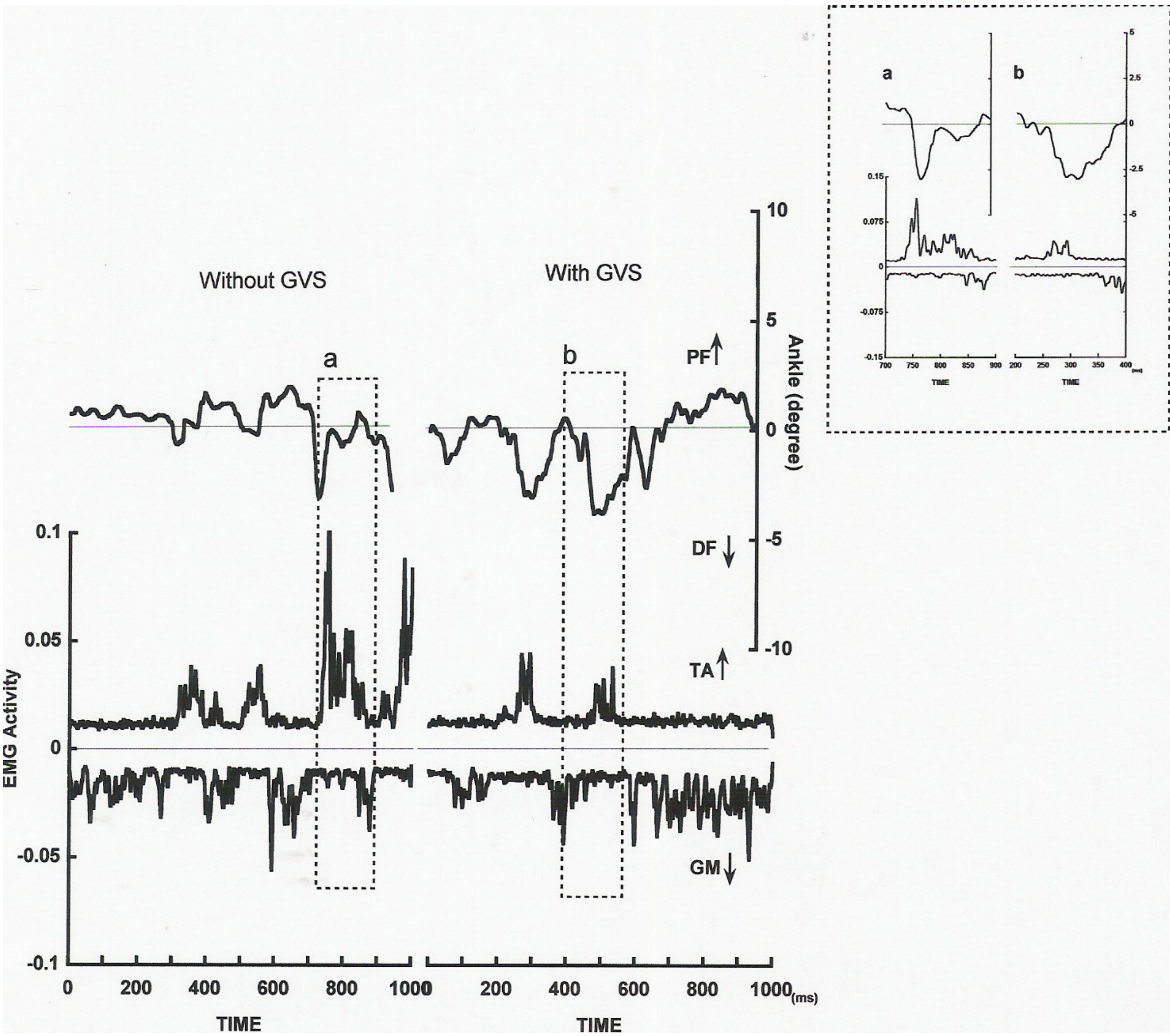
Wilson V, Boyle R, Fukushima K, Rose P, Shinoda Y, Sugiuchi Y & Uchino Y (1995) The vestibulocollic reflex. *J Vest Res* 3, 147-170

CAPTIONS

Figure 1. Muscle activation patterns of the gastrocnemius medialis (GM), tibialis anterior (TA) and ankle-joint displacement during the balance with or without GVS

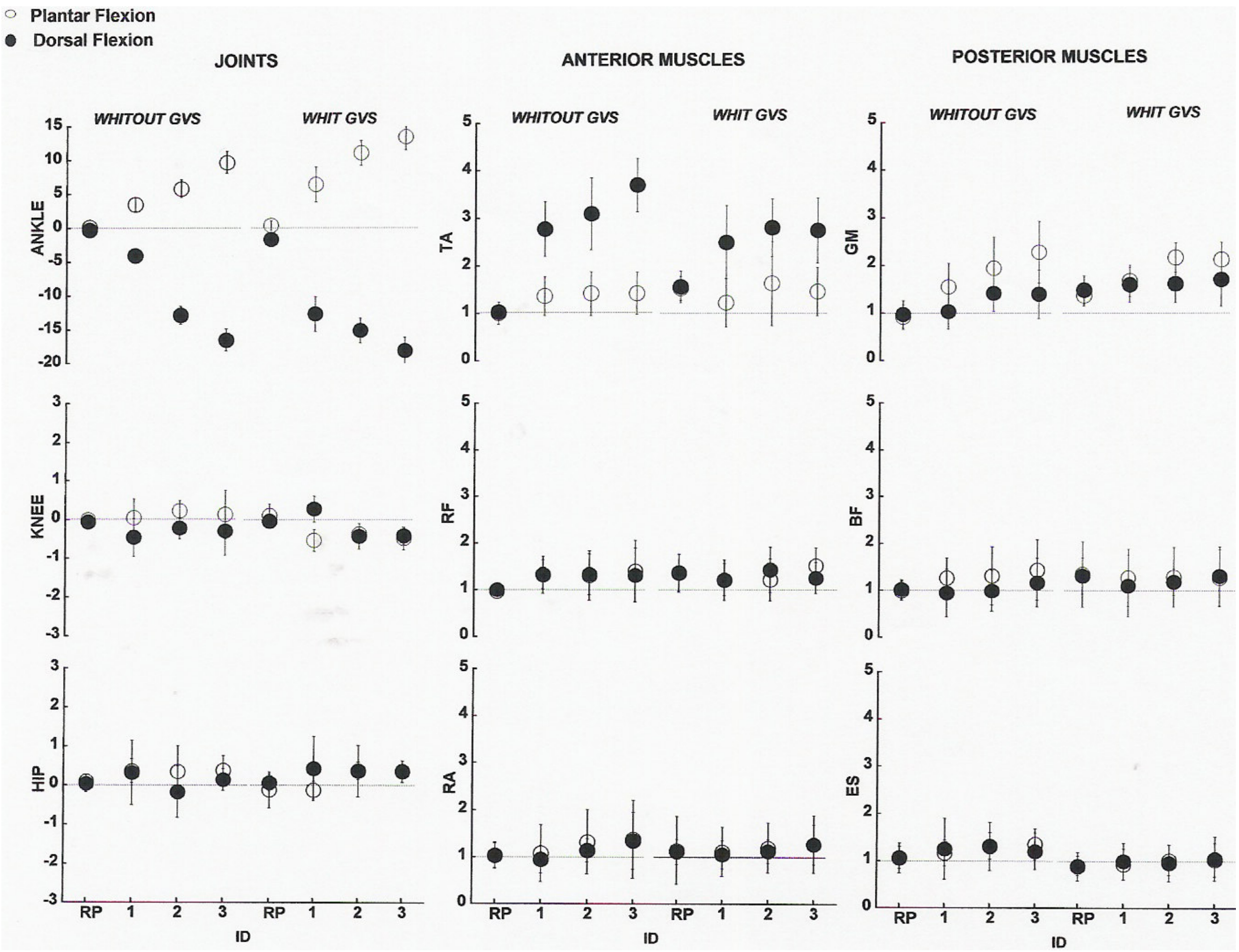
Figure 2. Displacement of the ankle, knee and hip angular excursions and the integrated EMG activities of the tibialis anterior (TA), gastrocnemius medialis (GM) rectus femoris (RF), biceps femoris (BF), rectus abdominis (RA) and erector spinae (ES) during maximum plantar flexion (open circles) and dorsal flexion (closed circles) with and without Galvanic Vestibular Stimulation (GVS). Data represent mean values obtained from eight individuals. The vertical lines represent the standard error.

Table 1. ANOVA results $p<0,05$ for the Kinematics, and Electromyography variables on rigid platform, one way ANOVA (GVS) and on seesaw Two way ANOVA (Index of Difficult and GVS).



Without GVS
With GVS
a
b
PF
DF
TA
GM
Ankle (degree)
EMG Activity
TIME
(ms)

Figure 1



Plantar Flexion
Dorsal Flexion
JOINTS
ANTERIOR MUSCLES
POSTERIOR MUSCLES
WHITOUT GVS
WHIT GVS
ANKLE
KNEE
HIP
TA
RF
RA
GM
BF
ES
RP
1
2
3
ID

Figure 2

Table 1.

	A- Rigid Platform				**B- Seesaw**											
	Plantar Flexion		Dorsal Flexion		Plantar Flexion						Dorsal Flexion					
	GVS		GVS		GVS		ID		GVS/ID		GVS		ID		GVSxID	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Ankle	8.88	+	8.01	+	9.61	+	14.2	+	1.99	-	6.59	+	92.3	+	4.11	-
Knee	1.07	-	0.04	-	12.6	+	1.51	-	0.01	-	1.63	-	2.50	-	0.35	-
Hip	34.2	+	15.5	+	2.96	-	8.18	-	8.49	-	1.16	-	1.14	-	0.94	-
TA	4.27	+	4.20	+	0.00	-	1.77	-	0.38	-	8.16	+	12.8	+	1.58	-
G.M	3.96	+	3.97	+	4.97	+	17.4	+	0.72	-	1.36	-	1.33	-	4.34	-
R.F	2.85	+	5.09	+	0.29	-	5.57	+	0.49	-	0.05	-	1.04	-	1.02	-
B.F	8.90	+	23.4	+	0.17	-	1.19	-	1.66	-	4.01	-	0.27	-	0.29	-
R.A	7.26	+	4.47	+	0.74	-	3.19	-	0.92	-	0.06	-	3.97	+	0.34	-
E.S	2.36	-	0.04	-	6.88	+	3.16	-	0.42	-	0.06	-	0.01	-	0.57	-

+ $p<0,05$
- $p> 0,05$

V. Capítulo 4.

The effect of Galvanic Vestibular Stimulation on postural response of individuals with Down syndrome on seesaw

Carvalho RL, Almeida GL.

