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EQUILÍBRIO E ATIVAÇÃO DA MUSCULATURA DA PERNA PRÉ E PÓS FADIGA DE MEMBROS INFERIORES EM MULHERES COM DIABETES TIPO 2

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Equilíbrio e ativação da musculatura da perna pré e pós fadiga de membros inferiores em mulheres com diabetes tipo 2

Dissertação apresentada ao Programa de Pós-graduação Mestrado em Ciências da Reabilitação e Desempenho Físico-Funcional da Universidade Federal de Juiz de Fora como requisito a obtenção do grau de Mestre em Ciências da Reabilitação e Desempenho Físico-Funcional

Orientador: Prof. Dr. Alexandre Wesley Carvalho Barbosa - UFJF

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“Os que se encantam com a prática sem a ciência são como os timoneiros que entram no navio sem timão nem bússola, nuca tendo certeza do seu destino”.

(Leonardo da Vinci)

RESUMO

Introdução: Quedas em idosos estão relacionadas a lesões e altos custos para o sistema de saúde. Os adultos mais velhos que desenvolvem diabetes tipo 2 têm maior chance de cair. A queda nesses indivíduos está relacionada à neuropatia, prejuízos somatossensoriais, cognitivos, visuais e vestibulares e declínio funcional. A força muscular e o comprometimento do equilíbrio podem aumentar o risco de quedas e a fadiga muscular reduz a capacidade de gerar força. Portanto, o objetivo do presente estudo foi comparar os padrões de ativação muscular e as medidas de equilíbrio durante o teste de equilíbrio de apoio unipodal em mulheres idosas diabéticas e não diabéticas, antes e após a tarefa de ficar na ponta dos pés até a fadiga.
Métodos: No presente estudo de caso-controle, 54 mulheres idosas foram divididas em dois grupos: diabetes tipo 2 (n = 28; 70 ± 6 anos) e sem diabetes tipo 2 (n = 26; 71 ± 8 anos). A eletromiografia de superfície foi utilizada para avaliar a ativação do tibial anterior (TA) e do gastrocnêmio medial (GM) e uma plataforma de força foi utilizada para avaliar o equilíbrio durante o teste de equilíbrio unipodal antes e após a tarefa de fadiga. Teste t independente foi utilizado para avaliar as diferenças entre os grupos. Foi adotado nível de significância de 0,05. A curva ROC foi usada para determinar a responsividade e a acurácia de cada variável individualmente para discriminar mulheres diabéticas tipo 2 de idosas não diabéticas.
Resultados e Discussão: O grupo de mulheres idosas com Diabetes Tipo 2 apresentou valores de RMS_ML, RMS_AP e TA_MEAN mais elevados do que o grupo de mulheres idosas não diabéticas, tanto antes quanto depois da tarefa de fadiga. Não foram observadas diferenças significativas intragrupos antes e depois da fadiga. Os valores RMS_ML_PRE, RMS_ML_POST, RMS_AP_PRES, RMS_AP_POST, TA_MEAN_PRE e TA_MEAN_PRE podem discriminar mulheres idosas diabéticas tipo 2 de a mulheres idosas não diabética.
Conclusões: As mulheres idosas diabéticas apresentaram pior equilíbrio em apoio unipodal, sem influência da tarefa de fadiga. Diabetes tipo 2 levou a uma ativação desequilibrada dos músculos da perna com aumento da ativação da TA. Além disso, o estudo identificou ponto de corte para discriminar o equilíbrio postural de idosas diabéticas.

Palavras-chave: equilíbrio postural; eletromiografia; fadiga muscular; idosos; diabetes tipo 2

ABSTRACT

Background and Purpose: Falls in older adults are related to injuries and high costs to the health care system. Older adults who develop type 2 diabetes have increased chance of falling. Falling in these individuals relates to neuropathy, somatosensory, cognitive, visual and vestibular impairments, and functional decline. Already know that muscle strength and balance impairments can increase the risk for falls and muscle fatigue reduces the capacity to generate force. Therefore, the objective of the present study was to compare muscle activation patterns and balance measurements during one-leg stance balance test in diabetes and nom diabetes older women before and after completion of a fatiguing rise-to-toes task.
Methods: In the present case-control study, 54 older women were divided into two groups: type 2 diabetes (n=28; 70±6 years old) and non-type 2 diabetes (n=26; 71±8 years old). A force platform was used to assess balance during 1-legged stance, and surface electromyography was used to assess the tibialis anterior (TA) and gastrocnemius medialis (GM) activation. Independent t-test was used to assess differences between groups. The significance was set at $\alpha=0.05$. The Receiver Operating Characteristic (ROC) curve was used to determine the responsiveness and the accuracy of each variable individually for discriminate type 2 diabetic older women from non type 2 diabetic older women.
Results and Discussion: The Type 2 Diabetes older woman group had higher RMS_ML, RMS_AP, and TA_MEAN values than Nom-Diabetes older woman group, for both, before and after the fatiguing task. No significant differences were observed intragroups before and after fatiguing task. RMS_ML_PRE, RMS_ML_POST, RMS_AP_PRES, RMS_AP_POST, TA_MEAN_PRE and TA_MEAN_PRE values could discriminate type 2 diabetic older women than non-diabetic older women.
Conclusions: Diabetic older women showed worse one-leg stance balance than non-diabetic, with no influence of the fatiguing rise-to-toes task. Type 2 Diabetes leaded to an unbalanced activation of leg muscles with increased TA activation. Moreover, the study identified cutoff point to discriminate diabetic older women's postural balance.

Keywords: postural Balance; electromyography; muscle fatigue; older adults; diabetes type 2

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LISTA DE ABREVIATURA E SIGLAS

ACh	Acetilcolina
AChR	Receptor de acetilcolina
ADP	Adenosina difosfato
ATP	Adenosina trifosfato
ATPase	Adenosinatrifosfatases
Ca	Íon cálcio
DHPR	Receptor de Dihidropiridina
DNA	Ácido Desoxirribonucleico
EMG	Eletromiografia
ERO	Espécie reativa de oxigênio
FADH2	Flavina-adenina dinucleótido
Fe^{2+}	Íon ferro
FES-I-Brasil	Falls Efficacy Scale - International em idosos Brasileiros
GH	Hormônio de crescimento
GID	Grupo Idosas Diabéticas
GInD	Grupo Idosas não Diabéticas
GM	Gastrocnêmio medial
H	Hidrogênio
H_2O_2	Molécula de água
IGF-1	Fator de crescimento semelhante à insulina tipo 1
IL-6	Interleucina 6
IPAC	International physical activity questionnaire
JNM	Junção neuromuscular
MHC	Cadeia de Miosina Pesada
mRNA	Ácido ribonucleico mensageiro
MuSK	Cinase específica muscular
NADH	Nicotinamida adenina dinucleótido
Pi	Fosfato
PPTM	Poro de permeabilidade transitória mitocondrial
RyR	Receptor de Rianodina
sEMG	Sinal eletromiográfico
TA	Tibial anterior
UCM	Uniporte de Ca2+ mitocondrial
UM	Unidade motora
Vmax	Velocidade máxima

SUMÁRIO

1. INTRODUÇÃO

1.1 ENVELHECIMENTO

Não há consenso entre os países sobre quando se inicia a terceira idade. No Brasil, pessoas a partir de 60 anos são consideradas idosas (BRASIL, 2003). Em 2013, o Brasil era o sétimo colocado mundial em número de idosos, com expectativa de chegar à sexta posição em 2025 (ISHIDA; WATANABE, 2013). O aumento no número de idosos se deve em grande parte à redução das taxas de fecundidade e mortalidade. Com o aumento da expectativa de vida a população idosa passará inerentemente por alterações nas funções fisiológicas e funcionais que irá predispor a quedas. Embora a prevalência de quedas seja maior em mulheres com mais de 65 anos, a taxa de mortalidade para essa população é de 52,4 por 100.000 habitante, enquanto para homens idosos é de 72,2 (US DEPARTMENT OF HEALTH AND HUMAN SERVICES/CENTERS FOR DISEASE CONTROL AND PREVENTION, 2017). Os custos médicos com hospitalização são altos, podendo variar de poucos dias à permanentemente hospitalizado. Nos EUA, foram gastos em 2015 US$ 637,5 milhões com quedas fatais e US$ 31,3 bilhões com quedas não fatais (BURNS; STEVENS; LEE, 2016). Nesse sentido, o envelhecimento tem se revelado como um grande desafio para saúde pública (REZA et al., 2017).

É comum o processo de envelhecimento cursar com o declínio progressivo de todos os processos orgânicos, em decorrência de alterações estruturais e funcionais em vários sistemas do organismo (KHAN; SINGER; VAUGHAN, 2017). Normalmente, o impacto sobre os músculos esqueléticos é grave. Ocorre progressiva e generalizada perda de massa e força muscular, condição conhecida como “sarcopenia” (CRUZ-JENTOFT et al., 2010). Dos 20 aos 60 anos há perda de 40% da massa muscular. E aos 80 anos, uma pessoa possui 60% de força comparada a adultos jovens (DOHERTY, 2003). Essas perdas do sistema musculoesquelético podem se converter em prejuízos nas atividades cotidianas dos idosos (FAULKNER et al., 2007). Tais mudanças são atribuídas à atrofia progressiva, perda de fibras musculares e perda de unidades motoras (RYALL; SCHERTZER; LYNCH, 2008). A contração muscular acontece pelo recrutamento sucessivo de unidades motoras (um neurônio motor alfa e todas as fibras musculares que ele inerva). Com o envelhecimento, algumas fibras musculares são desnervadas, passam a não ser controladas pelo sistema nervoso e não mais contribuem para a geração de força durante uma contração muscular (GONZALEZ-FREIRE et al., 2014). A desnervação é um dos principais fatores que levam à sarcopenia (RUDOLF et al., 2014). Há evidências sugerindo que mudanças que ocorrem nas mitocôndrias da junção neuromuscular – JNM (neurônio motor terminal, lâmina basal sináptica, fibra muscular e membrana muscular) (PUNGA; RUEGG, 2012), contribuem para o envelhecimento e morte celular, tanto muscular quanto do neurônio motor terminal, resultando em desnervação (GONZALEZ-FREIRE et al., 2014).

Essas organelas são responsáveis pela respiração celular, que compreende uma sequência de reações de transferência de energia que resulta na produção de ATP (adenosina trifosfato) e normalmente termina com os elétrons se combinando com o oxigênio, formando água. No entanto, em condições não tão comuns em que o Fe^{2+} está disponível, o oxigênio sofre diversas reações que culminam na formação de ERO_S (espécies reativas de oxigênio). As ERO_S extraem elétrons e abrem poros na membrana mitocondrial, permitindo a entrada de água. Esse inchaço da mitocôndria pode causar ruptura da matriz e da crista mitocondrial, promovendo a liberação para o citosol proteínas apoptogênicas intermembranais determinando a morte do neurônio motor terminal (WALLACE; FAN; PROCACCIO, 2010).

Existe um mecanismo de reinervação que normalmente é bem-sucedido. As fibras desnervadas expressam proteínas e produzem sinais quimiotáticos que estimulam o crescimento de novos dendritos a partir de neurônios motores remanescentes de outras unidades motoras. No entanto, é comum este mecanismo falhar com o envelhecimento, e as fibras que não foram reinervadas morrem por apoptose (GONZALEZ-FREIRE et al., 2014).

O envelhecimento é caracterizado por aumento nos níveis de marcadores inflamatórios, como a Interleucina 6 (IL-6), circulantes no sangue e tecidos, frequentemente sem causa clara. Por exemplo, o aumento da IL-6 está relacionado à danos nas células de Schwann que são responsáveis por secretar fatores tróficos e de crescimento que direcionam o crescimento axonal após a desnervação (RANGARAJU et al., 2009; RANGARAJU; NOTTERPEK, 2011). O seu comprometimento contribui para reinervação ineficaz com consequente disfunção neuromuscular no envelhecimento (KAWABUCHI; TAN; WANG, 2011).

Essa inflamação crônica reduz a produção de IGF-1 (Fator de crescimento semelhante à insulina tipo 1(MAGGIO et al., 2013), que também diversas função neurotrófica e. seu declínio pode contribuir para a desnervação da unidade motora (DELBONO, 2003)..

Além das alterações na morfologia e funcionamento das mitocôndrias, com o envelhecimento acontece um desacoplamento progressivo da JNM, causada pela redução do número de pregas da membrana pós sináptica e redução da área do neurônio motor terminal que irá comprometer a contração muscular. (DELBONO, 2003).

O envelhecimento favorece a proteólise da agrina (proteoglicano responsável pela aglomeração de receptores de acetilcolina-AChR), isso torna os AChR mais dispersos, dificultando a associação da acetilcolina com seu receptor, desestabilizando a JNM e resultando em sarcopenia precoce (DREY et al., 2013; HETTWER et al., 2013).

Acontece aindaum desequilíbrio no número de canais de DHPR (Receptor de Dihidropiridina) e RyR (Receptor de Rianodina), com maior npumero de RyR, o que reduz a liberação de cálcio após um potencial de ação, resultando em contração menos eficiente (RENGANATHAN; SONNTAG; DELBONO, 1997).

Outro ponto relevante que vem esclarecer o prejuízo na potência, força e velocidade de contração/relaxamento muscular, é a alteração na composição do tipo de miofibrilas. As fibras tipo I, de contração lenta, apresentam maior proporção do que as fibras do tipo II, contração rápida em músculos de idoso (KELLY et al., 2018). Isso se dá ao somatório de perda particular de fibras tipo II e conversão de fibras tipo II em tipo I. Embora não esteja claro todo esse mecanismo de remodelação algumas explicações parecem plausíveis:

- Redução no nível de atividade física:
  O envelhecimento é, em geral, acompanhado por uma pronunciada diminuição da atividade física, o que causa atrofia e uma mudança no tipo de fibra no sentido rápida para lenta (MINAMOTO, 2005).
  Durante o treinamento de hipertrofia, núcleos são adicionados à fibra. Como cada núcleo é responsável pela manutenção de uma determinada área do citoplasma, acontece então aumento do volume citoplasmático e hipertrofia (YONG, 1994). Da mesma forma, quando acontece períodos de inatividade, ocorre diminuição do número de núcleos dentro da fibra, e assim redução do volume citoplasmático, caracterizando a hipotrofia (HIKIDA et al., 1997). Assim, sugere-se que a diminuição das áreas transversais observadas nas fibras senescentes resulta de uma redução no número de domínios nucleares (HIKIDA; WALSH; BARYLSKI, 1998).
  A demanda funcional à qual o músculo é submetido determina o tipo de fibra. Uma vez que atividades de força, velocidade e potência muscular não são muito

praticadas por essa população ocorre atrofia das UM de fibras tipo II. Além de resultar em músculos mais lentos, provoca diminuição de sua função (MINAMOTO, 2005).