ABSTRACT

The purpose of this study was to investigate the partially block of vestibular information on postural responses during balance on seesaw. *Methods:* Eight individuals with Down syndrome (DS) and eight controls (CG) stood on seesaws of different heights during two sensory conditions: with or without Galvanic Vestibular stimulation (GVS). The movement of hip, knee and ankle and the EMG activities of selected ankle, knee, and hip muscles were recorded. *Results*: Without GVS the balance was kept mainly at the ankle joint for both groups. The CG adopted an alternated pattern of ankle muscles activation during balance and was able to modulate the magnitude of postural response with the seesaw height. The individuals with DS showed the co-contraction muscle pattern during balance and were not able to modulate the postural response with the seesaw height. The GVS neither affected the ability of CG maintain balance neither the pattern of muscle contraction although the muscle activation has been partially inhibited. On the other hand, individuals with DS lacked the ability to keep balance during GVS. *Discussion and Conclusion*: The individuals with DS were not able to successfully balance whit the detriment of vestibular and visual information. We suggest that due to impairment of proprioception system the individuals with DS increase the vestibular weight during balance control on unstable conditions

Key words: Down syndrome, galvanic vestibular stimulation, seesaw.

INTRODUCTION

It has been described in the literature several atypical behaviors in the postural control of individuals with Down syndrome (DS) (Virji- Babul & Brown 2004; Ulrich et al. 2004). They are unable to respond rapidly to changes in the environment (Haley 1986), typically they take more time to initiate and complete a motor task (Anson 1992; Shumway-Cook & Woollacott 1985). The simultaneously activation of agonist and antagonist (co-activation) has been reported during the performance of several motor tasks, including pointing movements (Latash 2003) in anticipation of a perturbation (Aruin & Almeida 1997) and in quiet standing (Weber et al. 2004). They also showed this pattern of co-activation during balance on seesaw (Carvalho 2001).

Contrary to the individuals with DS, the control individuals kept balance on seesaw mainly at the ankle joint using an alternated pattern of ankle muscles contraction (Almeida et al 2006). The goal of this study was to asses the rule of vestibular information to keep balance on the seesaw.

The contribution of vestibular information has been studied using vestibular galvanic stimulation (GVS) in several motor tasks (Fitzpatrick & Brian 2004; Day et al 2002). The GVS serves to modulate the continuous firing level of the vestibular afferents (Scinicariello et al. 2001) and causes a standing subject to lean in different directions depending on the polarity of the current (Pavlik et al. 1999). Also when standing on compliant surfaces, such as a piece of foam rubber (Horak & Hlavacka, 2001) or on translation surfaces (Fitzpatrick et al. 1994) the sway response due to GVS was increased.

Individuals with vestibular lesion were able to keep balance on translation platforms, which requires the ankle strategy. (Horak et al. 1990; Popov et al. 1999).On the other hand individuals with periferical neuropathies (lack of proprioception) lost thecapability to use the ankle strategy moving more the hip than the ankle to active the correction of postural response (Bloem et al.1998).

Based on the studies reported above our first hypothesis is that control individuals will increase the EMG activity and sway amplitude with GVS.

We did not find any study exploring the effect of GVS in individuals with DS on unstable platform including seesaw. We expected see a large sway increase in individuals with DS as compared as control individuals. One explanation for this idea is the possible organic deficits in proprioceptive system of individuals with DS. For example deficits in proprioceptive level has been reported by Cole et al. (1988) showing that they failed on modulate the grip force with object surface. Also Brandt et al. (1995) showed reduction in the amplitude of the action potencial of sensory nerve. Thus, when the CNS of these individuals relied only in reliable proprioception input to over come the partially block of vestibular and visual information's its possible that fail and lost the ability of balance.

To test this hypothesis GVS was used as a means to manipulate vestibular spatial reference frame and the blindfolding to prevent visual feedback during balance on different seesaws.

METHODS

Eight individuals with DS (4 male, 4 female, average age 28.1years) and eight age and sex-matched control subjects (CG) (average age 27.5) were studied after they or their parents had signed an institutional (UNICAMP) term of informed consent. Six balancing conditions were collected combining 3 seesaw heights (7,12 and 17cm) to provide an index of difficulty (figure 1), and two GVS conditions (with or without stimulation).

Insert here figure 1

Kinematic data

The X, Y and Z coordinates Light Emitting Diodes (LED) marks were recorded using a 3D-motion- analysis system (OPTOTRAK 3020). The LED marks were attached on the left side of the shoulder (lateral aspect of the humerus), hip (between the greater trochanter and superior iliac crest), knee (lateral condyle), ankle (external malleolus), foot (head of the 5th metatarsal), and on the seesaw. The (LED) coordinates were recorded at 100 Hz and used to calculate the ankle, knee, and hip angular displacements.

EMG activities

The activities of the gastrocnemius medialis (GM), tibialis anterior (TA), biceps femoris (BF), rectus femoris (RF), erector spinae (ES) at the L4 level, and the rectus abdominis (RA) were recorded using bipolar surface EMG electrodes (DeLSys). All data were band pass filtered (45-450 Hz), amplified (x 2000) and digitized at 1000 Hz. The EMG signals were rectified and smoothed using a second order Butterworth filter with 10 Hz. cutoff frequencies.

Procedure

The researcher helped the individuals to stand on seesaw keeping the feet at the center, and the seesaw was kept parallel to the floor. From this position, the individual could start balancing with or without GVS. Initially, the individual was blindfolded with a mask, the face rotate to right and the seesaw was kept parallel to the floor. The GVS of 1.5mA was randomicaly applied via 2.5cm carbon- rubber electrodes placed behind the subject's ears over the mastoid processes. The anodo was placed on right ear. The balance began after 2s of stimulation and lasted for 10s. During the balance, the individual held each shoulder with the opposite hand, keeping the upper limbs crossed and in contact with the chest

Two trials of 10 seconds each were recorded for each seesaw with and without GVS, proceeding from the lower to the higher. This sequence was used to guarantee the safety of the subject who might fall off the higher seesaw. After two trials of balancing without getting off, the individual was evaluated on the subsequent seesaw.

Data quantification

The Matlab program was used to calculate the maximum plantar and dorsal ankle flexion and the corresponding angular displacement of the hip and knee joints during this time. The activities of the six muscles cited above were integrated during 50 milliseconds, just before and 50 milliseconds after the maximum dorsal and plantar flexion time. The EMG values were normalized to the values obtained during stationary standing condition.

To analyze the pattern of muscle contraction the index of co-contraction (ICC) was calculate. This index was defined by the integrate (+-50ms) muscle activity at the maximum plantar flexion divided by the same muscle activity at the maximal dorsal flexion.

Statistical analysis

We run a two ways analyses of variance ANOVA ($p<0,05$) to test the effect of stimulation (with or without GVS) and seesaws difficulty index (7, 12 and 17cm height) on each variable analyzed. These variables were the displacement of hip, knee, ankle and the EMG activity of the GM, TA, BF, RF, ES and RA at the time that the individuals were maximally displaced in anterior and posterior direction. The effect of stimulation and index of difficulty was evaluated separately for the groups. For individuals with DS the effect of GVS was tested just for seesaw of height 7cm once a considerable number of subjects lacked the equilibrium in another heights.

We also run the two ways analyses of variance ANOVA ($p<0,05$) to test the effect of group (CG x DS) and index of difficulty (Height) for the index of co-contraction.

RESULTS

All CG subjects were able to keep balance in all experiment conditions with or without GVS (Figure 2). On the other hand, the balance capacities varied among subjects with DS. Without GVS just two subjects showed difficulties in balance on the most unstable seesaw, but with GVS three individuals lost the equilibrium in medium and six on most unstable seesaw.

Insert here figure 2

Figure 3 illustrates the CG individual using an alternated pattern of TA and GM muscles activation during balance on seesaw. This pattern of muscle activation was not affected by the GVS. On the other hand, the individual with DS kept balance by continuously and simultaneously co-activation of TA and GM muscles. They were not able to modulate the pattern of muscle contraction with the direction of movement (dorsal x plantar flexion). When the balance was possible with GVS the pattern of co-activation was not affected. The data of two individuals are representative in terms of muscle activity pattern and joint displacement.

Insert here figure 3

When the CG individuals were under the effect of the GVS the ankle movement increased in both directions (plantar x dorsal flexion) (see GVS effect on ANOVA Table I). However the amount of TA muscle activity decreased during dorsal flexion and the GM during plantar flexion, in other words, the amount of EMG activity when the muscle acted as agonist decreased with GVS (See ANOVA effect on Table I). Also, the amount of these movements and the muscle activities were modulate with the seesaw index of difficulty (Table I). Knee and hip movements and activity amount of RF, BF, RA and ES were neither affected by the GVS nor by the index of difficulty (see results of ANOVA Table I).

Contrary what was observed for the CG the GVS neither affected the amount of ankle excursion nor the amount of TA and GM muscles activity of individuals with DS (see GVS effect on Table II). Note that for the DS group we did not test the index of difficulty effect for one simple reason, at the middle and at the height seesaw several subjects failed to keep balance (Figure 2).

The muscle activity amount during plantar flexion was divided by their respective amount during dorsal flexion (see methods). This ratio was called index of co-contraction and was calculated for each muscle. The control individuals used, on average, half of the amount of TA muscle activities into plantar flexion, as compared with dorsal flexion. The opposite was observed for the GM. Note that during plantar flexion, these individuals used on average one and half times more GM muscles activities as compared as dorsal flexion (Figure 4).

The individuals with DS were not able to modulate the muscle contraction with the direction of movement. They activated the ankle muscles (GM and TA) independently of movement direction. This fact was reflected by an index of co-contraction near to 1. Than, the main difference between groups for index of co-contraction was in the ability to modulate the contraction of TA (F 62.9 p=0.00), GM (F 13.8 p=0.002) and BF (F 5.13 p=0.04) muscles with the movement direction. The GVS did not affect the index of co-contraction for the muscles studies except by a decrease on GM that was not significant. Also the application of GVS during balance on seesaw neither affected the alternated pattern of CG contraction nor the co-contraction pattern chose by DS individuals.