- Mecanismo de desnervação-reinervação:
  Como dito anteriormente, acontece desnervação das unidades motoras. Uma miofibra desnervada segue 1 de 2 destinos: atrofia e morte ou reinervação pelo axônio ramificado de um neurônio motor viável próximo. E, como a distribuição espacial das miofibrilas é aleatória, muito provavelmente a miofibra será reinervada por um neurônio motor de um tipo diferente de miofibra e inevitavelmente haverá uma mudança em seu fenótipo, e assim irão se formar agrupamentos de tipo de miofibras (KELLY et al., 2018). Essa desnervação é seletiva, com maior preferência pelas fibras tipo II (LEXELL; DOWNHAM, 1991). Isso explica a maior proporção fibras tipo I em músculos de idosos.
- Mudanças na regulação gênica do músculo:
  Abordagens biológicas moleculares revelaram diminuição no conteúdo de mRNA (ácido ribonucleico mensageiro) da miosina. Fibra de idosos apresentam diminuição no mRNA IIA, maior diminuição na transcipção de IIX, mas nenhuma alteração no conteúdo de mRNA em tipo I (BALAGOPAL et al., 2001).

Todas essas alterações em nível celular ocorrem em idosos saudáveis como parte natural do processo de envelhecimento. Entretanto, tais alterações comprometem intensamente a função motora (YU et al., 2007). Na presença de comorbidades essas alterações podem ser ainda mais significativas e determinantes no processo de perda funcional e limitações das atividades usuais do idoso.

1.2 DIABETES MELLITUS

Com o aumento da proporção de idosos aumenta também a prevalência das doenças crônicas degenerativas, dentre elas, se destaca o Diabetes Mellitus acometendo 387 milhões de pessoas em todo mundo (MOORADIAN; CHEHADE, 2012). Este é um grupo heterogêneo de distúrbios metabólicos que apresenta como característica comum a hiperglicemia (SBD, 2016)

De acordo com a Sociedade Brasileira de Diabetes, o Diabetes Mellitus tipo 2 é a forma mais frequente, verificada em 90 a 95% dos casos, destes, 50% possuem mais de 60 anos de idade (SBD, 2014). Caracteriza-se por defeitos na ação e secreção da insulina e na regulação da produção hepática de glicose. É causada por fatores genéticos, que em grande parte permanecem inexplicados, e fatores ambientais como sedentarismo, dietas ricas em gorduras e envelhecimento (SBD, 2016).

Pessoas com diabetes tendem a ter um processo de envelhecimento mais rápido, o que os coloca em maior risco de desenvolver fragilidade em uma idade mais precoce (PERKISAS; VANDEWOUDE, 2016). O DM2 está associado a uma perda acelerada de força em adultos idosos que vivem na comunidade (PARK et al., 2007). A neuropatia diabética é a complicação mais comum associada ao diabetes mellitus, envolve todo o nervo periférico, desde a raiz até o axônio terminal (JUSTER-SWITLYK; SMITH, 2016) e pode ser detectada desde o momento do diagnóstico do DM. A prevalência é próxima a 100% quando se utilizam métodos eletrofisiológicos para diagnóstico (LAMONTAGNE; BUCHTHAL, 1970). A principal manifestação clínica é a parestesia de membros inferiores, no entanto, sua ausência não exclui a neuropatia, pois pode acontecer evolução direta para perda total de sensibilidade (SBD, 2016).

Há algumas décadas, acreditava-se que a neuropatia periférica era decorrente apenas da hiperglicemia (GROUP, 1993). Estudos mais recentes, mostram que o estresse oxidativo, disfunção mitocondrial, adiposidade tóxica, e elevação de marcadores inflamatórios são alguns fatores importantes que contribuem para o risco de neuropatia (JUSTER-SWITLYK; SMITH, 2016).

Outras condições secundárias ao diabetes como retinopatia, hipotensão ortostática, pé com úlceras diabéticas, hipoglicemia (MAURER; BURCHAM; CHENG, 2005) e o uso de medicamentos como insulina e metformina podem potencializar o risco de quedas. (BERLIE; GARWOOD, 2010).

1.3 QUEDAS

Se somarmos o processo de envelhecimento natural ao Diabetes temos uma combinação de fatores de risco para propensão às quedas (INTERNATIONAL DIABETES FEDERATION, 2013). Alguns estudos tem evidenciado que idosos diabéticos caem mais quando comparado aos não diabéticos (CHIBA et al., 2015; METTELINGE et al., 2013; PIJPERS et al., 2012). As quedas nesses indivíduos estão relacionadas à sensibilidade diminuída (causada por neuropatia), diminuição do controle do equilíbrio, da força muscular (sarcopenia), da propriocepção (cinestesia) e os déficits visuais, cognitivos e polifarmácia (CENTOMO et al., 2007). A combinação de idade e diabetes aumenta o risco de queda em 17 vezes (PIJPERS et al., 2012). A queda é um evento catastrófico, que quando não leva ao óbito reduz a capacidade funcional, a autonomia e independência prejudicando a qualidade de vida (COSTA et al., 2011).

Queda é definida como evento não intencional no qual um indivíduo cai ao chão ou a um nível inferior (HAUER et al., 2006), excluindo causas ambientais (CHORIN et al., 2016). Ao que parece, as pessoas mais ativas e as mais inativas são as que têm maior risco de cair, possivelmente pelo grau de exposição ao risco das primeiras e pela fragilidade dos demais (SBGG, 2008). Por serem menos ativos, os idosos são menos propensos a sofrer lesões, no entanto quando esta ocorre, a taxa de mortalidade é definitivamente superior, em razão de distúrbios nas funções fisiológicas e a presença de outros problemas médicos (REZA et al., 2017)

Considerando que a incidência de queda em idosos com mais de 65 anos é de 28-35%, (PERRACINI; RAMOS, 2002), e que a prevalência aumenta com a idade (MASUD; MORRIS, 2001), podendo chegar à 50% naqueles com mais de 80 anos (ARAÚJO et al., 2014; LEVY; THRALLS; KVIATKOVSKY, 2016), as quedas situam-se como o maior problema de saúde pública mundial da atualidade relacionada a pessoa idosa (CHANG; DO, 2015), pois elevam os custos com hospitalização e tratamento de lesões (COSTA et al., 2011). Somente no Brasil, entre 2005 e 2010 foram gastos R$ 464.874.275,91 apenas com internações hospitalares pagas pelo SUS (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2010).

A queda é precedida de uma complexa interferência de fatores de risco. São estes fatores que determinam o risco de quedas, quanto mais fatores de risco maior a chance de cair (IINATTINIEMI; JOKELAINEN; LUUKINEN, 2009). Estudos têm reportado maiores taxas de queda em mulheres idosas do que em homens idosos (SCHOENFELDER; RUBENSTEIN, 2004; SWANENBURG et al., 2010). Essa diferença de gênero provavelmente reflete as diferenças nas condições de saúde, como a redução significante na densidade mineral óssea após a menopausa, além de diferenças no estilo de vida e fatores comportamentais (CHANG; DO, 2015).

Após a primeira queda, os idosos têm 66% de chance de sofrer outra queda num período de um ano (NEVITT et al., 1989). O medo de cair é um fator de risco importante para recorrência de quedas (CUMMING et al., 2000; VIEIRA; PALMER; CHAVES, 2016a), acomete de 30% a 73% dos idosos caidores[1] (RUBENSTEIN; JOSEPHSON, 2002). Ao que parece, idosos com medo de cair desenvolvem intuitivamente e antecipatoriamente uma rigidez que em tarefas de baixa demanda funciona como estratégia protetora diante de fatores desestabilizadores. No entanto, em tarefas mais complexas que exigem igual complexa interação com o meio, ocorre um aumento do uso da estratégia de rigidez, tornando as respostas às perturbações externas insuficientes, com maior predisposição à ocorrência de episódio de queda (WOOLLACOTT; SHUMWAY-COOK, 2002; YOUNG; YOUNG; WILLIAMS, 2015).

Outro fator que eleva o risco de quedas é a diminuição do controle do equilíbrio. A manutenção do equilíbrio é essencial uma vez que uma queda é sempre precedida de perda de equilíbrio (BAUER et al., 2016). E as deficiências de equilíbrio são causas modificáveis de quedas (VIEIRA; PALMER; CHAVES, 2016a).

1.4 EQUILÍBRIO

Qualquer postura adotada por uma pessoa, por mais efêmera que pareça, demanda ajustes compensatórios para manter e recuperar o equilíbrio continuamente. Em pé, o corpo humano se comporta como um pêndulo invertido, inerentemente instável. Nessa circusntância, a projeção vertical do centro de massa passa em frente à articulação do tornozelo (LORAM; LAKIE, 2002) e requer rigidez do tornozelo para reduzir a amplitude de oscilação (WARNICA et al., 2014).

Várias estruturas contribuem para a rigidez do tornozelo. Elementos não contráteis como ligamentos e tendões são responsáveis pela rigidez passiva. No entanto, essa rigidez passiva é insuficiente, sendo necessário a ativação, em especial, dos músculos plantiflexores, para gerar torque ativo e manter o equilíbrio de pé (LORAM; LAKIE, 2002; VLUTTERS et al., 2015). Essa rigidez ativa é gerada principalmente por co-contração dos musculos flexores plantares e dorsais (SASAGAWA et al., 2009).

Estes ajustes na rigidez do tornozelo afim de manter o centro de massa corporal dentro da base de suporte (polígono delimitado pelas bordas laterais dos pés) e entre os limites de estabilidade (distância máxima que o centro de massa pode ser deslocado sem alterar a base de suporte) são atribuídos ao sistema de controle postural (ISHIZUKA, 2003; LIMA et al., 2001).

Para isso, o sistema de controle postural realiza uma complexa interação entre os sistemas sensorial, nervoso e motor. Na presença de uma oscilação o sistema sensorial envia informações ao sistema nervoso central que as integra e então envia impulsos nervosos que geram respostas musculares, afim de fornecer estabilidade e prevenir quedas (DUARTE; FREITAS, 2010). No entanto, ocorre declínio do sistema sensorial com a idade (GOUGLIDIS et al., 2011).

Outros fatores surgem com o envelhecimento, como o declínio da capacidade máxima de produção de força dos músculos do tornozelo e comprometem o equilíbrio (CATTAGNI et al., 2016). A redução do torque máximo dos flexores plantares encontra-se mais pronunciada (BILLOT et al., 2010; CATTAGNI et al., 2016).

Por outro lado, alguns autores encontraram aumento da atividade eletromiográfica dos músculos da panturrilha (BILLOT et al., 2010; LORAM; MAGANARIS; LAKIE, 2004). Sugerindo que o aumento da atividade eletromiográfica dos músculos da panturrilha é uma tentativa de compensar a perda de força desses músculos.

[1] Idosos que já sofreram alguma queda

A flexão plantar é realizada pelo tríceps sural, que é composto pelos músculos: sóleo, gastrocnêmio medial e gastrocnêmio lateral. Embora compartilhem o mesmo tendão e sejam agonistas da flexão plantar, esses músculos apresentam diferenças anatômicas, neurofisiológicas e funcionais. O sóleo é um músculo monoarticular, com ≅88% de fibras de contração lenta. Enquanto o gastrocnêmio é um musculo biarticular com ≅52% de fibras de contração rápida (JOHNSON et al., 1973).

Estudo prévio encontrou relativa ausência de atividade do gastrocnêmio lateral no equilíbrio de pé. Possivelmente devido ao maior limiar de recrutamento e à distinta orientação dos fascículos desse músculo em comparação com o sóleo e gastrocnêmio medial. Já a atividade do sóleo foi tônica, permanecendo continuamente ativo durante o equilíbrio em pé. Enquanto a atividade do gastrocnêmio medial foi fásica, com ativação intermitente das unidades motoras. Isso evidencia a importância do gastrocnemio medial, produzindo torque adicional para a manutenção do equilíbrio em pé (HEROUX et al., 2014).

A análise eletromiográfica indica que em jovens a ativação de flexores plantares é maior, com pouca ativação de tibial anterior, quando em bipedestação. Entretanto, em idosos ocorre maior co-contração de flexores plantares e tibial anterior quando em ortostatismo (VETTE et al., 2017). De modo geral as co-contracções aumentam a rigidez das articulações. E isso não é diferente para os músculos da articulação do tornozelo (MIRBAGHERI; BARBEAU; KEARNEY, 2000; SINKJAER et al., 1988). Uma vez que idosos apresentam capacidade de equilíbrio inferior, as co-contrações observadas parecem contribuir para aumentar a rigidez da articulação do tornozelo durante a postura de pé (CARPENTER et al., 2001). Assim, as co-controções estão associadas à diminuição da estabilidade postural em idosos, quanto maior a instabilidade maior a co-contração (VETTE et al., 2017).

1.5 FADIGA

O desempenho de atividades de vida diária está intrinsecamente relacionado à capacidade de realizar tarefas repetidamente ou por períodos prolongados, o que requer a capacidade de resistir ao desenvolvimento da fadiga muscular (CHRISTIE; SNOOK; KENT-BRAUN, 2011). No entanto, o maior uso de co-contrações dos músculos do tornozelo implica em aumento do custo energético para a manutenção do equilíbrio, o que pode resultar em fadiga muscular prematura e comprometer a estabilidade postural (CATTAGNI et al., 2016).

A fadiga muscular, geralmente é definida como a perda da capacidade de produção de força ou potência em resposta à atividade contrátil, é uma característica fundamental do músculo esquelético (KENT-BRAUN, 2009). Ao que tudo indica, a fadiga altera o senso de posição articular (ALLEN; LEUNG; PROSKE, 2010) induzindo viés na representação interna do corpo (esquema corporal). A fadiga modifica negativamente o senso de força (percepção da força produzida) (VUILLERME; BOISGONTIER, 2008), a amplitude e a velocidade do movimento (ENOKA; STUART, 1992). Todas essas alterações diminuem a precisão do movimento, o que, em uma situação de instabilidade, pode resultar em resposta insuficiente ou exagerada, aumentando ainda mais a oscilação postural predispondo a quedas (PROSKE; GANDEVIA, 2012).

Nesse sentido, já foi demostrado que a fadiga de membro inferior induz prejuízo no controle postural e equilíbrio de jovens (BISSON et al., 2010, 2012; GIMMON et al., 2011; THEDON et al., 2011) e de idosos (BISSON et al., 2012; BOYAS; HAJJ; BILODEAU, 2013). Muito embora, vários estudos evidenciarem aumento de resistência à fadiga com a idade (CHRISTIE; SNOOK; KENT-BRAUN, 2011; KENT-BRAUN, 2009).

De fato, idosos são menos sensíveis à fadiga muscular do que jovens durante contrações isométricas. Por outro lado, são mais susceptíveis à fadiga durante contrações dinâmicas (CHRISTIE; SNOOK; KENT-BRAUN, 2011). Uma possível explicação, é o remodelamento das unidades motoras. Com o envelhecimento ocorre grande atrofia de unidades motoras de contração rápida e alguma reinervação por neurônios de unidades motoras de contração lenta, em hipótese, tornando o músculo mais oxidativo (KENT-BRAUN, 2009) e assim mais resistente à fadiga.

Outra adaptação que favorece a resistência à fadiga é o fato de que idosos apresentam menor força muscular. Assim a força produzida pela contração seria insuficiente para ocluir o fluxo sanguíneo intramuscular, mantendo a entrega de oxigênio durante as contrações e permitindo o prolongamento da tarefa, ou seja, resistência muscular (LANZA; LARSEN; KENT-BRAUN, 2007).

Apesar da resistência à fadiga, idosos continuam apresentando maior prejuízo no controle postural do que jovens após fadiga (BISSON; LAJOIE; BILODEAU, 2014; HELBOSTAD et al., 2010; PAPA; GARG; DIBBLE, 2015; PAPA; HASSAN; BUGNARIU, 2016; ROSSETO, 2016). Os prejuízos no controle postural de idosos são evidenciados quando mais de um input sensorial não está disponível ou não é confiável (BISSON; LAJOIE; BILODEAU, 2014). O que não é raro, devido aos prejuízos impostos pelo envelhecimento aos sistemas visual (CLARKE; EVANS; SMEETH, 2018), vestibular (ARSHAD; SEEMUNGAL, 2016) e proprioceptivo (PROSKE; GANDEVIA, 2012).

Com efeito, um estudo demostrou que jovens foram capazes de limitar as oscilações posturais devido à fadiga, possivelmente utilizando fontes sensoriais mais confiáveis, como inputs vestibulares e proprioceptivos (PAILLARD, 2012a). Outro estudo evidenciou que a fadiga influencia mais o controle postural de idosos quando a informação proprioceptiva no tornozelo é alterada e que idosos tem mais dificuldade e necessitam de mais atenção para ficar em pé parado após fadiga, em comparação com adultos jovens (BISSON; LAJOIE; BILODEAU, 2014).

Já se sabe que a atrofia, redução de massa, força, potência e resistência muscular e prejuízo na condução do nervo motor em idosos são ainda mais acentuadas na presença de Diabetes tipo 2 (ALLEN et al., 2016) . Dados prévios indicam que o diabetes predispõe à maior fadiga muscular tanto em contrações isométricas (ORLANDO et al., 2016) quanto dinâmicas (IJZERMAN et al., 2012). E que a fadiga muscular pode ser um marcador mais sensível que a força muscular aos danos causados pelo diabetes tipo 2 (ORLANDO et al., 2016).

Os mecanismos que explicam a maior fadiga muscular em diabéticos permanecem pouco claros. Tem sido sugerido que o déficit na condução nervosa decorrente de neuropatia periférica causa atrofia muscular dos segmentos distais dos membros inferiores, devido à desnervação combinada com uma reinervação insuficiente (ANDREASSEN et al., 2009). Vários autores têm relatado aumento da porcentagem de fibras tipo II, redução de fibras tipo I (OBERBACH et al., 2006; STUART et al., 2013) e baixa densidade capilar em diabéticos (MARIN et al., 1994). No mesmo sentido, tem sido demonstrado aumento da capacidade glicolítica e redução da capacidade oxidativa em pacientes com diabetes tipo 2. Isso tem sido atribuído à atividade enzimática alterada, com maior atividade das enzimas glicolíticas e redução da atividade enzimática oxidativa (OBERBACH et al., 2006).

Outro ponto que interessante, é que músculos oxidativo possuem mais receptores de insulina (JAMES; JENKINS; KRAEGEN, 1985). A diminuição na proporção de fibras oxidativas poderia contribuir para a resistência à insulina, que por sua vez, predispõem a hiperglicemia (MARIN et al., 1994). A baixa densidade capilar poderia dificultar a chegada da glicose e de insulina à célula, assim, o aumento da atividade glicolítica se configuraria como um mecanismo compensatório. Oberbach et al. (2006) sugeriu que a absorção e função da insulina tem sido dependente da densidade capilar. E que as alterações na composição da fibra muscular em condição de resistência à insulina são secundárias à hiperinsulinemia.

Apesar das hipóteses apresentadas, todos os autores citados concordam que os mecanismos para a redução da atividade enzimática oxidativa e a redução das fibras tipo I em pacientes com diabetes tipo 2 ainda precisam ser melhor estudados. E isso poderia ajudar a esclarecer a maior fadiga apresentada por indivíduos diabéticos tipo 2.

Em todo caso, o aumento da fadiga observada em diabéticos é preocupante, sobretudo quando associados aos declínios relacionados à idade e ao gênero. Essa combinação pode representar um maior prejuízo no controle postural, predispondo mulheres idosas diabéticas à maior risco de queda. Até o presente momento não existem estudos que investigaram a influência da fadiga dos músculos de tornozelo no equilíbrio de indivíduos diabéticos tipo 2.

2 OBJETIVOS

2.1 OBJETIVO GERAL

Comparar a ativação dos músculos da perna (tibial anterior e gastrocnêmio) e o equilíbrio pré e pós fadiga de membro inferior de mulheres idosas com e sem diabetes tipo 2.

3 HIPÓTESE

Mulheres idosas diabéticas irão apresentar prejuízo no controle postural decorrente de menor ativação dos músculos de tibial anterior e gastrocnêmio medial que será evidenciada ou acentuada pela fadiga muscular.

4 MATERIAIS E MÉTODOS

4.1 DESENHO DO ESTUDO

Esse é um estudo observacional de corte transversal não randomizado. A amostra foi composta por idosas da cidade de Governador Valadares. As avaliações para recrutamento seguiram até atingirmos um n= 54 idosas, sendo 28 idosas Diabéticas e 26 Idosas não Diabéticas.

4.2 CÁLCULO AMOSTRAL

O cálculo amostral foi realizado no programa G-Power (Versão 3.1.5, Franz Faul, Universidade de Kiel, Alemanha) baseado no estudo de Kukidome et al., (2017) que comparou idosos adultos com e sem diabetes tipo 2 com um tamanho de efeito de 1.6 para medidas de área de oscilação na postural em pé, o poder foi de 0,95 considerando nível alfa de 5%. A análise de potência de duas caudas retornou uma potência real de 0,96 para uma amostra de 24 sujeitos.

4.3 AMOSTRA

Os participantes foram recrutados na comunidade local via chamada pública com cartazes e panfletos na universidade e clínica de fisioterapia do Campus Governador Valadares. Os procedimentos foram realizados na Clínica Escola de Fisioterapia da UFJF-GV com ambiente privativo e adequado às regras sanitárias vigentes, conforme atesta a declaração de infraestrutura e concordância para realização da pesquisa (APÊNDICE I).

Todos os participantes assinaram o termo de consentimento informando sua participação no estudo (APÊNDICE II), previamente aprovado pelo Comitê de Ética da instituição, parecer nº 62606616.2.0000.5147. Além disso, os investigadores responsáveis por este trabalho estavam comprometidos com a resolução 466/12 do Conselho Nacional de Saúde. A pesquisa só teve início após aprovação do Comitê de Ética em Pesquisa via plataforma Brasil.

Os participantes foram orientados sobre os procedimentos para a participação na investigação, obtendo assim mais familiaridade com a equipe e os comandos verbais para realizarem os exercícios.

4.4 CRITÉRIOS DE INCLUSÃO

Os critérios de inclusão utilizados para essa pesquisa foram: GID - Grupo Idosas Diabéticas: ter diagnóstico médico de diabetes tipo 2 verificado através de prontuário médico, possuir 60 anos ou mais, ser fisicamente independente, ter pontuação acima de 21 no questionário Mini-Exame do Estado Mental (ANEXO I); GInD - Grupo Idosas não Diabéticas: não ser diabética, possuir 60 anos ou mais, ser fisicamente independente, ter pontuação igual ou superior à 22 no questionário Mini-Exame do Estado Mental que é o ponto de corte para declínio cognitivo em pessoas alfabetizadas (BRUCKI et al., 2003).

4.5 CRITÉRIOS DE EXCLUSÃO

Foram excluídos os indivíduos que apresentaram doença neurológica, doença cardiovascular, retinopatia proliferativa instável, doença renal em estágio terminal, história de doenças vestibulares, hipertensão não controlada, distúrbios de atenção e de fala, submetidos a algum tipo de cirurgia do aparelho locomotor e/ou participação em treino equilíbrio/resistência no ano anterior. Todos os participantes estavam livres de lesão no joelho ou no quadril, o que poderia afetar seu equilíbrio.

4.6 INSTRUMENTOS DE AVALIAÇÃO

A plataforma de força BTrackS (Balance Tracking System, San Diego, CA, USA) foi usada para mensurar o equilíbrio. O equipamento é uma plataforma de força (40x60 cm, com frequência de amostragem de 25 Hz) com quatro medidores de tensão que determinam a área de excursão do centro de gravidade enquanto o sujeito permanece sobre ela. A frequência de amostragem da BTrackS satisfez a teoria de Nyquist (25 Hz), sendo as mudanças do centro de gravidade em torno de 10 Hz (O'CONNOR; BAWEJA; GOBLE, 2016). A plataforma de força utilizada foi validada e tem a mesma precisão de uma plataforma de força laboratorial (LEVY; THRALLS; KVIATKOVSKY, 2016). A plataforma de força foi nivelada via ajuste nos apoios inferiores e verificada com uma ferramenta de nivelamento. O equipamento foi conectado a um computador via cabo USB que também forneceu energia para a plataforma.

Para avaliar a atividade muscular, foi utilizado o eletromiógrafo de superfície com oito canais analógicos e software integrado para coletar e analisar os sinais (MiotecSuite, BiomedicalEquipment, Porto Alegre, RS, Brasil). A conversão analógico-digital foi realizada pela placa A/D com resolução de 14 bits, frequência de amostragem de 2 kHz, módulo de rejeição comum maior que 100 dB, relação de ruído de sinal com menos de 3 µV RMS e impedância de 109 ohms. Os sinais da eletromiografia de superfície (sEMG) foram gravados com eletrodos Meditrace Ag/AgCl com uma distância de 2 centímetros de centro a centro. Os sinais sEMG foram amplificados e filtrados. A raiz média quadrática (RMS) foi analisada em um janelamento predefinido de fábrica de 125 ms, usando o software MiotecSuite. Os eletrodos de sEMG foram colocados paralelamente às fibras musculares subjacentes do gastrocnêmio medial e do tibial anterior no membro inferior dominante, de acordo com as recomendações do SENIAM. Um eletrodo de referência foi colocado no epicôndilo lateral do úmero esquerdo. Antes da fixação, a pele foi higienizada com álcool 70% para eliminar gorduras residuais, seguido de esfoliação com uma lixa específica para a pele e foi limpa, novamente, com álcool. Todos os procedimentos para captar os sEMG foram conduzidos de acordo com as recomendações da Sociedade Internacional de Eletrofisiologia e Cinesiologia.

Para normalização do sinal, foram coletadas 3 contrações isométricas voluntárias (CVM) máximas de 5 segundos de duração. Para as CVMs os participantes foram instruídos a exercer o máximo de esforço em cada ensaio. Um período de 5 minutos de descanso separou cada contração. Para o gastrocnêmio medial (GM), o joelho estava completamente estendido. Os participantes foram convidados a empurrar o chão com o máximo de força possível com uma perna enquanto levantavam o corpo na ponta do pé (flexão plantar). Para manter o equilíbrio, foi permitido que o participante utilizasse um andador. Para tibial anterior (TA), os participantes foram instruídos a aumentar a força da dorsiflexão de tornozelo por no máximo 3 segundos e depois manter a força máxima por 5 segundos. A resistência manual foi oferecida sempre pelo mesmo avaliador no médio-pé.

Após normalizado o sinal eletromiográfico, o paciente foi posicionado sobre a plataforma de força, onde foi realizado o teste de equilíbrio monopodal de 20 segundos com os olhos abertos, com um período de familiarização prévia de igual tempo. Na sequência, o paciente desceu da plataforma de força e realizou um protocolo de fadiga que consistiu em contração voluntária sustentada na ponta dos pés com apoio bipodal até o momento de falha da tarefa. Nesse momento, o paciente voltou para a plataforma de forças e repetiu o teste de equilíbrio. Os testes foram conduzidos em uma sala privativa para minimizar interferências externas, como ruído e outros distúrbios. Todos os testes foram realizados sem calçados.