DISCUSSION

The aim of this work was describe the maintenance of the postural equilibrium when only the proprioceptive information was fully available during balance on seesaw.

Our first observation was that the CG were able to keep balance in all seesaw conditions despite the lack of fully vestibular and visual information. We can partially explain this finding based on Mergner model in which the proprioceptive information is important to stabilize the body motion relative to the support surface in a bottom up manner (Mergner & Rosemeier, 1998). Thus, according to our data, the proprioceptive information, that was fully available, was enough to overcome the accuracy reduction of the visual and vestibular information. Also in favor to this idea is the biomechanical model showing that on seesaw the balance occur mainly at ankle joint (Ivanenko et al. 1997, Almeida et al. 2006).

The effects of GVS were the reduction on the agonist muscles activity (Table 1) and increase on the ankle movement. One would expect observe a decrease in ankle movement seems that the amount of agonist muscle activity were decreased. One possible explanation for this finding is that on the seesaw the agonist activity has as primer function prevents the disturbance (Almeida et al 2006). Finally it must point out that the proprioceptive information alone or at least with part of the vestibular information blocked was enough to allow the CNS to scale the muscle response with the seesaw mechanical instability degree. This success of postural control can be attributed to ability of CNS re-weight the sensory information to over came the decrement of one system.

The more important findings were observed during balance of individuals with DS. When the vestibular information was reliable they were able to keep balance (except two subjects on the most unstable seesaw). This balance was possible due to a pattern of muscles co-contraction and the level of joint displacements and muscles activation were the same for seesaws with different indexes of difficulty. It seems that these individuals can not discriminate the seesaw heights. The pattern of muscle co-activation has been reported during several other tasks, including preprogrammed reactions (Latash 1992) and in anticipation of a perturbation (Aruin & Almeida 1997). Latash (2000) has proposed that co-contraction may be a general feature of movements in individuals with DS and may be used during unexpected perturbations to optimize safety and stability.

Under the effect of GVS the balance performance deteriorated for the two more unstable seesaws. (Figure 2). The balance lack under the GVS effect cannot be explained by a change in the muscle strategy once the pattern of co-activation was not changed by GVS. The pattern of co-contraction is a more generalized strategy that increases the safety of the response by increasing the joint stiffness. However the joint stiffness increase of the was not enough to guarantee the success of the balance on seesaw.

No GVS effect was observed for the index of co-contraction. Thus, one can say that for individuals with DS the GVS has one unspecific effect on the muscles despite the mode of activation.

Several studies indicate that individuals with DS may have problems with proprioceptive information. At central level the cerebellum has been assumed to play a central role in the coordination of afferent and efferent information to assure an optimal coupling between the movements (Horak et al 1990). It was implicate in the modification of several different motor behaviors (Bracha, 1995) and postural adjustment to platform perturbation (Horak & Diener 1994). The cerebellum weight has been reported to be lower in persons with DS compared with general population (Bellugi et al 1990). Because of that one could associate the co-activation and the inability to balance with reduced vestibular and visual input to a decrease of cerebellum function.

At peripherical level one could speculate that a proprioceptive deficit would impair their ability to balance and to discriminate the different mechanical demand of seesaw. Cole et al (1988) showed that individuals with DS failed to modulate the grip force when they were asked to lift one object with different surfaces. Brandt (1995) show low sensory nerve action potential amplitudes following stimuli of the thumbs suggesting impaired peripherical somatosensory functions. On the other hand they have a normal level of neuron pool excitability and intact stretch reflex (Shumway-Cook & Woollacott 1985).

It´s important to point out that first the individuals with DS lacked the balance ability with the detriment of vestibular information reliance. Second, contrary to control individuals they were not able to compensate the detriment of vestibular and visual information with proprioceptive system. The findings reported above indicate a possible proprioception dysfunction in individuals with DS. Taking together all those findings we can suggest that due to impairment of proprioceptive system the individuals with DS increase the weight of vestibular information to control balance on unstable conditions.

REFERENCES

Almeida GL, Carvalho RL, Talis VL. Postural strategy to keep balance on the seesaw. *Gait and Posture* 2006. 23: 17-21.

Almeida GL, Tortoza C, Ferreira SMS, Marconi NF, Corcos, DM, & Gottlieb,LG. Motor control in individuals with Down Syndrome: comparison with normals. In: Weeks DJ, Chua R, & Elliot D. Perceptual-motor behavior in Down syndrome. Human Kinetics, 2000; 151-174

Aruin AS, Almeida GL. A. coactivation strategy in anticipatory postural adjustments in person with Down Syndrome. *Motor Control* 1997; 1: 178-191.

Bellugi U, Bihrle A, Jernigan T, Trauner D, & Doherty S. Neuropsychological, neurological, and neuroanatomical profile of Williams syndrome. *American Journal of Medical Genetics*, 1990; 6: 115-125.

Bloem BR, Allum JHJ, Carpenter MG, Honegger F. Propriocepsis in the lower legs: Is it essential for triggering human balance corretions. *Exp Brain Res* 1998.

Bracha V, Bloedel JR, Shimansky Y, Milak MS. The role of the cerebellum in the acquisition of complex volitional forelimb movements. Cambridge London, 1996; pp 319-342.

Brandt BR, Rosen I. Impaired Peripheral Somatosensory Function in children with Down syndrome. *Neuropediatrics* 1995; 26: 310-312.

Carvalho RL.Ajustes Posturais em indivíduos neurologicamente normais e em portadores da síndrome de Down na gangorra: efeito do treino.Dissertação de mestrado-Universidade Estadual de Campinas 2001.

Cole KJ, Abbs JH, & Turner GS. Deficits in the production of grip force in Down syndrome. *Developmental Medicine and Child Neurology*, 1988; 30:752-758.

Day BL, Guerraz M, Cole J. Sensory interactions for human balance control revealed by galvanic vestibular stimulation. *Adv Exp Med Biol* 2002,508:129-137

Fitzpatrick RC & Day BL. Probing the human vestibular system with galvanic stimulation. *J Appl Physiol* 2004, 96: 2301-2316

Haley SM. Postural reactions in infants with Down syndrome: Relationship to motor milestone development and age. *Physical Therapy* 1986; 66:17-22.

Horak FB, Diener HC. Cerebellar control of postural scaling and central set in stance. *J Neurophysiol*, 1994; 72: 479-493

Horak FB, Hlavacka F. Somatosensory loss increases vestibulospinal sensitivity. *J Neurophysiol* 2001, 86, 575-585

Horak FB Nashner LM & Diener HC. Postural strategies associated with somatosensory and vestibular loss. *Experimental Brain Research* 1990 82, 167-177

Ivanenko YP, Levik S, Talis VL, & Gurfinkel VS. Human equilibrium on unstable support: the importance of feet-support interaction. *Neuroscience Letters*, 1997; 235: 109-112, 1997.

Latash ML. Motor Control in Down Syndrome: The role of adaptation and practice. *J. of Developmental and Phys. Disab* 1992; 3: 227-261.

Latash ML, Anson JG. What are normal movements in atypical populations? *Behavioral and Brain Sciences*. 1996; 19:55-68.

Latash ML. Motor coordination in Down syndrome: The role of adaptive changes In: Weeks DJ, Chua R, & Elliot D. Perceptual-motor behavior in Down syndrome. *Human Kinetics*, 2000; p. 151-174

Mergner T & Rosemeier T. Interaction of vestibular, somatosensory and visual signals for postural control and motion perception under terrestrial and microgravity conditions: a conceptual model. *Brain Research Reviews.* 1998 28, 118-135.

Pavlik A, Inglis Inglis JT, Lauk M, Oddsson L, Collins JJ. The effects os stochastic galvanic vestibular stimulation on human postural sway. *Exp Brain Res*1999, 124:271-280.

Popov KE, Kozhina BN, Smetanin, Shlikov. Postural responses to combined vestibular and hip proprioceptive stimulation in man. *European Journal of Neuroscience* 1999, 11, 3307-3311.

Shumway-Cook A, Woollacott MJ. Dynamics of postural control in the child with Down syndrome. *Physical Therapy* 1985; 65(9): 1315-1322.

Ulrich BD, Haehl V, Buzzi UH, Kubo M, Holt KG. Modeling dynamic resource utilization in populations with unique constrains: preadolescents with and without Down syndrome. *Hum. Mov Sci* 2004 23(2) 133-56

Virji- Babul N,V. Brown M. Stepping over obstacles: antecipatory modifications in children with and without Down syndrome. *Exp Brain Research* 2004.

Webber A, Babul V, Edwards R, Stiffness and postural stability in adults with Don syndrome. *Exp Brain research* 2004; 155:450-458.

CAPTIONS

Figure 1. Representative experimental setup. 1 fixed force platform, 2 seesaw, 3 height, 4 LED marks.

Figure 2. Number of individuals with (square) or without (circle) Down syndrome able to keep balance on seesaw of different heights (7, 12, 17cm) with (open symbol) or without (closed symbol) GVS.

Figure 3. Balance of one control (left) and one individual with Down syndrome on seesaw of height 12cm. Upper panel shows the ankle displacement and down panel shows the activities of the gastrocnemius medialis (GM) negative and tibialis anterior (TA) positive values with or without GVS.