Todos os dados de sEMG foram normalizados para CVM e a atividade muscular foi calculada a partir de janelas de 20 segundos, sincronizadas com os registros da plataforma de força por e uma webcam através o software MiotecSuite.

O nível de atividade física foi avaliado pelo questionário internacional de atividade física – IPAC versão curta (ANEXO II) (IPAQ RESEARCH COMMITTEE et al., 2005). O receio de queda foi avaliado pelo FES-I-Brasil, instrumento que apresenta questões sobre a preocupação com a possibilidade de cair ao realizar 16 atividades, com respectivos escores de um a quatro. O escore total pode variar de 16 (ausência de preocupação) a 64 (preocupação extrema) sendo que 23 é tido como ponto de corte para a presença de preocupação com quedas. (ANEXO III) (CAMARGOS et al., 2010).

4.7 METODOLOGIA DE ANÁLISE DE DADOS

Participaram do estudo 54 pacientes, que realizaram todas as avaliações, resultando em 32 variáveis diferentes.

A estatística descritiva foi apresentada como média e desvio padrão. O teste de Lilliefors foi utilizado para testar a distribuição gaussiana dos dados. Como a normalidade foi aceita, o teste t independente foi utilizado para comparar as diferenças entre os grupos. A significância foi estabelecida em p <0,05.

Foi utilizada a curva Receiver Operating Characteristic (ROC) para discriminar mulheres idosas diabéticas tipo 2 de idosas não diabéticas e determinar a acurácia de cada variável individualmente. A curva ROC e sua área correspondente sob a curva (AUC) foram estimadas e foram obtidos os pontos de corte ótimos que melhor discriminaram entre indivíduos com e sem diabetes tipo 2. Todas as análises foram realizadas no pacote SPSS (versão 18.0).

5 RESULTADOS

Balance and Leg Muscle Activation of Older Women with and without Type 2 Diabetes

Older adults who develop type 2 diabetes have increased chance of falling. Muscle strength and balance impairments can increase the risk for falls, and muscle fatigue reduces the capacity to generate force. The objective of the present study was to compare the muscle activation patterns and the postural balance during one-leg stance balance test in type 2 diabetes and non-diabetes older women before and after completion of a fatiguing rise-to-toes task. Fifty-four older women were divided into two groups: diabetes (n=28; 70±6 years old) and non-diabetes (n=26; 71±8 years old). A force platform was used to assess the postural balance and surface electromyography was used to evaluate the tibialis anterior (TA) and gastrocnemius medialis (GM) activation. Independent t-test was used to assess differences between groups. The significance was set at α=0.05. The Receiver Operating Characteristic curve was used to determine the responsiveness and the accuracy of each variable to discriminate diabetic older women from non-diabetic. The diabetic group had higher RMS_ML, RMS_AP, and TA_MEAN before and after the fatiguing task. No significant intra-group differences were observed before and after the fatiguing task. RMS_ML_PRE, RMS_ML_POST, RMS_AP_PRES, RMS_AP_POST, TA_MEAN_PRE and TA_MEAN_PRE values can discriminate diabetic older women from those without Diabetes.

Keywords: postural Balance; electromyography; muscle fatigue; older adults; type 2 diabetes

Introduction

Falls in old adults are a major public health concern worldwide; 1 out of 3 older adults fall each year and 68% of people who fall suffer some injury (Vieira, Palmer and Chaves, 2016). Falls are the largest contributor to the economic burden of injuries concerning lifetime costs in old adults (Heinrich, Rapp, Rissmann, Becker and König, 2010). For several decades, research has focused on identifying risk factors, reducing and managing falls in old adults (Binda, Culham and Brouwer, 2003; Jalali, Gerami, Heidarzadeh and Soleimani, 2015). Falls are associated with sex and chronic conditions such as type 2 diabetes (Vinik, Vinik, Colberg and Morrison, 2015; Vieira, Palmer and Chaves, 2016). Older women have more balance impairments than older men (Valentine *et al.* 2009; Ambrose, Paul and Hausdorff, 2013; Scaglioni-Solano and Aragón-Vargas 2015); and they are more prone to falls and its complications because balance deteriorates due to estrogen deficiency after menopause (VALENTINE et al., 2009); The type 2 diabetes involves insulin resistance and relative insulin deficiency (WATANABE et al., 2012). In 2000, it was expected that around 366 million individuals would have type 2 diabetes in 2030 (WILD et al., 2004), but in 2013, 382 million people already had diabetes; with an expectation for 592 million by 2035 (GUARIGUATA et al., 2014). Individuals with type 2 diabetes have increased chance of falling compared with those without diabetes (Morrison *et al.* 2010; Vinik, Vinik, Colberg and Morrison, 2015). The combination of older age (>65 years) and diabetes increases 17-fold the risk of falling (Vinik, Vinik, Colberg and Morrison, 2015). Falling in older people who have type 2 diabetes is associated with the functional decline due to neuropathy, somatosensory, cognitive, visual and vestibular impairments (Hewston and Deshpande, 2015; Vieira, Palmer and Chaves, 2016).

An essential and modifiable factor to be assessed for falls management is the postural balance (Morrison *et al.* 2010; Jalali, Gerami, Heidarzadeh and Soleimani, 2015; Vieira, Palmer and Chaves, 2016). The loss of muscle strength is an essential factor to impaired balance function in older adults (Vieira, Palmer and Chaves, 2016). Several balance tests can be used to assess impairments associated with components of postural control among older adults, but the force platform is considered the gold standard equipment for such quantitative assessments. The force platform can register forces applied in its corners while the subject stands in a semi-static position (Piirtola and Era, 2006). Another test is the 1-legged stance task on the force platform, which was suggested as more predictive of balance impairments than the bipedal quiet standing task as it provides more challenge to balance-control (Parreira *et al.*, 2013). A derived from all forces affecting the force platform's corners represents the center of pressure (COP). Increased COP variables have been considered as an indicative of poorer balance in old adults, with the association of stabilometric parameters to a higher likelihood of falling (Hita-Contreras *et al.*, 2013; Muir *et al.*, 2013; Park, Jung and Kweon, 2014).

Muscle strength decreases with age (Morrison *et al.*, 2010) and adequate strength is essential to optimal balance. The dorsiflexion strength is considered an important factor for postural stability, fall recovery, and normal walking among old adults (Perry *et al*,. 2007; Siddiqi, Kumar and Arjunan, 2015; Vieira *et al.*, 2017) and the strength and activation of tibialis anterior (TA) and gastrocnemius medialis (GM) are essential for balance control (Shumway-Cook and Woollacott, 2000; Jeon and Choi, 2015). Muscle fatigue reduces the capacity to generate force, and completing fatiguing tasks can affect balance control (Bellew and Fenter, 2006). The ability to perform tasks for prolonged periods of time during activities of daily living is affected by fatigability and fatigue-induced changes in motor control (Bellew and Fenter, 2006; Christie, Snook and Kent-Braun, 2011). Muscle fatigue may alter postural control in healthy young and older individuals, and possibly increase the risk for falls (Paillard, 2012; Papa, Foreman and Dibble, 2015).

Previous data indicate that diabetes predisposes to greater muscular fatigue (Ijzerman *et al.*, 2012, Orlando *et al.*, 2016). The primary purpose of the present study was to compare muscle activation patterns and balance measurements in diabetes and no diabetes older women before and after completion of a fatiguing rise-to-toes task. The hypothesis was that one-leg stance balance would be worse in type 2 diabetes older women and that fatiguing task will highlight the differences between groups. A secondary purpose was to determine cutoff points to discriminate between diabetes and no diabetes older women. We hypothesized that stabilometric and electromyography measures would have the ability to discriminate both groups.

Methods

Experimental Approach to the Problem

This is a cross-sectional study, developed in Governador Valadares City, Brazil. The local ethics committee for human investigation approved the procedures employed in the study (Protocol number 62606616.2.0000.5147) and participants were notified of the benefits and potential risks involved before signing an institutionally approved informed consent form prior to participation.

Participants

The participants were recruited by public invitation through folders and personal contacts. The inclusion criteria were to have 60 years old or more, to be physically independent, to have a score higher than 21 on the Mini-Mental State Examination, the participants were divided into 2 groups: (1) Diabetes Group (n=28; 70±6 years-old); (2) Non-Diabetes Group (n=26; 71±8 years-old). All participants were free of any knee or hip injury which could affect their balance. Exclusion criteria included cardiovascular disease, unstable proliferative retinopathy, end-stage renal disease, uncontrolled hypertension, and/or participation in balance/resistance training during the previous year. All participants have medical diagnostic as verified through their medical records. The participants included in the Diabetes Group should present more than one year of type 2 diabetes diagnosis.

Based on a previous study (Kukidome *et al.*, 2017) which compared older adults with and without type 2 diabetes with an effect size of 1.6 for measurement of the standing postural sway area, the power was set at 0.95 and the sample size was calculated using the G-Power software (Version 3.1.5, Franz Faul, Universitat Kiel, Germany) considering an alpha level of 0.05. The power two-tailed analysis returned an actual power of 0.96 for a sample size of 24 subjects.

Equipment

The BTrackS Balance Plate (Balance Tracking System, San Diego, CA, USA) was used to assess balance. The equipment is a force platform (40x60 cm, sampling frequency of 25 Hz) with 4 implanted strain gauges that determines the COP excursion area while the subject stood on it. The BTrackS sampling frequency satisfied the Nyquist theorem for the slow (<10 Hz) COP changes measured in the present study (O'Connor, Baweja and Goble, 2016). The force platform has the same accuracy/precision of a laboratory-grade force platform (Levy, Thralls and Kviatkovsky, 2016; O'Connor, Baweja and Goble, 2016). The force platform was leveled via adjustable legs and verified with a leveling tool. The force platform was connected to the computer through USB cable which also provided power to the platform.

To assess the muscle activity, a surface electromyographer with 8 analog channels and integrated software was used to collect and analyze the surface electromyographic signals (sEMG) (Miotec Suite™, Biomedical Equipment, Porto Alegre, RS, Brazil). Analog to digital conversion was performed by an analog to digital board with 14-bit resolution input range, the sampling frequency of 2 kHz, common rejection module greater than 100 dB, signal noise ratio of less than 3 μV RMS and impedance of 109 ohms. The sEMG signals were recorded with surface Meditrace™ Ag/AgCl electrodes with a center to center distance of 2 cm. sEMG signals were amplified and filtered (Butterworth fourth order; 20-450 Hz bandpass filter; 60 Hz notch filter).The root mean square (RMS) of the sEMG data was windowed at 125 ms using the Miotec™ Suite Software.

Procedures

The sEMG electrodes were applied parallel to the underlying muscle fibers of the medial gastrocnemius and tibialis anterior on the dominant lower limb according to SENIAM recommendations (http://seniam.org/sensor_location.htm). A reference electrode was placed on the left lateral humeral epicondyle. Prior to fixation, the skin was cleaned with 70% alcohol to eliminate residual fat, followed by an exfoliation using a specific sandpaper for skin and a second cleaning with alcohol. All sEMG procedures were conducted accordingly to the International

Society of Electrophysiology and Kinesiology (ISEK) recommendations.

All sEMG data were normalized to the maximum voluntary isometric contraction (MVIC), and the mean muscle activity was calculated from 20-second windows, synchronized to force platform recordings through the Miotec Suite™ software. Participants were instructed to provide maximal efforts on each trial. A 5-minute rest period separated each contraction. For GM, the knee was fully extended. Participants were asked to push the ground as hard as possible with 1 leg while raising the body to toes (plantarflexion). The other limb remained extended but did not touch the ground while data were collected. To keep the balance, the participant was allowed to use a walker. For TA, participants were instructed to increase ankle dorsiflexion force from baseline to maximum over 3 seconds and then to maintain the maximum force for 5 seconds. Manual resistance was always provided by the same rater on the midfoot.

After normalizing the electromyographic signal, the patient was positioned on the force platform for performed 20-s one-leg stance with open eyes to assess balance with a previous familiarization period. Participants were instructed to look straight ahead at a target placed on a wall at eye level 2 meters away, with their arms resting at their side. After balance test, the patient went down from the force platform and performed a fatigue protocol that consisted of sustained voluntary contraction on the tip of the feet with bipodal support until the task failed. At that moment, the patient returned to the force platform and repeated the balance test. All tests were performed without shoes. The same experienced researcher performed all testing. Repeatability of foot placement between trials was maintained by tapes fixed on top of the force platform. Participants were attached to a belt fixed to the wall to prevent falls during testing and a examiner stood close to the participant during all trials. The tests were conducted in a private room to minimize outside interference such as noise and other disturbances.

Statistical Analysis

We had 54 patients and several independent variables showed on table 1.

The preliminary Lilliefors test was not significant, and the independent t-test was used to set differences between the groups. The significance was set at $p<0.05$. The Receiver Operating Characteristic (ROC) curve was used to determine the responsiveness and the accuracy of each variable individually in discriminating diabetic older women from non-diabetic older women. Based on the ROC curve, the optimal cutoff points that best discriminated between individuals with and without type 2 Diabetes were obtained. ROC curve and its corresponding area under the curve (AUC) were estimated with the SPSS package (version 18.0).

Table 1. Independents variables description.