Figure 4. Illustrate the index of co-contraction- ICC (activity amount during plantar flexion divided by their respective amount during dorsal flexion) of TA, GM, RF, BF, RA, ES muscles of individuals with (rhombus) or without (circle) Dow syndrome during balance on seesaws of 7,12, 15cm heights (S1,S2,S3) with or without GVS

Table I. Two ways ANOVA (GVS and ID) for the Kinematics and Electromyography variables of control individuals during maximal plantar flexion

Table II. One way ANOVA (GVS) for the Kinematics and Electromyography variables of individuals with Down syndrome during maximal plantar and dorsal flexion**.**

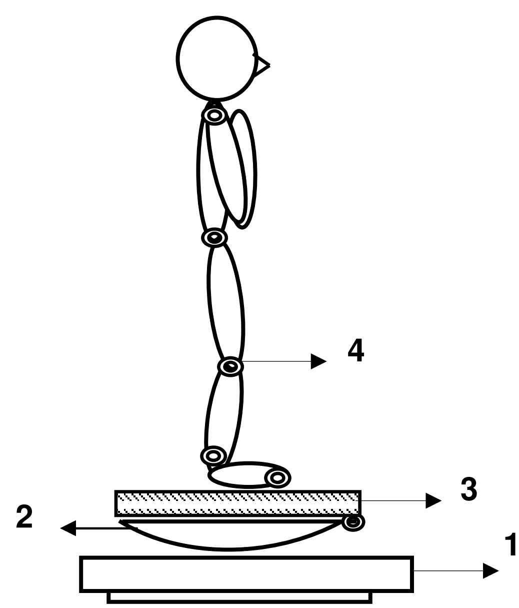


Figure 1

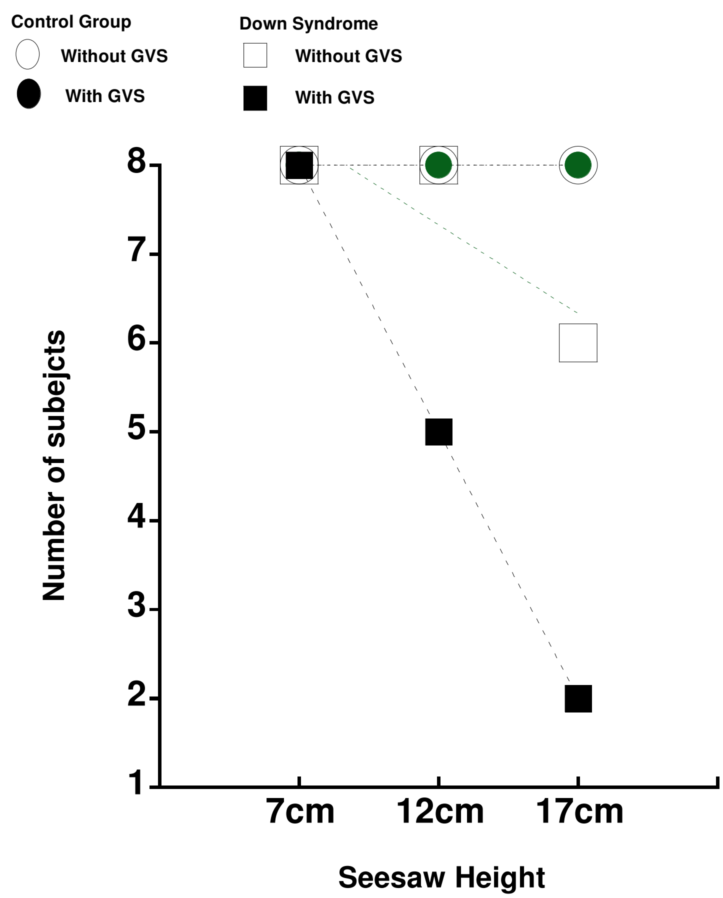
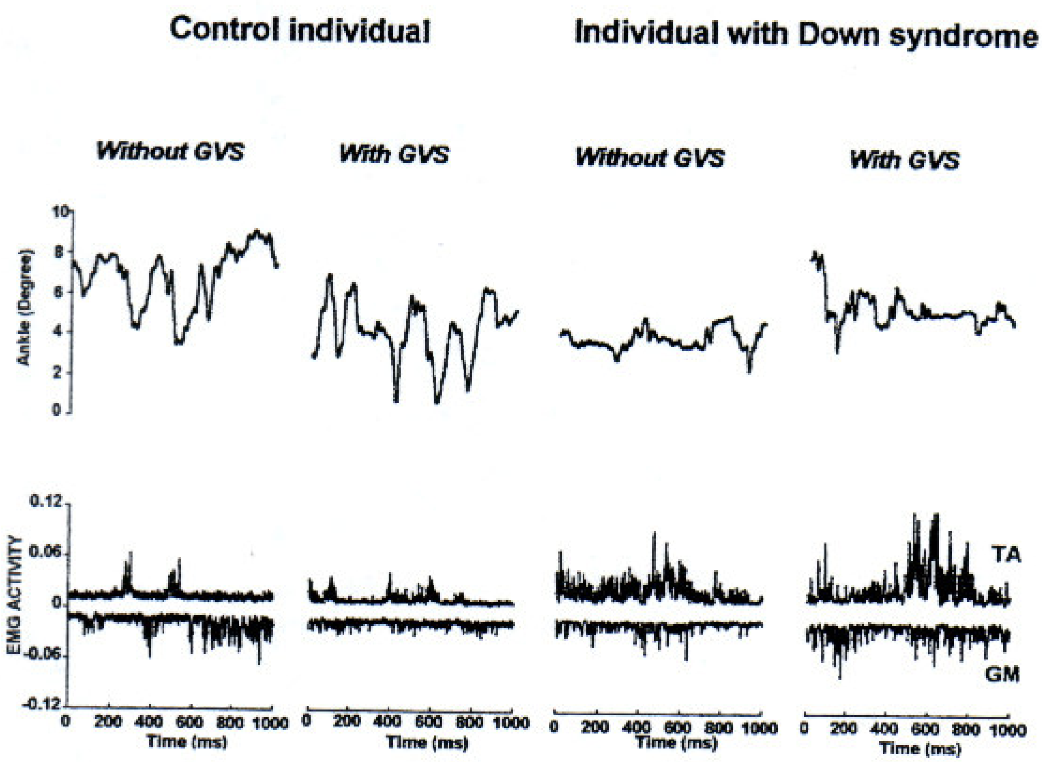

Control Group
Without GVS
With GVS
Down Syndrome
Without GVS
With GVS
8
7
6
5
4
3
2
1
Number of subejcts
7cm
12cm
17cm
Seesaw Height

Figure 2



Control individual
Individual with Down syndrome
Without GVS
With GVS
Without GVS
With GVS
Ankle (Degree)
EMG ACTIVITY
TA
GM
Time (ms)

Figure 3

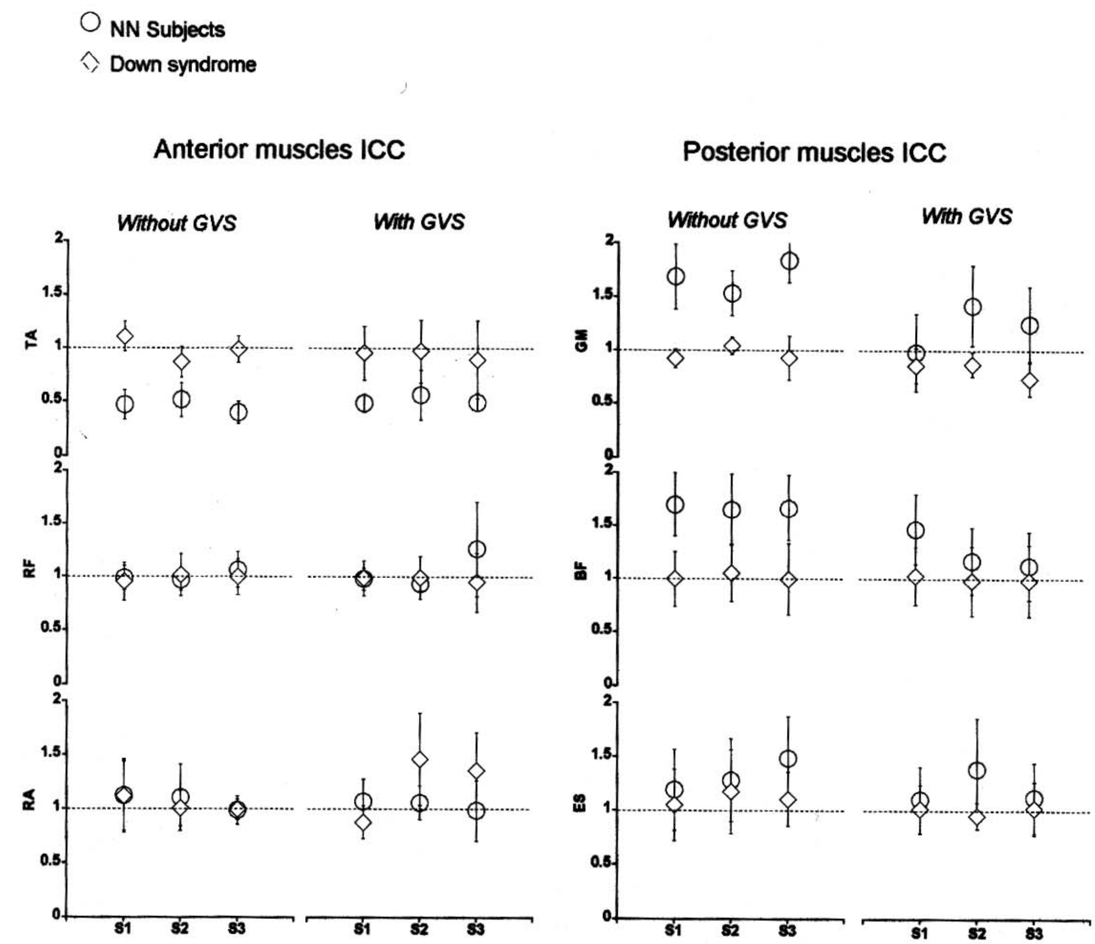

NN Subjects
Down syndrome
Anterior muscles ICC
Posterior muscles ICC
Without GVS
With GVS
Without GVS
With GVS
TA
RF
RA
GM
BF
ES
2
1.5
1
0.5
0
S1
S2
S3

Figure 4

Table I.

	Control Group											
	Plantar flexion						**Dorsal Flexion**					
	GVS		ID		GVSX ID		GVS		ID		GVSXID	
	F	p	F	p	F	p	F	p	F	p	F	p
Ankle	9.61	0.02	14.2	0.00	1.99	0.18	6.59	0.04	92.3	0.00	4.11	0.07
Knee	12.6	0.00	1.51	0.25	0.01	0.98	1.63	0.24	2.50	0.11	0.35	0.06
Hip	2.96	0.12	8.18	0.40	8.49	0.98	1.16	0.31	1.14	0.34	0.94	0.41
TA	0.00	0.95	1.77	0.21	0.38	0.69	8.16	0.02	12.8	0.00	1.58	0.23
GM	4.97	0.06	17.4	0.00	0.72	0.50	1.36	0.28	1.33	0.29	4.34	0.06
R.F	0.29	0.60	5.57	0.01	0.49	0.61	0.05	0.82	1.04	0.37	1.02	0.38
B.F	0.17	0.69	1.19	0.17	1.66	0.22	4.01	0.09	0.27	0.76	0.29	0.75
R.A	0.74	0.42	3.19	0.08	0.92	0.42	0.06	0.80	3.97	0.05	0.34	0.71
E.S	6.88	0.07	3.16	0.08	0.42	0.66	0.06	0.81	0.01	0.98	0.57	0.57

Table II.