	Variables	Description
1	BMI	Body Mass Index is body mass divided by the square of the body height.
2	TYPE 2 DIABETES	Yes or no
3	HISTORY OF FALLS	History of falls in the last 12 months
4	FES-I-BRASIL	Falls Efficacy Scale–International-Brazil. Score of the questionnaire.
5	FES-I-BRASIL	Falls Efficacy Scale–International-Brazil. Classification as faller (≥23) or non-faller (<23)
6	IPAQ	International Physical Activity Questionnaire. Classification as very active, active, irregularly active or sedentary
7	PATH_LENGTH_PRE	Total length of COP displacement
8	PATH_LENGTH_POST	
9	MEAN_VELOCITY_PRE	Total COP length divided by the trial duration
10	MEAN_VELOCITY_POST	
11	MEAN_DISTANCE_PRE	Average distance from COP data center
12	MEAN_DISTANCE_POST	
13	MEAN_FREQUENCY_PRE	Average number of loops to cover COP data
14	MEAN_FREQUENCY_POST	
15	RMS_ML_PRE	Square root of mean squared medial-lateral COP data
16	RMS_ML_POST	
17	RMS_AP_PRE	Square root of mean squared anterior-posterior COP data
18	RMS_AP_POST	
19	95%_CI_ELLIPSE_AREA_PRE	Smallest ellipse fitting 95% of COP data
20	95%_CI_ELLIPSE_AREA_POST	
21	EXCURSION_ML_PRE	Max minus Min COP data in medial-lateral direction
22	EXCURSION_ML_POST	
23	EXCURSION_AP_PRE	Max minus Min COP data in anterior-posterior direction
24	EXCURSION_AP_POST	
25	TA_PEAK_PRE	Max amplitude of the Tibialis anterior EMG signal
26	TA_PEAK_POST	
27	TA_MEAN_PRE	Mean amplitude of the Tibialis anterior EMG signal
28	TA_MEAN_POST	
29	GM_PEAK_PRE	Max amplitude of the Gastrocnemius medialis EMG signal.
30	GM_PEAK_POST	
31	GM_MEAN_PRE	Mean amplitude of the Gastrocnemius medialis EMG signal
32	GM_MEAN_POST	

Legend: IPAQ = international physical activity questionnaire; FES-I-Brazil = Falls Efficacy Scale–International-Brazil; PRE = pre fatiguing task; POST = post fatiguing task; RMS = root mean square; AP = anterior-posterior; ML = medial-lateral; CI = confidence interval; TA = tibialis anterior; GM = Gastrocnemius medialis

Results

The participants did not report pain or discomfort during tasks. Participants's characteristics were similar between groups (Table 2).

Table 2. Participants' characteristics.

	Groups		
Characteristics	**Diabetes** (mean and standard deviation)	**non-Diabetes** (mean and standard deviation)	**p**
n	28	26	-
Age (years)	70 (6)	71 (8)	0.34
BMI (Kg/m^2)	30.1 (6)	26.1 (3)	0.22
FES-I-Brazil	28.3 (9.5)	25.7 (6.5)	0.28
History of Falls (falls in last 12 mouth)	1.5 (0.5)	1.5 (0.5)	0.34

Legend: BMI = body mass index; FES-I-Brazil = Falls Efficacy Scale–International-Brazil.

The international physical activity questionnaire (IPAQ) classification shows that in diabetic group all participants were irregularly active. While in the non diabetic group 65,3% were irregularly active, 30,7% were active and only 3,8% were sedentary.

From all studied variables, only RMS_ML_PRE, RMS_ML_POST, RMS_AP_PRE, RMS_AP_POST, TA_MEAN_PRE and TA_MEAN_POST showed significant differences between both groups (Table 5). No additional significant intra-group differences were observed before and after the fatiguing task (Table 3 and 4).

Table 3. Intragroup comparisons of postural balance and surface electromyography pre and post fatiguing task of the diabetic group

Parameters	**Diabetes**		
	PRE	POST	**p**
RMS_ML (cm)	1.11 (0.58)	1.15 (0.62)	N/S
RMS_AP (cm)	2.55 (1.63)	2.82 (2.01)	N/S
TA_MEAN (Hz)	49.74 (23.58)	51.55 (28.33)	N/S

Table 4. Intragroup comparisons of postural balance and surface electromyography pre and post fatiguing task of the non-diabetic group

Parameters	**Non-Diabetes**		
	PRE	POST	**p**
RMS_ML (cm)	0.61 (0.18)	0.63 (0.13)	N/S
RMS_AP (cm)	0.75 (0.20)	0.66 (0.20)	N/S
TA_MEAN (Hz)	29.69 (12.03)	27.00 (11.71)	N/S

Table 5. Inter-group comparisons of postural balance and surface electromyography data pre and post fatiguing task.

Parameters		Diabetes	Non-Diabetes	p	95% Confidence Interval
RMS_ML (cm)	PRE	1.11 (0.58)	0.61 (0.18)	0.0001	0.25 - 0.73
	POST	1.15 (0.62)	0.63 (0.13)	0.0001	0.27 - 0.76
RMS_AP (cm)	PRE	2.55 (1.63)	0.75 (0.20)	0.0001	1.14 - 2.44
	POST	2.82 (2.01)	0.66 (0.20)	0.0001	1.36 - 2.95
TA_MEAN (Hz)	PRE	49.74 (23.58)	29.69 (12.03)	0.0001	9.07 - 30.39
	POST	51.55 (28.33)	27.00 (11.71)	0.0001	12.53 - 36.55

Legend: RMS = root mean square; AP = anterior-posterior; ML = medial-
-lateral; PRE = pre fatiguing task; POST = post fatiguing task;
TA_MEAN = mean amplitude of the tibialis anterior;

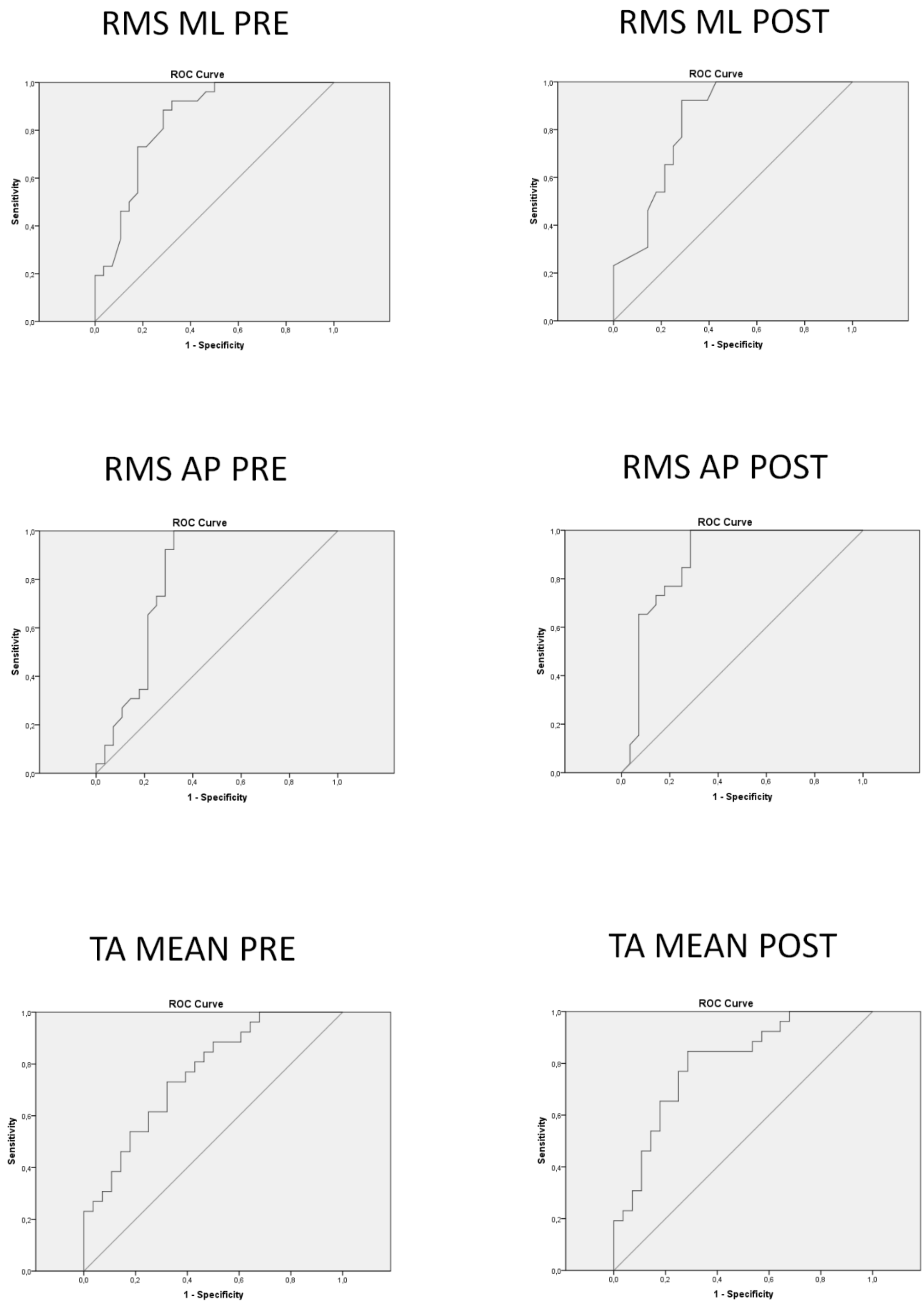
The ROC curve analysis (Table 6) allowed the extraction of the sensitivity, the specificity, and the accuracy from each variable at the best cutoff point. The AUC indicated the discriminatory efficiency between type 2 Diabetes and non-Diabetes groups (Figure 1). The best sensibility scores were RMS_AP_POST, RMS_AP_PRE and RMS_ML_POST 0.96, 0.92, 0.92 respectively, but moderate specificity (0.72 each) and moderate accuracy (0.74, 0.60, 0.66 respectively) were also noted. The TA_MEAN_PRE showed the lowest result for AUC (0.76), sensibility (0.73), specificity (0.68) and accuracy (0.52).

Table 6. ROC curve analysis

Parameter	Cutoff point	AUC	Se	Sp	Accuracy
RMS_ML_PRE (cm)	0.80	0.84	0.88	0.72	0.68
RMS_ML_POST (cm)	0.80	0.83	0.92	0.72	0.66
RMS_AP_PRE (cm)	0.99	0.80	0.92	0.72	0.60
RMS_AP_POST (cm)	1.05	0.87	0.96	0.72	0.74
TA_MEAN_PRE (%)	34.17	0.76	0.73	0.68	0.52
TA_MEAN_POST (%)	34.68	0.80	0.84	0.72	0.60

Legend: AUC = area under the curve; RMS = root mean square; AP = anterior-posterior; ML = medial-lateral; PRE = pre fatiguing task; POST = post fatiguing task; TA_MEAN = mean amplitude of the tibialis anterior; Se = sensibility; Sp = specificity.

Figure 1. ROC curves for cutoff point to discriminate diabetic form non-diabetic older women for stabilometric and electromyography measures.



Legend: RMS ML PRE = root mean square medial-lateral pre fatiguing task; RMS ML PPST = root mean square medial-lateral post fatiguing task; RMS AP PRE = root mean square anterior-posterior pre fatiguing task; RMS AP POST = root mean square anterior-posterior post fatiguing task; TA MEAN PRE = mean amplitude of the tibialis anterior pre fatiguing task; TA MEAN POST = mean amplitude of the tibialis anterior post fatiguing task;

Discussion

In the present study, we compared older women with and without type 2 diabetes during one leg stance balance before and after a fatiguing task. The Diabetes group had higher RMS_ML_PRE, RMS_ML_POST, RMS_AP_PRE, RMS_AP_POST, TA_MEAN_PRE and TA_MEAN_POST. No intra-group differences were observed before and after the fatiguing task. The ROC curve analysis of each parameter showed good results for the combined sensibility and specificity to discriminate diabetic and non-diabetic groups. Nevertheless, the accuracy showed moderate results to discriminate the groups.

The RMS_ML and RMS_AP were higher for the diabetic group in both conditions (before and after fatigue). A review indicated that increased postural sway in ML direction was identified as the best factor to predict a fall episode in older adults (Piirtola and Era, 2006). Another review indicated that anteroposterior sway can distinguish older adult fallers from non-fallers (Pizzigalli, Micheletti Cremasco, Mulasso and Rainoldi, 2016). For these authors, mediolateral sway in bipedal stance was associated with the ability to use hip's abductors/adductors and the ankle's pronators/supinators muscles to distribute the body weight between the two lower limbs, while anteroposterior sway is associated with variations in ankle flexor muscles activity. In the present study, the balance task was one-legged stance that is a greater challenge compared with a bipedal task, demanding a greater control of hip muscles. Another study assessed the postural balance in many situations, standing with eyes open/closed on a firm surface, eyes open/closed on a compliant surface, eyes open on a firm/compliant surface while performing a cognitive task, and suggested that an increase in the difficulty level of the balance task may probably result in a switch from the ankle to the hip control mechanism (Maranesi *et al.,* 2016). The diabetic group showed impaired sway in both directions: increased ML oscilations to control movements in the frontal plane and increased AP displacements to control the postural balance in sagittal plane. The current findings of increased RMS AP and ML are in agreement with previous studies that have found decreased ability to keep balance in older women with type 2 diabetes (Centomo *et al.,* 2007; Morrison, Colberg, Parson and Vinik, 2012; Kukidome *et al.*, 2017). Morrison et al. (2012) assessed the differences in dynamic postural motion and the fall risk in older men and women with type 2 diabetes classified as fallers/non-fallers. The authors also evaluated the impact of exercise on balance and falls risk. Thirty-seven older individuals were allocated in 4 groups (control-non fallers, control fallers, diabetic-non fallers and diabetic fallers), and performed double leg stance in four different conditions, eyes open/firm surface, eyes closed/firm surface, eyes open/ foam surface and eyes closed/ foam surface. At baseline, they found decreased COP amplitude with higher standard deviation and higher sway velocity in diabetic fallers group in more challenging conditions. They hypothesized the decreased amplitude occurs simultaneously to the increased frequency of sway COP, and that such changes were due to an increased body stiffness. Such strategy is often adopted under situations where a perceived threat to overall balance is assumed (Adkin, Frank, Carpenter and Peysar, 2000; Carpenter *et al.*, 2004). These findings contrast with our findings of increased sway amplitude in diabetic group, possibly due differences in group conditions or differences between balance tests. In the present study, we investigated only older women due to worse balance (Vieira, Palmer and Chaves, 2016) by using the one-leg stance balance test, which is a more challenging test. The small sample size of each group is also an issue of Morrison's study, which was probably responsible for the higher amplitude variability results.