	Down syndrome Group			
	Plantar Flexion		Dorsal Flexion	
	F	p	F	p
Ankle	0.78	0.40	0.46	0.68
Knee	3.67	0.30	2.63	0.27
Hip	41.3	0.09	3.93	0.20
TA	0.64	0.44	1.40	0.31
GM	0.78	0.40	1.48	0.29
R.F	0.004	0.94	0.82	0.48
B.F	0.078	0.78	2.68	0.14
R.A	4.80	0,07	0.47	0.64
E.S	0.15	0.70	0.65	0.55

VI. Capítulo 5.

The effect of ankle tendon vibration on seesaw balance in individuals with and without Down syndrome

Carvalho RL, Almeida GL

ABSTRACT

The purpose of this study was to investigate the tendon vibration effect on postural responses during balance on seesaw. *Methods:* Eight individuals with Down syndrome (DS) and eight controls (CG) stood on seesaws of different heights during two sensory conditions: with or without Achilles tendon vibration. The movement of hip, knee and ankle and the EMG activities of selected ankle, knee, and hip muscles were recorded. *Results and Discussion*: Without vibration control subjects adopted an alternated pattern of ankle muscles activation during balance and were able to modulate the magnitude of postural response with the seesaw height. The individuals with DS used the lees efficient strategy to keep balance on the seesaw and this strategy were not affected by vibration. On the other hand CG change their muscle strategy with vibration adopting a similar behavior observed for individuals with DS. Taking together all findings we are possible learning that the proprioceptive information is essential for the motor control system to release the appropriate motor strategy based on the reciprocal activation among the agonist and the antagonist and that the individuals with SD probably have deficits in this system. .

Key words: Down syndrome, vibration, seesaw, proprioception.

INTRODUCTION

One of the most widely used experimental approaches to understand the sensory contribution to postural control is the manipulation of sensory information during postural disturbance. The vibration of muscle tendons has become a frequent tool for studying the relative role of muscle proprioception in human posture control (Wierzbicka et al. 1998). The magnitude of the response due to vibration has been found to diminish when it is applied during balance on unstable rocking surface (Ivanenko et al. 1999), translation surface (Hatzitaki et al. 2005) or even during normal walking (Courtine et al. 2001). These authors suggest that when vibration is applied in combination with unstable support surface the CNS reduces reliance on proprioceptive information

On unstable rocking surface such seesaw, a typical strategy characterized by maintenance of balance mainly at ankle joint with an alternated activation of the tibialis anterior and gastrocnemius medialis muscles has been described (Almeida et al 2006).

Based on studies of Ivanenko et al. (1999) and Wierzbicka et al. (1998) we hypothesizes that the Achilles tendon vibration on seesaw would not be detrimental to the level of provoking a fail in control group. We would expect to see a decrease in postural response but not the lost in the ability of modulate the muscle response with the seesaw height. This hypothesis are based on the idea that under this perceptual condition the postural control system rely on other sensorial information such as vestibular to keep the balance.

The second hypothesis is relates with the effect of the proprioception detriment in postural responses used by individuals with DS. These individuals are often described as clumsy. Researchers have reported atypical movement sequence (Pitetti et al 2004), longer reaction time (Anson 1992) and increased motor feasibility (Spano et. al 1999). They are unable to respond rapidly to changes in the environment (Haley 1986). During self-inflicted disturbance they reacting using the generalized pattern of co-activation (Aruin & Almeida 1997). On the seesaw these individuals user a pattern of muscle co-activation instead of using the reciprocal pattern showed by individuals with DS. (Almeida et al 2006)

One possible explanation for the co-activation pattern is one deficit on the proprioceptive level. In favor to this idea is the study of Cole et al (1988) showing the fail on modulation of grip force with object surface. Also Brandt et al (1995) showed low sensory nerve action potential amplitudes following stimuli of the thumbs. Other possible explanation is a delay in central processing (Shumway-Cook & Woollacott 1985). This idea is based on the observation that they have a normal level of neuron pool excitability and intact stretch reflex (Shumway-Cook & Woollacott 1985) as well cerebellar dysfunctions (Bellugi et al.1990).

Based on those studies we hypothesize that the reduction of the proprioception due to the vibration would not change the co activation pattern used by individuals with DS that possibly have a organic deficit in proprioceptive system (Cole et al .1988).

We tested our hypotheses by asking to individuals with and with Down syndrome balance on different seesaws with or without vibration.

METHODS

Eight individuals with DS (4 male, 4 female, average age 28.1years) and eight age and sex-matched control subjects (CG) (average age 27.5) were studied after they or their parents had signed an institutional (UNICAMP) term of informed consent. Six balancing conditions were collected combining 3 seesaw heights (7,12 and 17cm) to provide an index of difficulty, and two vibration conditions (with and without stimulation).

Kinematic data

The X, Y and Z coordinates Light Emitting Diodes (LED) marks were recorded using a 3D-motion- analysis system (OPTOTRAK 3020). The LED marks were attached on the left side of the shoulder (lateral aspect of the humerus), hip (between the greater trochanter and superior iliac crest), knee (lateral condyle), ankle (external malleolus), foot (head of the 5th metatarsal), and on the seesaw. The (LED) coordinates were recorded at 100 Hz and used to calculate the ankle, knee, and hip angular displacements.

EMG activities

The activities of the gastrocnemius medialis (GM), tibialis anterior (TA), biceps femoris (BF), rectus femoris (RF), erector spinae (ES) at the L4 level, and the rectus abdominis (RA) were recorded using bipolar surface EMG electrodes (DeLSys). All data were band pass filtered (45-450 Hz), amplified (x 2000) and digitized at 1000 Hz. The EMG signals were rectified and smoothed using a second order Butterworth filter with 10 Hz. cutoff frequencies.

Procedure

The researcher helped the individuals to stand on seesaw keeping the feet at the center, and the seesaw was kept parallel to the floor. From this position, the individual could start balancing with or without vibration. In some trials continuous tendon vibration was applied transversally to the Achilles tendons at the ankle levels. A moderate vibration (40Hz) was produced by two identical cylindrical vibrators attached to the Achilles tendons by means of a rubber band. The rubber band ensure good fixation of the vibrator on the tendon during the seesaw balance. The balance began after 2s of stimulation and lasted for 10s. During the balance, the individual held each shoulder with the opposite hand, keeping the upper limbs crossed and in contact with the chest. Two researchers stood all time close individuals to hold him/her in case of complete loss of equilibrium and to avoid any accident during the experiment.

Two trials of 10 seconds each were recorded for rigid surface and seesaw with and without vibration, proceeding from the lower to the higher. This sequence was used to guarantee the safety of the subject who might fall off the higher seesaw. After two trials of balancing without getting off, the individual was evaluated on the subsequent seesaw.

Data quantification

The Matlab program was used to calculate the maximum plantar and dorsal ankle flexion and the corresponding angular displacement of the hip and knee joints during this time. The activities of the six muscles cited above were integrated during 50 milliseconds, just before and 50 milliseconds after the maximum dorsal and plantar flexion time. The EMG values were normalized to the values obtained during stationary standing condition.

To analyze the pattern of muscle contraction the index of co-contraction (ICC) was calculate. This index was defined by the integrate (+-50ms) muscle activity at the maximum plantar flexion divided by the same muscle activity at the maximal dorsal flexion.

Statistical analysis

We run a two ways analyses of variance ANOVA ($p<0,05$) to test the effect of stimulation (with or without vibration) and seesaws difficulty index (height) for each variable analyzed. These variables were the displacement of hip, knee, ankle and the EMG activity of the GM, TA, BF, RF, ES and RA at the time that the individuals were maximally displaced in anterior and posterior direction. The effect of stimulation and index of difficulty was evaluated separately for the groups.

We also run the two ways analyses of variance ANOVA ($p<0,05$) to test the effect of group (CG x DS) and index of difficulty (Height) for the index of co-contraction.

RESULTS

Figure 1 shows that the control subject kept balance by alternating the activation of the TA and the GM muscles. The detriment of this pattern of muscle activities was observed with vibration of the Achilles tendon. The vibration leaded to a reduction in the amount of GM and TA activities. On the other hand, the individual with Down syndrome co-activated both the GM and TA during balance on the seesaw, instead of using the alternated EMG pattern. Also the vibration neither affected the amount of GM and TA activities, nor the movement at the ankle joint of the individuals with DS. The data of these two subjects are representative of their respective groups.

Insert here figure 1

The effect of availability of proprioceptive information to the CNS (with or without vibration) and the seesaw index of difficulty (ICC) were tested for each dependent variables studied, for each group and movement direction separately, using two-way ANOVA. During plantar-flexion, the control individuals increased the amount of ankle excursion with the increment of seesaw instability. (Fig. 2 and index of difficulty effect on Table I) and the vibration decreased this movement (See vibration effect Table I). Even thought the individuals with DS balance mainly at ankle joint they were not able to modulate the amount of ankle angular excursion with the ICC, and those movements were not affected by vibration (Fig. 2 Table I).

Insert here figure 2 and Table I

Figure 2 also shows that the amplitude of sway at the ankle joint was larger for control as compared with DS. We did not quantify the sway frequency but a visual analyze revealed that the DS individuals sway more frequently than control.

The ANOVA analyses revealed that the minimal angular displacement at the knee and hip joints (Figure 2) were did not affected by ICC and by vibration. These observations extend for both groups (TableI).

During sway into plantar flexion the CG modulated the amount of GM activity with ICC and this activity decreased with vibration. The activities of RF, ES and RA muscles were neither affected by ICC nor by vibration. The only exception was a decrease of BF muscle activity (Fig. 2 Table I).

Contrary that was observed by CG the ICC and vibration did not affect the EMG activity of any reported muscle of individuals with DS.