The one-leg stance balance test was performed associated with the electromyography TA and GM muscles to assess the differences in the muscle activation pattern between both groups. The diabetic group showed higher TA activation compared with the non-Diabetes group. The ankle joint is the greatest source of corrective actions during one-legged standing (Hwang, Huang, Cherng and Huang, 2006). The requested force output is also proportional to the amplitude of the sEMG signal (De Luca, 1997). The mean amplitude value provides an overall estimate of muscle activation, and it is related to the number of motor units (MU) recruited and their discharge frequency (Merletti, Farina and Gazzoni, 2003). Previous research showed that diabetic subjects showed weakest dorsiflexors and plantar flexors compared with control subjects during a quiet stance task

(Błazkiewicz *et al.,* 2015, Gomes *et al.,* 2017). Another study noted the loss of motor units as partially responsible for muscle atrophy and weakness (Yu *et al.,* 2007). Current findings showed greater TA amplitude while failing on support the postural balance. The increased TA activation in the diabetes group does not imply enhanced efficiency to stabilize the COP, as can be noted by the stabilometry results. We hypothesize that the lower ability to maintain balance in older diabetic women requires greater ankle stiffness and greater force production. Hyperglycemia leads to increased oxidative stress which may contribute to micro-vascular disease, nerve dysfunction (Fernando *et al.,* 2013) and loss of motor units which will overload the remaining fibers and increase the amplitude of the sEMG to generate enough torque to maintain the postural balance. The nerve dysfunction affects not only motor nerves, but also the sensitive nerves. The changes in sensitive nerves affect their feedback to the central nervous system, impairing the accuracy of compensatory adjustments to maintain postural balance. The present study showed no differences in postural balance between the conditions pre and post fatiguing task for non-Diabetes group. Similar to our findings, Lin et al. (2009) investigated the effects of fatigue and age in postural control. They found an impaired postural control immediately after the fatiguing task only in the younger group. They suggested that the older group may have employed a more efficient hip strategy to compensate postural perturbations induced by muscle fatigue. They suggested that older group may have experienced less fatigue due to differences in motivation, tolerance for discomfort, or differences in central fatigue processing (Lin *et al.,* 2009). In the present study the hip strategy in sagittal plane was not allowed, but the findings were similar to Lin's study. Older people also present greater proportion of type I fiber, which are more fatigue resistant (Kelly *et al.,* 2018). However, diabetic people have higher percentage of type 2 fiber than non-diabetic (Marin, Andersson, Krotkiewski and Bjorntorp, 1994; Oberbach *et al.,* 2006; Stuart *et al.,* 2013), so we expected type 2 diabetic older women would have a worse balance after fatigue. As far as we know, this is the first study that investigated the one-legged balance ability in type 2 diabetic older women before and after a fatiguing task. The findings showed that fatigue did not affect diabetic older women's balance, as expected. The aging-related changes in muscle fibers seem to overlap the changes related to Diabetes. Further studies are necessary to clarify the exact process on how those changes occur in older women with and without Diabetes.

We aimed to determine cutoff points to discriminate diabetic from non-diabetic older women, establishing the sensibility, the specificity and the accuracy. The ROC curve analysis returned 88% sensitivity in identifying type 2 diabetic older women and 72% of specificity in identifying healthy older women for a 0.80 cm RMS_ML_PRE cut-off point, with an accuracy of 68%. A 92% of sensitivity and 72% of specificity for 0.80 cm RMS_ML_POST cut-off point was also reported, with an accuracy of 66%. When assuming 92% sensitivity of and 72% of specificity for RMS_AP_PRE, a 0.99 cm cut-off point was found, with an accuracy of 60%. For 96% sensitivity of and 72% of specificity for RMS_AP_POST, there was an accuracy of 74% at the 1.05 cm cut-off point. The increased postural sway in AP direction after fatiguing task was the best discriminative value between diabetic and non-diabetic group. Although, it seems that the increased postural sway in ML and AP directions also have the ability to discriminate both groups.

A study investigated standing posturography in older adults to determine appropriate outcome measure cut-off point to discriminate fallers and non-fallers. They reported 81% of sensitivity and 32% of specificity for 0.2cm RMS_ML cut-off point, with an accuracy of 55% (Howcroft, Lemaire, Kofman and McIlroy, 2017). The authors conclude that RMS-AP could discriminate between fallers and non-fallers. The optimal test would show low frequency of false positives and false negatives, which means maximum accuracy. The sensitivity of a clinical test refers to the ability of the test to correctly identify those patients with the dysfunction, and the specificity refers to the ability of the test to correctly identify those patients without the dysfunction (Lalkhen and McCluskey, 2008). The accuracy is the closeness of agreement between a measured value and a true or accepted value, and the measurement error is the amount of inaccuracy (Lalkhen and McCluskey, 2008; Portney, Watkins and Portney, 2009). Our best discriminatory measure was

RMS_AP_POST with 96% of sensitivity, 72% of specificity and 74% of accuracy. The present study is the first in determine cutoff points for stabilometric measures to discriminate between diabetic and non-diabetic older women. Such results determinate thresholds for changes in balance before a fall event occurs, leading to preventive interventions.

We also suggest a cutoff point for electromyographic measures. The ROC curve analysis of the electromyographic activity of tibialis anterior revealed the cutoff point in 34.17% of MVIC for TA_MEAN_PRE when adopted 73% sensitivity of and 68% of specificity for an accuracy of 52%. And the cutoff point was 34.68% of MVIC for 84% sensitivity and 72% of specificity with an accuracy of 60% for TA_MEAN_POST. The greater TA activation in diabetic group is an essential component to keep semi-static stability during 1-legged standing (Hwang, Huang, Cherng and Huang, 2006). The present study is the first to suggest a cutoff point for static postural control parameters and for the electromyographic activity in diabetic older women, so we could not compare our preliminary results with other studies. Another limitation of the present study is the cross-sectional design, which does not allow cause-effect inferences. To respect our subjects' privacy, the activation of hip's muscles were not assessed, which could provide more information about ML movement in the frontal plane. Finally, the muscle strength assessment could provide more insights about the observed changes. However, the time-consuming of the fatigue process decreased the participants' ability to collaborate.

The current results showed that diabetic older women had worse one-leg stance balance than non-diabetic, with no influence of the fatiguing rise-to-toes task. Type 2 Diabetes leaded to an unbalanced activation of leg muscles with increased TA activation. Moreover, the study identified cutoff point to discriminate diabetic older women's postural balance. Further studies would prospectively assess the balance ability in a diabetic group, by evaluating the effectiveness of focused interventions to improve the postural balance control. Such studies could use the cut-off points values as a reference to decreasing the preexisting differences between diabetic and non-diabetic groups, also decreasing the incidence of falls.

Practical applications

The present findings may assist the balance impairments classification in diabetic older women, identifying patients who are more prone to postural deficit and possible falls. The stabilometric parameters establish thresholds for balance impairments in older diabetic women, leading to adequate prescription of targeted approaches with early interventions to decrease the risk of falls. The results also allow objective follow-up of the postural balance evolution in groups under high risk of falls.

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6 CONSIDERAÇÕES FINAIS

Os achados dessa dissertação sugerem que durante o apoio monopodal de 20 segundos idosas diabéticas apresentam pior equilíbrio e maior ativação de TA do que de GM quando comparada a idosas não diabéticas. Possivelmente a maior ativação de TA representa o aumento na rigidez de tornozelo que é necessário para manter o equilíbrio em condições de menor habilidade de controle postural, como é o caso de idosas diabéticas.

Concluímos que a tarefa de fadiga, realizar plantiflexão sustentada máxima (ficar nas pontas dos pés) até a falha da tarefa, não influenciou o equilíbrio nem das idosas diabéticas e nem das não diabéticas. Possivelmente isso seja decorrente da conversão de fibras tipo II em fibras tipo I que acontece com o envelhecimento.

Ainda, identificamos pontos de corte para variáveis estabilométricas que discriminam o equilíbrio de mulheres idosas diabéticas e não diabéticas. Esses limiares serão capazes de determinar mudanças no equilíbrio em idosas diabéticas mesmo que um evento de queda não tenha ocorrido, permitindo estabelecer intervenções preventivas. Além de permitir acompanhar a melhora da capacidade de equilíbrio de idosas diabéticas com a intervenção proposta.

Sugerimos que estudos futuros busquem investigar intervenções capazes de melhorar o controle postural tanto no plano sagital quando no frontal, que representam as alterações observadas nas direções AP e ML em idosas diabéticas.

Por fim, reservei este último parágrafo para contar um pouco da minha experiência com o mestrado. Tudo começou com a escolha do orientador. Estudei o currículo de todos os professores do mestrado e selecionei dois cujas linhas de pesquisa eu me identifiquei. Optei pelo Alexandre, que não era de Juiz de Fora. Essa foi uma estratégia muito bem pensada, pois um professor que estaria chegando em Juiz de Fora provavelmente não conheceria nenhum aluno e assim não teria preferência. O processo seletivo seguiu seus tramites, e chegou o momento da entrevista. Qual não foi a minha surpresa quando Alexandre me questionou se mudar para Governador Valadares não seria um problema. Passou um filme na minha cabeça, eu não estava preparada para essa pergunta, não havia nem ao menos pensado nessa possibilidade. Pensei em tantas coisas tão rápido, família, amigos e empregos. E a resposta saiu com tanta firmeza e certeza, que me surpreendi. Sai da entrevista e decidi não pensar que havia me comprometido em mudar de cidade caso eu passasse, até porque, não sabia se eu tinha sido selecionada, tinham outras pessoas disputando a mesma vaga. E cada problema ao seu tempo. Quando saiu o resultado e vi que havia sido selecionada, foi um mix de sentimentos, uma felicidade, saber que consegui algo que eu desejei tanto, ao mesmo tempo teria que abrir mão de coisas que trabalhei muito para conseguir. A sensação de que minha "estratégia" não foi bem-sucedida, não parava de passar pela minha cabeça. Iniciei o curso, e logo no começo, a sensação de escolha errada foi se esvaindo. Mesmo à distância, Alexandre sempre esteve presente em todos os momentos de elaboração do projeto. Os meses foram passando, eu vim para GV, e eu já não me questionava a escolha que fiz. Tive a oportunidade de fazer parte do NIME, trabalhar em vários projetos e não apenas nesse que aqui apresentei. Participamos de alguns congressos, apresentamos alguns resumos, escrevemos alguns artigos. Tive a oportunidade de ser professora do departamento de fisioterapia da UFJF-GV. Foi um mergulho no mundo científico e acadêmico. Mas claro, no mestrado nem tudo é fácil, o projeto nunca sai exatamente como planejado. E nessas horas, quando tudo parece dar errado, o projeto não sai do papel, e quando sai, você percebe que não tem mais tempo para concluí-lo, são nessas horas que você reconhece a experiência do seu orientador. Que não te deixa desesperar e te apresenta um plano B, e caso o B plano não tivesse funcionado ele já tinha o plano C em mente. Com a vinda para GV percebi que além de um excelente orientador eu tinha um grande amigo, que me apoia e me incentiva. Hoje eu tenho certeza que escolha que fiz foi a escolha mais acertada. Mudar para GV, me tirou do comodismo, me fez crescer profissionalmente e pessoalmente. Meu currículo melhorou muito nesse último ano, mas, mais importante que isso, Alexandre me abriu a porta para o mundo científico, me mostrou que não existe limite, posso ir onde quiser.

7. PRODUÇÃO BIBLIOGRÁFICA

O artigo apresentado aqui como resultado da dissertação será submetido para publicação após as considerações da banca.

Segue a produção bibliográfica em conjunto com o orientador durante o mestrado.

ARTIGO 1

HUMAN MOVEMENT
2018; 19(1): 64–70

GLUTEAL ACTIVATION AND INCREASED FRONTAL PLANE PROJECTION ANGLE DURING A STEP-DOWN TEST IN YOUNG WOMEN

original paper
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ABSTRACT

Purpose. To investigate how the activation of gluteus maximus and gluteus medius interacts with different frontal plane projection angles (FPPA) in healthy young women presenting dynamic knee valgus in one limb while performing the step-down test.
Methods. The total of 18 young women presenting FPPA > 15° during the step-down test in one limb (dynamic knee valgus) were assessed. The other limb should present less than 15° for comparisons. The amplitude of muscle activation was assessed through surface electromyography of gluteus medius and gluteus maximus during 8 subsequent weight bearing step-down tests.
Results. FPPA was positively correlated with gluteus maximus activation and with the assessed side showing FPPA > 15°, which also revealed increased activation of gluteus maximus. No differences were noted for gluteus medius. The principal component analysis explained 73% of the variance in 2 components, with gluteus maximus explaining 48% of the variance on the 1st component. Gluteus medius explained 25% on the 2nd component.
Conclusions. Gluteus maximus seems to be a major component to explain dynamic knee valgus in women without symptoms of patellofemoral pain, probably owing to weakness and lack of stabilization of other proximal muscles of the hip-knee complex during the task.
Key words: assessment, knee, hip, valgus, electromyography

Introduction

Gluteal weakness is often associated with abnormal femoral movements in internal rotation associated to adduction of the hip, leading the knee to move medially on the frontal plane [1]. The misalignment may change the knee kinematics, increasing lateral forces acting on the patella and the occurrence of patellofemoral pain (PFP) [2]. Young women (18–35-year-old) are more affected and show greater changes in lower limb kinematics than age-matched men [3–7]. A systematic review noticed increased dynamic valgus of the knee and increased joint load in women compared with men during landing and pivoting movements [8]. During weight bearing activities, excessive dynamic knee valgus seems to be controlled by increased strength and activation of muscles that oppose the internal rotation associated with the adduction of the femur [9]. A study [10] assessed kinematic variables of the hip and the level of activation of hip muscles while running and landing from a jump, as well as during a step-down test. The results showed decreased hip muscle activation in females with PFP compared with pain-free controls.

The frontal plane projection angle (FPPA) is a two-dimensional measurement often used to assess knee

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kinematics during closed kinetic chain activities [11]. FPPA is related to knee pain severity [12], the prediction of PFP [13], and the interaction between hip abductor isometric torque [14]. Also, passive hip internal rotation range of movement predicts the occurrence of high FPPA during single leg squatting [14].