We are not showing the kinematics and EMG strategy when the ankle moved into dorsal flexion. However as showed in Table II the same strategy reported during plantar flexion was also observed during dorsal flexion. The only peculiarity was that during dorsal flexion the agonist muscle was TA and vibration and ICC affected its activity for CG.

Insert here Table II and III

The muscle activity amount during plantar flexion was divided by their respective amount during dorsal flexion (see methods). This ratio was called index of co-contraction and was calculated for each muscle. The control individuals used, on average, half of the amount of TA muscle activities into plantar flexion, as compared with dorsal flexion. The opposite was observed for the GM. Note that during plantar flexion, these individuals used on average one and half times more GM muscles activities as compared as dorsal flexion (Figure 3). On the other hand the individuals with DS were not able to modulate the muscle (GM and TA) contraction with the movement direction. This fact was reflected by an index of co-contraction near to 1. Than, the main difference between groups for index of co-contraction was in the ability to modulate the contraction of TA and GM (see group effect on Table III)

With vibration the CG switched from the alternated pattern of ankle muscle activity to one close to a pattern of co-activation typically present in individuals with DS (See vibration effect on Table III). The vibration did not interfere on co-contraction pattern chose by DS individuals.

DISCUSSION

As reported before on the seesaw a specifically muscle strategy has been used. This strategy was characterized by alternated activation of the TA and the GM muscles and by the modulation of these muscles response with the degree of seesaw stability (Almeida et al 2006). In this sense the results presented here just reproduce previous data.

Like previously reported the balance on the seesaw occurred mainly at the ankle joint with very small involvement of the knee and hip joints (figure 2). With the partially block of proprioceptive information by vibration the amount ankle angular excursion decreased. The fact that vibration did not affect the movement in the hip and knee joints favor the idea that the balance on the seesaw is programmed in terms of the ankle movements.

Like our initial hypothesis vibration of Achilles tendon leaded to a decrease of the muscle activity. These results confirm the previous data showing that under unstable platform (Ivanenko et al. 1999; Ivanenko et al. 2000) or during normal walking (Courtine et al 2001) the response to vibration are reduced. Also our results showed that with vibration the CG lost their ability to modulate the amount of ankle muscle activities with the movement direction, or else, with contraction mode. In this way the CG muscle strategy with vibration remember the one reported for the individual with DS. The balance of DS group was characterized by small amplitude, higher frequency and the pattern of muscle co activation.

As we initially predicted the vibration was more detrimental to the balance performance of CG as compared with DS. The possible reason is that the individuals with DS have a kind of proprioceptive block due to several deficits. For example Cole et al. (1988) showed that they fail to modulate the grip force whit object surface. Brandt et al. (1995) described low sensory nerve action potential amplitudes following stimuli of the thumbs. Also it has been advanced that the problem of individuals with DS are in integrate the afferent and efferent information at cerebellum level.

The fact is that the DS is a multi modal disease affecting several areas of the motor control system and because of that it is very difficulty pinpoint one specifically organic dysfunction for all the balance problems of these individuals

Several authors have shown that under unstable conditions the CNS rely more on the vestibular information than on the proprioception. For example, the sway response due to galvanic vestibular stimulation has been increased when subjects stand on compliant surfaces, such as a piece of foam rubber (Horak & Hlavacka, 2001) or translation surfaces (Fitzpatrick et al. 1994). Our data showed that despite the changes in postural strategy, provoked by vibration in the case of CG and disease in the case of DS, all individuals were able to keep balance on the seesaw when just proprioception was reliably. In other words functionally all subjects were able to sway on the seesaw even thought the strategy was sub-optimal. So, our data is probably revealing that the proprioceptive information is very important to elicit a muscle couple response as the ones observed by CG without vibration. Favor to this idea are the study of Bloem et al. (1998) suggesting that lower leg proprioception is used to trigger and modulate coupled ankle reflexes.

In this sense we have reported some place also. The partially lack of the vestibular information by galvanic vestibular stimulation did not affect the postural strategy adopted by CG on seesaw. Under this condition they were able to couple the muscle activation pattern. On the other hand individuals with DS failed to keep balance on unstable seesaws.

Those findings favor the idea that under unstable platform the vestibular information prevails to assure the functional balance and proprioception to elucidated an efficient strategy in terms of joint and muscle coupling.

It´s very important to point out that: first the individuals with DS adopted one lees efficient kinematics and EMG strategy to keep balance on the seesaw. Second this strategy was not affected by vibration and finally the CG changed the strategy with vibration adopting a similar ones used by individuals with DS. Taking together all those findings reported above we are possible learning that the proprioceptive information is essential for the motor control system to release the appropriate motor strategy based on the reciprocal activation among the agonist and the antagonist to performer one efficiently balance.

REFERENCES

Almeida GL, Carvalho RL, Talis VL. Postural strategy to keep balance on the seesaw. *Gait and Posture* 2006, 23, 17-21

Anson JG. Neuromotor Control and Down Syndrome. *Approaches to the study of motor control and learning*. 1992; 387-412.

Aruin AS, Almeida GL. A coactivation strategy in anticipatory postural adjustments in person with Down Syndrome. *Motor Control*. 1997; 1:178-191.

Brandt BR, Rosen I. Impaired Peripheral Somatosensory Function in children with Down syndrome. *Neuropediatrics* 1995, 26: 310-312

Bellugi U, Bihrle A, Jernigan T, Trauner D, Doherty S. Neuropsychological, neurological, and neuroanatomical profile of Williams syndrome. *American Journal of Medical Genetics*, 1990,6: 115-125.

Bloem BR, Allum JHJ, Carpenter MG, Honegger F. Propriocepsis in the lower legs: Is it essential for triggering human balance corretions. *Exp Brain Res* 1998.

Cole KJ, Abbs JH, Turner GS. Deficits in the production of grip force in Down syndrome. *Developmental Medicine and Child Neurology* 1988, 30:752-758.

Courtine G, Pozzo T, Lucas B, Shieppati M.. Continous, bilateral Achilles' tendon vibration is not detrimental to human walk. *Brain Res Bull* 2001,55: 107-115.

Fitzpatrick RC, Burke D, Gandevia SC. Task-dependent reflex responses and movement illusions evoked by galvanic vestibular stimulation in standing humans. *J Physiol* 1994, 478, 363-372

Haley SM. Postural reactions in infants with Down syndrome: Relationship to motor milestone development and age. *Physical Therapy*. 1986; 66:17-22.

Ivanenko, Y. P., Talis, V. L., & Kazennikov ,O. V. Support stability influences postural responses to muscle vibration in humans. *European Journal of Neuroscience*, 11: 647-654, 1999.

Hatzitaki V, Pavlou M, Bronstein AM. The integration of multiple proprioceptive information: effect of ankle tendon vibration on postural responses to platform tilt. *Exp Brain Res*. 2004;154(3):345-54.

Horak FB, Hlavacka F. Somatosensory loss increases vestibulospinal sensitivity. *J Neurophysiol* 2001, 86, 575-585

Pitetti K, Fernhall B. Comparing Run Performance of Adolescents With Mental Retardation, With and Without Down Syndrome. *Adapted Physical Activity Quarterly*; 2004, 21 (3)219-229.

Spano M, Mercuri E, Rando T et al. Motor and perceptual-motor competence in children with Down syndrome: variation in performance with age. *Europ.J. Paediatr.Neurol*. 1999;3:7-13.

Shumway-Cook A, Woollacott MJ. Dynamics of postural control in the child with Down syndrome. *Physical Therapy*. 1985; 65(9):1315-1322.

Wierzbicka, M. M., Gilhodes, J. C. & Roll, J. P. Vibration-induced postural post effects. Journal Neurophysiology, 79: 143-150, 1998 .

CAPTIONS

Figure 1. Balance of one control (left) and one individual with Down syndrome on seesaw of height 12cm. Upper panel shows the ankle displacement and down panel shows the activities of the gastrocnemius medialis (GM) negative and tibialis anterior (TA) positive values with or without vibration.

Figure 2. Displacement of the ankle, knee and hip angular excursions and the integrated EMG activities of the tibialis anterior (TA), gastrocnemius medialis (GM) rectus femoris (RF), biceps femoris (BF), rectus abdominis (RA) and erector spinae (ES) during maximum plantar flexion with (closed circles) and without (open circles) vibration. Data represent mean values obtained from eight individuals. The vertical lines represent the standard error.

Figure 3. Illustrate the index of co-contraction- ICC (activity amount during plantar flexion divided by their respective amount during dorsal flexion) of TA, GM, RF, BF, RA, ES muscles of individuals with (rhombus) or without (circle) Dow syndrome during balance on seesaws of 7,12, 15cm heights (S1,S2,S3) with or without GVS

Table I. Two ways ANOVA (Vibration and ID) for the Kinematics and Electromyography variables of control and Down syndrome individuals during maximal plantar flexion

Table II. Two ways ANOVA (Vibration and ID) for the Kinematics and Electromyography variables of control and Down syndrome individuals during maximal dorsal flexion

Table III. Two ways ANOVA (Group and vibration) results $p<0,05$ for the index of co-contraction of Electromyography variables.

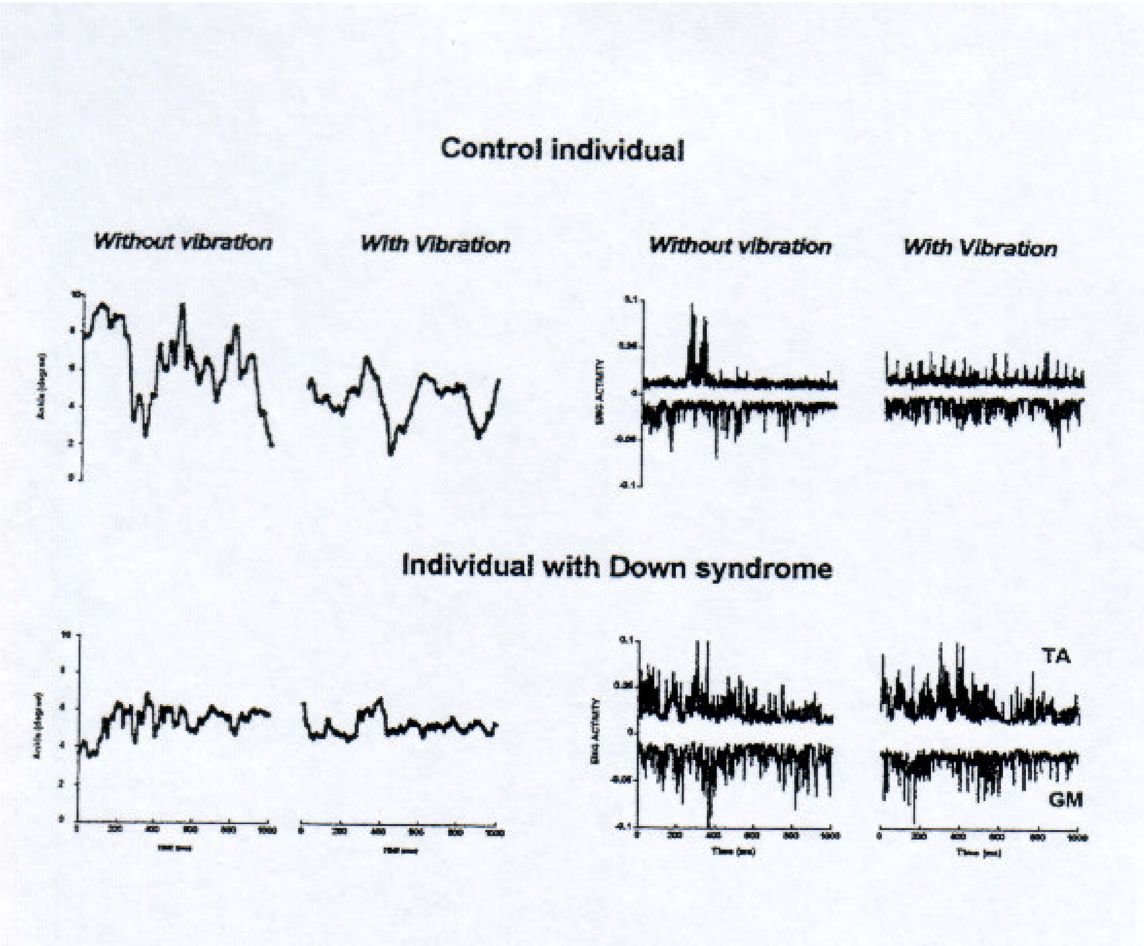
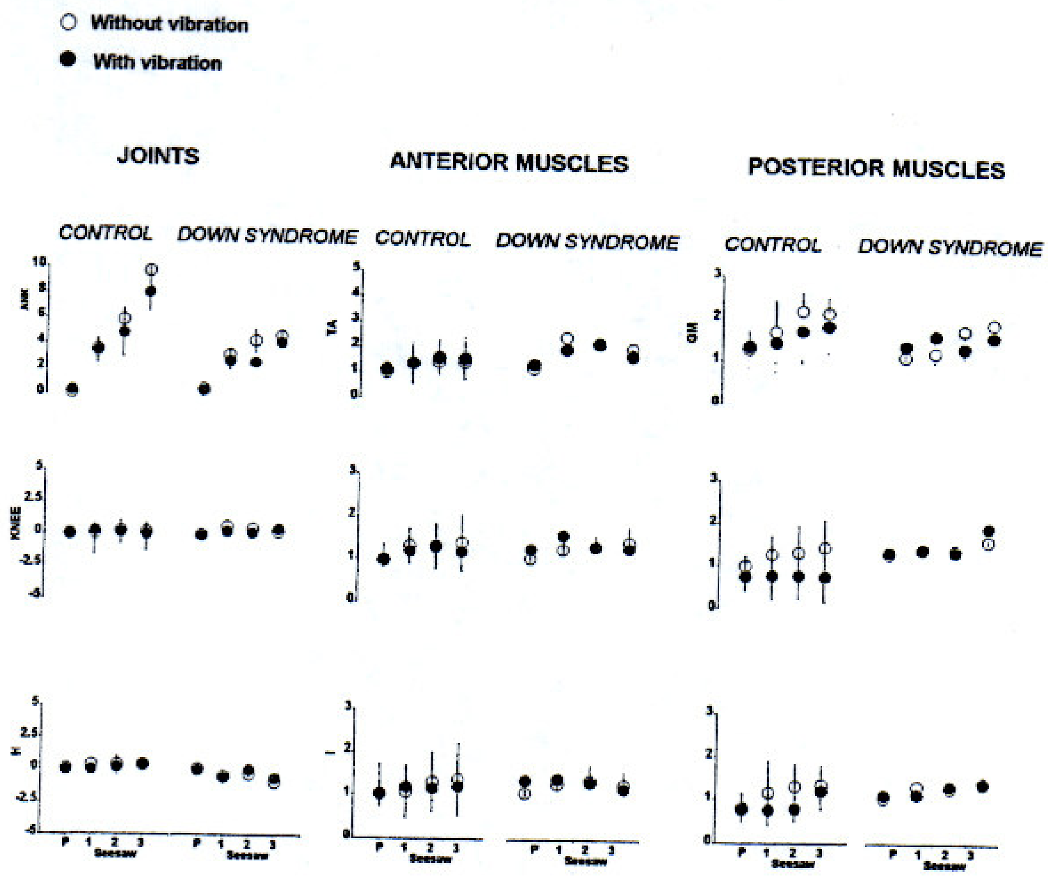
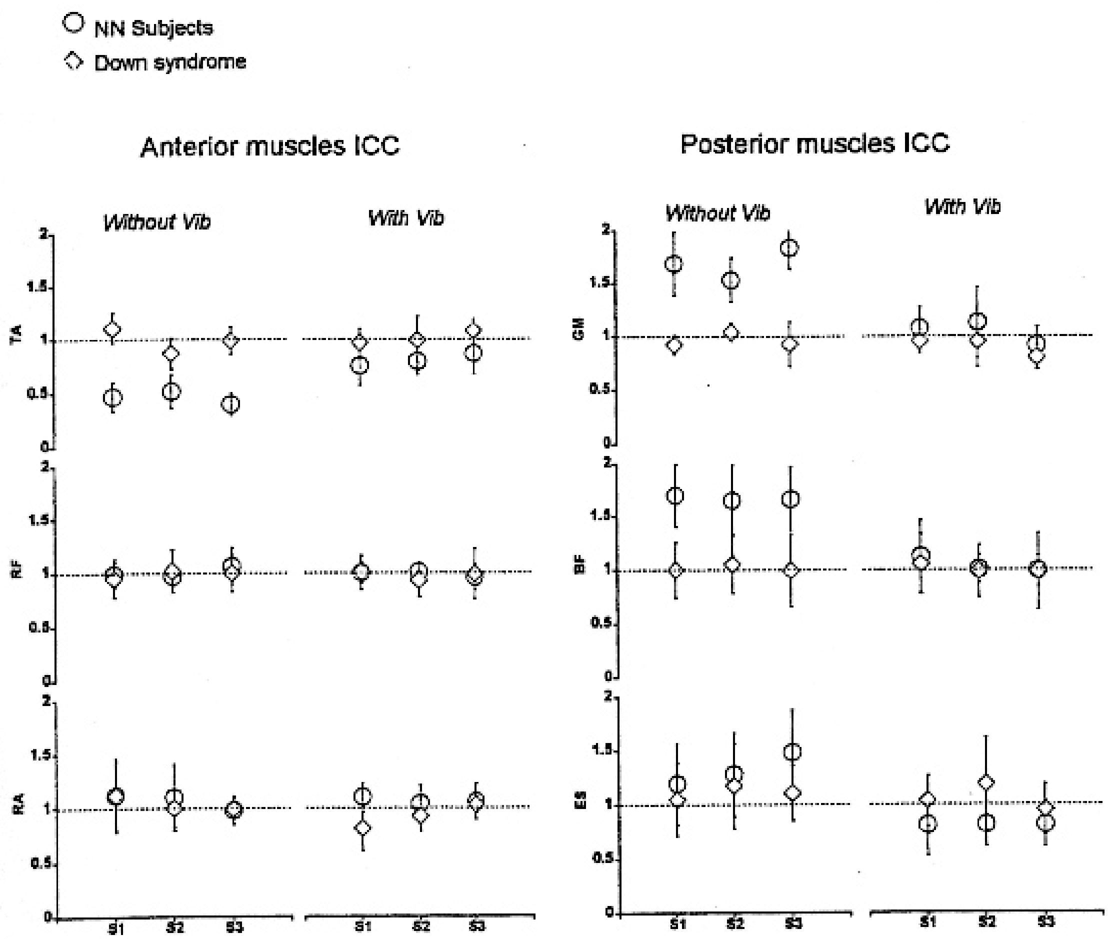

Control individual
Without vibration
With Vibration
Without vibration
With Vibration
Individual with Down syndrome
TA
GM

Figure1



Without vibration
With vibration
JOINTS
ANTERIOR MUSCLES
POSTERIOR MUSCLES
CONTROL
DOWN SYNDROME
CONTROL
DOWN SYNDROME
CONTROL
DOWN SYNDROME
ANK
KNEE
HI
TA
GM
Seesaw

Figure 2



NN Subjects
Down syndrome
Anterior muscles ICC
Posterior muscles ICC
Without Vib
With Vib
Without Vib
With Vib
TA
RF
RA
GM
BF
ES
S1
S2
S3

Figure 3

Table I.	Plantar Flexion											
	Control Group						**Down syndrome**					
	Vibration		ID		Vibration x ID		Vibration		ID		Vibration x ID	
	F	p	F	p	F	p	F	p	F	p	F	p
Ankle	50.1	+	13.7	+	11.3	-	0.30	-	6.06	+	3.93	-
Knee	0.05	-	0.29	-	0.31	-	2.12	-	0.11	-	0.95	-
Hip	3.79	-	0.58	-	2.81	-	2.58	-	3.49	-	2.12	-
TA	0.04	-	0.24	-	0.11	-	1.01	-	1.04	-	1.01	-
GM	3.06	+	3.94	+	3.90	-	2.19	-	0.37	-	0.07	-
R.F	0.28	-	0.05	-	0.90	-	5.42	-	0.05	-	7.53	-
B.F	16.5	+	2.82	+	0.82	-	2.78	-	3.00	-	2.24	-
R.A	0.03	-	1.47	0.28	0.80	-	1.66	-	0.50	-	0.31	-
E.S	7.31	-	2.48	-	0.31	-	0.21	-	0.34	-	1.24	-