Surface electromyography (sEMG) can assess hip muscles activation during dynamic knee valgus, highlighting the important role of the gluteus medius to lower limb kinematics [1, 15]. However, no association was observed between the FPPA of the knee and strength of posterolateral hip muscles in a sample with PFP [11]. In a recent study, deficits of strength (28%, approximately) were observed on hip extensors in women with PFP compared with the control group [11]. Another study suggested an association between gluteus maximus weakness and PFP [12]. Additionally, a systematic review with meta-analysis showed inconclusive outcomes to determine whether deficits in hip muscle strength are predisposing factors or a consequence of PFP [16]. The gluteus maximus muscle is a powerful hip extensor and lateral rotator [17], acting in synergy with gluteus medius to dynamically stabilize the hip-knee complex [18]. Souza and Powers [10] showed increased activation of gluteus maximus as an attempt to stabilize the hip joint in subjects with PFP and compensate gluteal weakness during weight bearing activities.

Preliminary evidence for preventive intervention could be provided by identifying the activation pattern on the main gluteal muscles in young women without PFP, who present dynamic knee valgus (FPPA > 15°). Future degenerative changes due to excessive retropatellar overpressure could be prevented by focal assessments and interventions [19].

Therefore, the purpose of this study was to investigate how the activation of gluteus maximus and gluteus medius interacts with FPPA in healthy young women while performing the weight bearing step-down test.

Material and methods

Participants

This was a non-randomized cross-sectional study, developed at the facilities of the Department of Physical Therapy of the Federal University of Juiz de Fora – Campus Governador Valadares, Brazil. Sample selection was carried out by a public call in the city of Governador Valadares. The total of 18 adult female subjects (22 ± 2 years of age, 165 ± 6 cm, 58 ± 8 kg) participated in the study. Inclusion criteria were to present with a FPPA greater than 15° during the step-down manoeuvre in one limb. The other limb should present less than 15° for comparisons. Among the exclusion criteria, there were pharmacological treatment for osteomioarticular pathologies, presenting signals or medical diagnosis of intervertebral disc herniation, hip, or knee degenerative injuries, overweight or obesity, and history of lower limb surgery.

Knee angle assessment

All procedures were conducted in a well lit reserved room with a non-reflective background to allow privacy. A camera (Coolpix S2700 16 MP, Nikon, Tokyo, Japan) was fixed and levelled on a tripod 3 m away from the subject horizontally and 0.85 m above the floor. Digital images were acquired in the continuous mode. All images were analysed with the use of the PAS/SAPO software (http://sapo.incubadora.fapesp.br) [20]. A plumb line was fixed on the roof with green cylinders 1 m apart from each other to calibrate the software.

A trained examiner identified the following anatomical landmarks through palpation: the midpoint of the ankle malleoli, the midpoint of the femoral condyles, and 30 cm above the knee on the proximal thigh along with a line from the anterior superior iliac crest (ASIS) [21]. Adhesive hypoallergenic tapes with attached reflexive green cylinders were positioned on the body landmarks for subsequent angle calculation. Subjects were instructed to stand up at a 20-cm step pad parallel to the plumb line and perpendicular to the camera.

Both lower limbs were assessed. The starting position was standing on the step pad [22] with arms crossed against the chest. The subjects were asked to step down, touch their toe to the ground, and return to the starting position. The test was standardized: 2 seconds for the descent phase, 1 second to touch the ground, and 2 seconds to return [11]. A chronometer was used to control the procedure. The first two trials were performed as familiarization and the obtained mean values from the last 8 trials were used for statistical analysis. The subjects did not present any sign of imbalance that could impair the analysis or cause any episode of falling. The offline FPPA was measured between the line from the marker on the midpoint of the ankle malleoli to the midpoint of the femoral condyles and the line from the proximal thigh along with a line from the ASIS to approximately 30 cm above the knee, at the

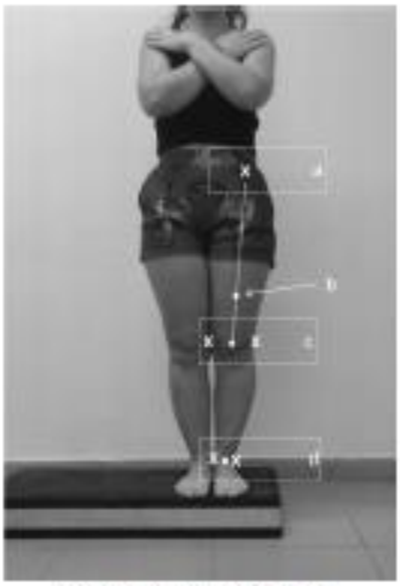


Figure 1. Landmarks position:
a. the anterior superior iliac crest (ASIS);
b. 30 cm above the knee on the proximal thigh along with a line from the ASIS;
c. the midpoint of the femoral condyles;
d. the midpoint of the ankle malleoli

Figure 2. The frontal plane projection angle (FPPA): measured between the line from marker 'c' (on the midpoint of the ankle malleoli) to the midpoint of marker 'b' (on the midpoint of the femoral condyles) and the line from marker 'a' (on the proximal thigh along with a line from the ASIS to approximately 30 cm above the knee) to marker 'b'. The frame that corresponded to the point of maximum knee flexion was used to measure the FPPA

frame that corresponded to the point of maximum knee flexion (Figures 1 and 2). Positive FPPA values above 15° denoted knee valgus and negative FPPA values pointed at knee varus [23].

Muscle activation recording

A biological signal acquisition module with 8 analogue channels was used (Miotec®, Biomedical Equipment, Porto Alegre, RS, Brazil) to continuously record muscle activation during concentric and eccentric phases. The conversion from analogue to digital signals was performed by an A/D board with 16-bit resolution input range, the sampling frequency of 2 kHz, common rejection module greater than 100 dB, signal-noise ratio less than 03 µV root mean square and impedance of 109 Ω. The sEMG signals were recorded in root mean square in µV with surface Meditrace® (Ludlow Technical Products, Gananoque, Canada) Ag/AgCl electrodes with the diameter of 2 cm and centre-to-centre distance of 2 cm, applied in a transverse orientation parallel to the underlying fibres on a muscle site. A reference electrode was placed on the left lateral humeral epicondyle. The sEMG signals were amplified and filtered (Butterworth fourth-order, 20–450 Hz bandpass filter, 60 Hz notch filter). All pieces of information were recorded and processed with the Miotec Suite® software (Miotec Biomedical Equipment, Porto Alegre, RS, Brazil). Prior to sEMG electrode placement, the skin was cleaned with 70% alcohol to eliminate residual fat, which was followed by an exfoliation with specific sandpaper for skin and the second cleaning with alcohol. Gluteus maximus electrodes were placed over the muscle belly, midway between the second sacral vertebra and the greater trochanter [10]. Gluteus medius (posterior fibres) electrodes were placed 33% of the distance between the posterior ilium and the greater trochanter [24, 25].

The maximal voluntary isometric contraction (MVIC) was used to normalize the sEMG signal. For the gluteus medius, the subject was positioned in side-lying with the test lower limb uppermost. The thigh and leg were extended and the lower limb in line with the trunk. The hip and knee of the untested limb were in flexion to provide stability. The subject performed abduction about 30° from the midline, and the examiner resisted manually just above the malleolus. For the gluteus maximus, the subject was placed in the prone position with a pillow placed under the pelvis to provide hip flexion at approximately 10–15°. The subject extended the thigh with the knee flexed at 90° through the available hip-extension range of motion. The rater resisted manually at the distal thigh [26]. Verbal encouragement was given with each trial.

Statistical analysis

Normality was tested by the Shapiro-Wilk test. Correlation among normalized sEMG data, limb (right or left), and FPPA (> or < 15°) were analysed with Pearson's coefficient. The independent t test was used to assess differences between sides – classified using the FPPA (> or < 15°). Additionally, the multivariate test principal component analysis (PCA) was performed to assess the cumulative variance of the variables. Alpha levels were set at 0.05 for all tests. The SPSS for Windows software, version 18.0 (SPSS Inc., Chicago, USA) was applied in all statistical analysis.

Ethical approval

The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the authors' institutional review board or an equivalent committee.

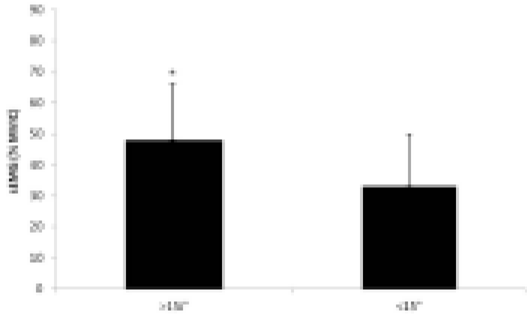
The Federal University of Juiz de Fora Ethics Committee approved this study (CAAE44416315.1.0000.5147). The participants were informed about the study details and signed the informed consent form prior to participation.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

None of the subjects reported any localized muscle pain during MVIC or while performing the step-down test. The FPPA was positively correlated with gluteus maximus activation (r = 0.40, p = 0.008) and with the limb's side (r = 0.30, p = 0.04). Also, a correlation was observed between the right and left gluteus maximus (r = 0.65, p = 0.001). Two components were extracted from PCA, explaining 73% of the variance. PCA showed



sEMG – surface electromyography, MVIC – maximal voluntary isometric contraction
* significant difference (p < 0.05)

Figure 3. Comparison of the gluteus maximus activation by surface electromyography in individuals with frontal plane projection angle above and below 15°

the gluteus maximus (right, 0.95; left, 0.78) explaining 48% of the cumulative variance of the first component and the gluteus medius (right, 0.41; left, 0.77) explaining additional 25% of the variance of the second component. Differences in muscle activation were found when FPPA was an independent variable. The gluteus maximus activation was higher on the side with angles above 15° (48 ± 18% vs. 33 ± 17%; p = 0.02, Figure 3), with no difference for other comparisons.

Discussion

The results showed an increased activation of the gluteus maximus during the step-down test on the affected side, suggesting a decreased neuromuscular efficiency, as greater muscle recruitment is needed to perform the task. Biomechanical analysis showed posterior fibres of gluteus maximus acting as hip external rotators from 0 to 90° of flexion combined with posterior fibres of the gluteus medius [27], with both muscles stabilizing the knee-hip complex in the frontal plane [28]. The majority of studies target PFP symptomatic subjects, but some research has hypothesized that PFP is caused by altered kinematics during weight bearing activities [4], so the presence of increased hip adduction-internal rotation could be indicative of preliminary findings for PFP development.

Holden et al. [13] suggested that baseline measures of knee valgus displacement > 10.6° were predictive of PFP with high sensitivity (75%) and specificity (85%) in female adolescents. The increased activation of gluteus maximus was positively correlated with an increased FPPA, suggesting greater activation of gluteus maximus when higher dynamic knee valgus was observed. The current results also indicate that the gluteus maximus is a major component to explain data variance when the task was performed and the dynamic knee valgus was perceived. Such combined data suggest the gluteus maximus activation as a predisposing factor to detect dynamic knee valgus and the development of PFP. Femoral internal rotation and adduction are thought to be controlled by gluteus maximus activation during unilateral tasks [29] and the current results suggest an increased activation of the muscle during step-down weight bearing to counteract the demand to maintain optimal alignment at the hip-knee complex. Similarly, Souza and Powers [10] reported increased activity of the gluteus maximus during the step-down task in females with PFP compared with the control group. Hollman et al. [30] showed the transverse-plane hip motion and hip extensor strength associated with frontal-plane knee kinematics during a jump-landing task. A systematic review noted females who presented PFP also showing deficits in hip extensor muscle strength [16], and a recent study found FPPA-peak values negatively correlated with the strength of hip abduction and posterolateral complex only for the group without PFP (FPPA-peak around 7°) [11]. The study assessed the relationship between the FPPA and hip and trunk muscle strength in women with and without PFP. However, individuals from PFP group with an average FPPA-peak smaller than 13° were considered, which impairs any comparisons with the present study. Another research proved gluteus maximus activation to be negatively correlated with knee valgus during a step-down test in healthy young women [29], but the knee valgus angle range was again lower (5.3–6.4°) than in the present study. Such differences in results may be explained by methodological issues concerning FPPA assessment and possible individual compensatory strategies during the step-down manoeuvre [11], such as lateral pelvic drop and the influence of external rotator muscles.

The results referring to gluteus medius were inconsistent with the presented outcomes: the muscle activation was not significantly correlated with FPPA, but the cumulative variance was explained by 25% at the second component. Such findings suggest a secondary role for gluteus medius during a single leg weight bearing task in women with increased FPPA and without PFP. A study assessed the activity of gluteus medius subdivisions [25] in healthy women presenting increased FPPA. The results showed that gluteus medius activation varied significantly across the subdivisions, with greater activation for mid and posterior subdivisions while performing a squat task [18]. Another study assessed the gluteus medius and other muscles recruitment during 2 different types of squat, showing different patterns of muscle activation when the task was performed at the same relative intensity by female athletes [31]. Such studies noted different levels of muscle activation owing to task and assessment variations, proving that gluteus medius activation could change depending on external loads and demands in coordinating the biomechanical function to keep the hip-knee complex stable. We speculate that such differences tend to be more evident when biomechanical abnormalities are present, like increased FPPA, demanding more from other powerful muscles surrounding the joint complex.

An important limitation of the present study is the cross-sectional design, which does not allow cause-effect inferences. Although the current data support the argument of greater activation of gluteus maximus as an attempt to provide dynamic stabilization of the hip-knee complex and as a compensatory outcome of gluteus maximus weakness, knee-hip kinematics may be influenced by other factors, such as thigh muscles activation and joint coupling. Additional prospective studies are needed to provide definitive conclusions. Thus, it is possible that excessive FPPA subjects could benefit from exercises to modulate the activation of the gluteus maximus during weight bearing activities.