Table II.	Dorsal Flexion											
	Control Group						**Down syndrome**					
	Vibration		ID		Vibration x ID		Vibration		ID		Vibration x ID	
	F	p	F	p	F	p	F	p	F	p	F	p
Ankle	96.2	+	43.3	+	35.0	-	0.43	-	0.11	+	3.95	-
Knee	1.39	-	0.05	-	0.27	-	1.04	-	1.71	-	4.36	-
Hip	0.63	-	0.59	-	2.06	-	4.25	-	1.44	-	1.80	-
TA	9.70	+	9.21	+	7.58	-	5.42	-	1.94	-	1.21	-
GM	2.08	-	5.14	-	1.23	-	0.15	-	2.90	-	0.53	-
R.F	0.56	-	0.02	-	0.00	-	1.15	-	0.02	-	13.6	-
B.F	0.23	-	0.32	-	0.35	-	4.76	-	3.10	-	2.66	-
R.A	0.04	-	3.04	-	1.83	-	1.64	-	1.83	-	1.05	-
E.S	0.65	-	0.21	-	2.65	-	1.32	-	0.01	-	6.79	-

Table III

INDEX OF CO-CONTRACTION						
	GROUP		VIBRATION		GROUP x VIBRATION	
TA	77,8	0,00	0,08	0,05	5,25	0,03
G.M	12,86	0,002	4.686	0,048	5,38	0,03
R.F	0,057	0,81	2,53	0,13	0,71	0,41
B.F	4,34	0,05	7,57	0,04	10,1	0,00
R.A	2,36	0,14	2,22	0,15	1,65	0,22
E.S	0,45	0,83	3,26	0,09	2,72	0,12

VII. Considerações finais

Nosso estudo reproduz alguns conhecimentos já descritos na literatura, assim como é inovador em vários pontos. Replicamos os achados Almeida et al. (2006) mostrando que manutenção do equilíbrio na gangorra para ambos os grupos analisados, foi possível principalmente devido a movimentos da articulação do tornozelo.

Observamos primeiro que durante a manutenção do equilíbrio em gangorra sem estimulação sensorial adicional (galvânica ou vibração) os indivíduos do grupo controle apresentaram um padrão alternado de ativação dos músculos agonistas e antagonistas do tornozelo (Gastrocnêmio Medial e Tibial Anterior) e foram capazes de modular a magnitude da resposta postural com a altura da gangorra, ou seja, com a demanda mecânica da tarefa.

Segundo, que a manipulação das informações vestibulares através da estimulação galvânica não alterou este padrão alternado de ativação muscular. Os principais efeitos da estimulação galvânica foram o aumento do deslocamento da articulação do tornozelo, assim como a redução da atividade muscular do gastrocnêmio medial e tibial anterior. Estas alterações nos permitem sugerir o maior envolvimento do sistema vestibular na modulação da magnitude da resposta e não na elaboração do padrão de ativação muscular (sinergia). De acordo com Bloem et al. (1998) a propriocepção dos membros inferiores é importante na modulação de respostas musculares coordenadas ao nível do tornozelo. Sendo assim, a imprecisão das informações vestibulares provavelmente não alterou o padrão de ativação muscular pois o controle deste ficaria a cargo das informações proprioceptivas.

Colaborando com esta hipótese está o modelo de Mergner (1997) que sugere um maior envolvimento do sistema vestibular no controle do tronco do que do tornozelo. Em contrapartida existem estudos mostrando que as informações vestibulares se tornam mais importantes para a manutenção do equilíbrio com a redução da precisão das informações proprioceptivas como a permanência sobre espuma (Horak & Hlavacka 2001) ou plataforma de translação (Fitzpatrick et al 1994). Nossos dados não nos permitem discordar destes estudos uma vez que a estimulação galvânica alterou a magnitude da oscilação. Nós apenas pontuamos que a maior importância do sistema vestibular em superfícies instáveis deve estar relacionada ao controle funcional, ao passo que a coordenação sinérgica deve estar relacionada a propriocepção.

Ao analisarmos o efeito da vibração observamos uma redução da resposta a este estímulo na gangorra. Este efeito tem sido descrito em outras tarefas de grande dificuldade como superfície instável (Ivanenko et al 1999) e durante a marcha (Courtine et al 2001). Para estes autores a imprecisão das informações proprioceptivas faz com que o sistema nervoso desconsidere as mesmas para a manutenção do equilíbrio. Este fato poderia explicar a alteração no acoplamento muscular observada na gangorra durante a vibração. Com a vibração os indivíduos do grupo controle passaram a utilizar um padrão de contração mais próximo ao observado nos indivíduos portadores da SD. Juntos estes dados sinalizam a grande importância das informações proprioceptivas na elaboração de respostas musculares coordenadas.

As respostas observadas nos indivíduos portadores da SD diferem das observadas no grupo controle em vários aspectos. Primeiro, mesmo na ausência de manipulação sensorial adicional os portadores da SD utilizaram um padrão de co-ativação durante o balanço na gangorra. Com o bloqueio parcial das informações vestibulares e oclusão da visão a habilidade de manutenção do equilíbrio na gangorra foi reduzida consideravelmente. Quando apenas as informações proprioceptivas estiveram totalmente disponíveis, a manutenção do equilíbrio não foi possível indicando déficits a este nível. Por outro lado à vibração não alterou nem a resposta postural nem a capacidade de balanço. Provavelmente às deficiências do sistema proprioceptivo levem os portadores da SD a reduzirem naturalmente a relevância destas informações durante a elaboração de respostas posturais, justificando assim a falta de efeito da vibração.

A perda do equilíbrio decorrente do bloqueio parcial das informações vestibulares associado à falta de resposta à vibração, comprova a existência de déficits proprioceptivos nos portadores da síndrome de Down.

Os nossos dados mostram a grande flexibilidade do SNC intacto e capacidade de se reorganizar na ausência ou imprecisão de uma informação sensorial. Por outro lado, esta flexibilidade está prejudicada nos indivíduos portadores da síndrome de Down.

REFERÊNCICAS BIBLIOGRÁFICAS

Almeida GL, Carvalho RL, Talis VL. Postural strategy to keep balance on the seesaw. *Gait and Posture* 2006, 23, 17-21

Bloem BR, Allum JHJ, Carpenter MG, Honegger F. Propriocepsis in the lower legs: Is it essential for triggering human balance corretions. *Exp Brain Res* 1998.

Courtine G, Pozzo T, Lucas B, Shieppati M.. Continous, bilateral Achilles' tendon vibration is not detrimental to human walk. *Brain Res Bull* 2001,55: 107-115.

Fitzpatrick RC, Burke D, Gandevia SC. Task-dependent reflex responses and movement illusions evoked by galvanic vestibular stimulation in standing humans. *J Physiol* 1994, 478, 363-372

Horak FB, Henry SM, Shumway-Cook A. Postural perturbations: new insights for treatment of balance disorders. *Phys Ther*. 1997 May;77(5):517-33.

Horak FB, Hlavacka F. Somatosensory loss increases vestibulospinal sensitivity. *J Neurophysiol* 2001, 86, 575-585

Ivanenko, Y. P., Talis, V. L., & Kazennikov ,O. V. Support stability influences postural responses to muscle vibration in humans. *European Journal of Neuroscience*, 11: 647-654, 1999.

Mergner T, Huber W & Becker W (1997) Vestibular Neck interaction and transformation of sensory coordinates. *Journal of vestibular research* 7, 347-367

Shumway-Cook A, Woollacott MJ. Dynamics of postural control in the child with Down syndrome. *Physical Therapy*. 1985; 65(9):1315-1322.

Shumway-Cook A, & Woollacott MJ. Motor Control Theory and Practical Applications. Williams &Wilkins, 1995

Uyanik M, Bumin G, Kayihan H. Comparison of different therapy approaches in children with Down syndrome. *Pediatrics International* 2003; 45: 68-73.

Woollacott Marjorie,Shumway-Cook Anne. Attention and the control of posture and gait: a review of an emerging area of research. Gait and Posture 16(2002) 1-14

VIII. ANEXO 1.

Termo de Consentimento Livre e Esclarecido

Nome do projeto: Reajustes Posturais em Indivíduos Neurologicamente Normais e em Portadores da Síndrome de Down na gangorra: Efeito da manipulação sensorial.

Nome completo:

Nome completo do responsável:

Objetivo:

Sabe-se que o equilíbrio em indivíduos portadores da Down é alterado. Observa-se um aumento no número de quedas assim como base alargada durante a marcha. Este projeto tem por objetivo estudar o efeito da manipulação das informações sensoriais no controle postural em situação de instabilidade como durante o balanço em gangorra.

Explicação do procedimento:

A avaliação será realizada em aproximadamente 2h30min, sendo que serão fixados com fita adesiva, eletrodos nos principais músculos dos membros inferiores, do tronco e nas articulações. Os indivíduos balançarão em 3 gangorras de 7,12 e 17cm de altura com os olhos abertos e fechados. Durante o balanço receberão vibração nos tendões de Aquiles e estimulação galvânica atrás da nuca.

Benefícios esperados:

Contribuir para um melhor entendimento do ajuste de equilíbrio em portadores da síndrome de Down. Esta compreensão servirá de base para elaboração de tratamentos mais eficazes.

Desconfortos e riscos:

O risco de queda durante os exercícios será minimizado com a presença de um experimentador próximo ao indivíduo. O estudo não apresenta demais riscos.

Liberdade de participação:

A participação do portador da síndrome de Down sob minha responsabilidade, neste estudo é voluntária. É meu direito interromper a participação a qualquer momento sem que isto incorra em qualquer prejuízo e penalidade. Estou ciente que não receberei nenhuma remuneração ou forma de ressarcimento das despesas decorrentes da participação na pesquisa.

Sigilo:

A identidade do indivíduo será preservada assim como seus dados confidenciais, assegurando a privacidade do mesmo.

Indenização:

Estou ciente que não receberei nenhuma indenização por algum dano decorrente da pesquisa visto que os riscos são mínimos.

EU, ____, responsável por____, declaro que concordo com a participação do(a) mesmo(a) no experimento.

Responsável pela pesquisa: Prof Ms.Regiane Luz Carvalho

Telefone do responsável 6037968

Assinaturas

Regiane Luz Carvalho Responsável

Local e data

TCLE de acordo com RS CNS 196/96-IV