Conclusions

The present results provide preliminary evidence that young women with dynamic knee valgus exhibit increased gluteus maximus activation even before experiencing any usual symptoms of PFP, such as anterior knee pain. Additionally, gluteus maximus seems to be an important component to explain dynamic knee valgus in women without symptoms of PFP. We speculate that greater gluteus maximus activation is due to other muscle weakness and lower neuromuscular efficiency to stabilize the hip-knee complex in the frontal plane during a single leg weight bearing activity.

Disclosure statement
No author has any financial interest or received any financial benefit from this research.

Conflict of interest
The authors state no conflict of interest.

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ARTIGO 2

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VALIDITY AND RELIABILITY OF SHOULDER STRENGTH ASSESSMENT DURING SCAPTION, INTERNAL ROTATION AND EXTERNAL ROTATION USING AN ANCHORED, NON-MODIFIED SPHYGMOMANOMETER

original paper
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ABSTRACT
Purpose. To determine the validity, intra-rater reliability, and inter-rater reliability of an anchored sphygmomanometer for assessing shoulder strength during scaption, lateral rotation, and medial rotation. The hand-held dynamometer (HHD) was used as the standard measurement tool for this purpose.
Methods. Fifty subjects (23 years old ±3 years) were included in the validity study. Shoulder strength was assessed using an HHD and a sphygmomanometer, both anchored to a fixed ladder by an inextensible belt. Twenty-three subjects (25 years old ±3 years) were included in the reliability study. Two raters assessed strength, each taking two measurements one week apart, using the fixed sphygmomanometer.
Results. Validity results showed high to very high magnitude correlations, and no differences were found between the sphygmomanometer and the HHD measurements or among trials. Intra-class coefficient of correlation (ICC) showed high reliability between measurement tools and among trials. Intra-rater results showed very high ICC, very high correlation, low coefficient of variation (CV) with adequate standard error of measurement (SEM), and minimal detectable change (MDC). Inter-rater results showed moderate to high ICC, high to very high correlation, acceptable SEM and CV, but not adequate MDC. The anchored sphygmomanometer is a low-cost tool that provides objective measurements. The results obtained from the anchored sphygmomanometer were found to be similar to those obtained from an HHD, which has a valid predictive model.
Conclusions. The sphygmomanometer is suitable for monitoring shoulder strength during scaption, internal rotation, and external rotation. The anchored sphygmomanometer enables coaches and physical therapists to establish the maximal voluntary isometric contraction and monitor exercise program outcomes at a low cost. However, caution is recommended when interpreting results between raters.
Key words: muscle, strength, dynamometer, sphygmomanometer, assessment

Introduction

Valid and reliable assessment tools enable physical therapists and coaches to accurately develop individualized exercise programs [1]. The strength assessment is especially important for providing data to inform a treatment diagnosis and accurate reporting of measurable outcomes for patients with neurological and musculoskeletal conditions. Additionally, muscle strength is correlated with a patient's functional capacity, and its accurate assessment provides objective data for measuring progress with intervention and informing discharge planning decisions [1, 2].

Sufficient muscle strength is required around the shoulder girdle to perform activities of daily living by providing stabilization for elbow and wrist movement. This proximal stability allows refined movement at the hand and fingers, providing stable muscle syn-

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ergy that is essential to functional upper limb movement [3]. Shoulder girdle muscle weakness has been associated with supraspinatus tear and shoulder impingement syndrome [4] as well as anterior shoulder instability and superior labral tear from anterior to posterior [5]. Weak internal rotators are associated with humeral retroversion, posterior-inferior capsular contracture, and posterior rotator cuff tightness [6]. Also, the ratio of strength between the external and internal rotators affects the balance of the glenohumeral joint [7]. Muscle strength and length imbalances between these opposing muscle groups increase the risk for shoulder injuries. [8]. Scaption is also a functional movement used during daily activities and requires deltoid, supraspinatus, and serratus anterior muscle activation [9]. Scaption, internal rotation, and external rotation elicit high levels of muscle activity in healthy individuals and are thought to play a critical role in stabilizing the humeral head within the glenoid cavity [10]. The muscles activated during these shoulder movements are assessed to determine the condition of the rotator cuff and inform the therapist on where to focus the patient's strengthening program. An objective, low-cost assessment to detect muscle weakness could help the physical therapist during the rehabilitation process and prevent future impairments.

Muscle strength may be assessed using subjective or objective methods [11]. The manual muscle test is a subjective test most frequently used in clinical practice because it is easy to perform and has no cost. However, its reliability is low [12], and it does not provide objective parameters for exercise prescription or treatment outcomes measurement. The isokinetic dynamometer is the gold standard for muscle strength assessment, but it is extremely expensive [1]. The hand held dynamometer (HHD) is a portable option with validity and reliability comparable to isokinetic dynamometry when assessing isometric muscle strength in several joint movements [1, 13, 14]. It is important to note the equipment's anchoring method when the strength test is performed using an HHD in order to maintain the validity and reliability [15]. A recent study achieved higher validity and reliability by using an inextensible band to keep the HHD stable while assessing knee extension strength compared to the non-fixed HHD method [14] suggesting that this adaptation could be a better way to assess muscle strength compared to non-fixed equipment [16]. Despite its usefulness and lower cost compared to an isokinetic dynamometer, the HHD is still a relatively expensive tool.

A possible alternative to the HHD is the aneroid sphygmomanometer; a well-known and low-cost tool that is commonly acquired to assess blood pressure. Studies have shown moderate reliability of the sphygmomanometer, when compared to an HHD, to assess hand grip strength in Parkinson's disease [17], upper limb muscles after stroke [2] and isometric strength of hip muscles [18]. Some of those studies also showed adaptations on the sphygmomanometer, such as removing the inflatable cuff, to assess isometric muscle strength [17, 19, 20]. Nevertheless, it is important to perform strength tests without adaptations in the equipment to ensure its usefulness in daily assessments. To reinforce the tool's consistency, both adapted (the sphygmomanometer without the inflatable cuff) and non-adapted (manufacturer's original sphygmomanometer) methods showed significant and adequate correlations with the HHD, requiring only one repetition after familiarization, to properly assess the muscle strength in healthy individuals [20].

Both hand-held dynamometry and the sphygmomanometer test (ST) have been shown to be preferable alternatives over manual muscle tests [1, 21]. The HHD has been shown to detect weakness in shoulder external and internal rotator muscles deemed normal by manual muscle testing [22], but previous studies have only investigated the correlation between the ST and the HHD for upper limbs in patients after stroke [2, 23]. The present study aims to present novel insights about the use of the sphygmomanometer compared to the HHD. These aspects, previously unstudied, include anchoring the equipment to improve stabilization thereby ensuring values closer to those obtained using an anchored HHD. The study also aims to address issues not usually noted by other authors, such as attention to air displacement prevention and the recalibration procedure. To our knowledge, no studies are available regarding the validity of the non-adapted sphygmomanometer compared to HHD for shoulder lateral rotation, medial rotation and arm elevation in the scapular plane (scaption).

Therefore, the present study aims to assess validity, intra-rater reliability and inter-rater reliability of an anchored ST during shoulder scaption, lateral rotation and medial rotation using a hand-held dynamometer (HHD) as the standard tool of measurement.

Material and methods

Experimental approach to the problem

This study assessed the concurrent instrumental validation between the ST and the HHD. A second, parallel study assessed intra-rater and inter-rater reliability of the ST. The selected standard tool, the HHD, is suitable to assess the sphygmomanometer validity. The HHD showed minimal differences compared to isokinetic testing (gold standard) for muscle strength measurement [1, 24]. Healthy young adults were tested twice, 1-week apart, by two raters. The relative reliability was assessed by intra-class coefficient of correlation (ICC) and Pearson's coefficient, exploring the agreement between raters and between measurements (intra-rater reliability). The absolute reliability provides the extent of measurement error by coefficient of variation (CV), standard error of measurement (SEM) and minimal detectable change (MDC).

Participants

Two sample selections for each study were carried out by public call in the city of Governador Valadares – Minas Gerais – Brazil. Table 1 summarizes the participants' characteristics for both studies. Inclusion criteria were 1) aged 30 years or less, 2) physically independent, and 3) scored higher than 21 on the Mini-Mental State Examination. Exclusion criteria were 1) self-reported shoulder pathologies, 2) cervical traumato-orthopedic injuries and/or 3) localized pain in the assessed region. Also, participants were excluded if unable to stabilize the continuous force applied over the sphygmomanometer. The usual procedure consisted of no consideration for the first impact over the sphygmomanometer, as it was usually higher than the average readings. Two participants were excluded due to inability to maintain continuous impacts over the sphygmomanometer during all trials. A post-hoc sample power analysis was carried with an effect size of 0.87 (derived from the weakest correlation analysis with $r = 0.77$ and sample size of 20), the alpha was set at 0.05, and the sample power was calculated using the G-Power software (Version 3.1.5, Franz Faul, Universitat Kiel, Germany). The power two-tailed analysis returned an actual power of 0.99.

Table 1. Participants' characteristics

Characteristics	Validity	Intra/inter-rater reliability
Sample size	n = 50	n = 23
Age (years-old)	24 (3)	25 (3)
Height (cm)	170 (9)	171 (9)
Weight (Kg)	69 (13)	66 (14)
Male/Female	24/26	12/11

mean (standard deviation)

Materials

The maximum voluntary isometric contraction (MVIC) was assessed through an HHD (Nicholas Manual muscle test, Co, Lafayette IN), considered the standard tool [20, 23, 25]. The tested tool was a new aneroid sphygmomanometer with a measuring range from 0 to 300 mmHg, division scale of 2 mmHg, cuff size 7x17x11cm, clamp in nylon non-allergic fabric, with pin locking, properly calibrated and checked by Brazilian National Institute of Metrology, Quality and Technology (INMETRO). Both instruments were positioned inside an inextensible belt which was fixed to a fixed ladder. This decision was based on a previous study that demonstrated greater reliability of MVIC measurements of the shoulder with an HHD when the tool was fixed with an inextensible belt [13].

Procedures

Tests were performed using the sphygmomanometer and the HHD, respectively, with 15-minute intervals between each test. Two randomly assigned examiners (https://www.randomizer.org/) positioned the equipment inside the fixed belt, a third examiner read the values and a fourth one recorded and stored the results. For each movement, subjects were asked to push as hard as possible against the assessment device. The tests consisted of 3 trials of MVIC for 6 seconds each, with one minute of rest between trials. All tests were performed on the volunteers' dominant upper limbs. The dominant upper limb was determined as the limb most frequently used to write. During the ST an assistant read and recorded the results, and another assistant controlled the chronometer. Calibration procedures were performed before ST data collection using 5 kg weights to verify that the equipment provided consistent measurements throughout the study [20]. The calibration procedure was performed for each volunteer as follows: (1) the sphygmomanometer was inflated (100 mmHg); (2) the pressure was reduced to 40 mmHg, and the valve was closed to prevent leakage, providing a measurement range of 20–300 mmHg. The examiner ensured the pre-inflation of the equipment before each subject's test. To assess the intra-rater reliability, one examiner performed the ST on two different occasions with 1-week between each test. Two examiners performed the ST independently on each participant to assess inter-rater reliability.

All tests were performed on participants in the standing position. For shoulder scaption, subjects placed

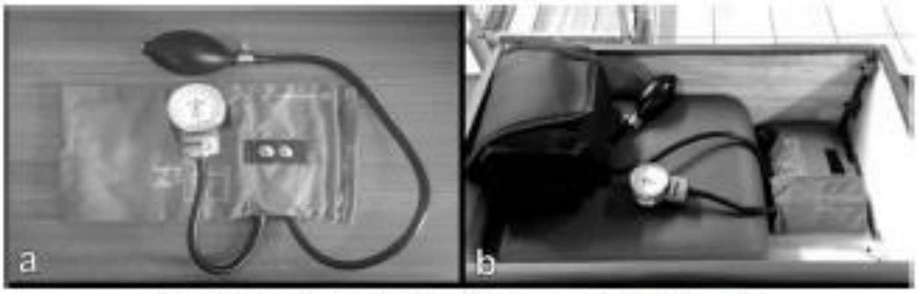

Figure 1. Aneroid sphygmomanometer (a), calibration apparatus (b)

Figure 2. Hand Held Dynamometer test – scaption (a), internal rotation (b), external rotation (c)

Figure 3. Sphygmomanometer test – scaption (a), internal rotation (b), external rotation (c)

their arms at 90 degrees of glenohumeral elevation in the "full can" position (full can position refers to the arm at 90° of elevation in the scapular plane with glenohumeral external rotation and thumb up). The sphygmomanometer and the HHD were placed right above the distal forearm (at the wrist level). For shoulder internal and external rotation the arm was placed against the body with elbow flexed at 90 degrees. Both the sphygnamometer and the HHD were placed on the distal forearm (at the wrist level) internally and externally to respectively assess internal and external rotation. All tests were performed with the tools fixed to a belt which was anchored to a fixed ladder (Figure 1, 2 and 3).

The test was explained to each volunteer, and standardized auditory stimulus was given to start the test by loudly repeating "go" during all tests. The first trial was used to familiarize the subject to the procedure, and the obtained mean values from the last 2 trials were used for statistical analysis.

Statistical analysis

The normality was assessed by the Shapiro-Wilk test. Descriptive data were presented by means and standard deviation. To analyze the concurrent validity, the linear regression analysis and the coefficient of determination were performed, and prediction equations of values in kilogram-force (Kgf) were established from data obtained through the sphygmomanometer in mmHg. Values in mmHg were then converted to Kgf (sphygmomanometer's transformed values – tST). After conversion, the paired t-test was performed to assess differences between tST and HHD results. The correlation was calculated using the Pearson's coefficient. ANOVA 1-way and ICC were used to respectively assess differences and reproducibility among trials. The reliability was assessed using the ICC and the respective 95% confidence interval (CI). To analyze the intra- and inter-rater agreement, the CV, the Pearson's coefficient, the SEM and the MDC were used. The SEM reflects the instrument error and was calculated by dividing the standard deviation (SD) of the mean difference by the square root of 2 (SD of the differences/√2). The MDC can be interpreted as real change and was calculated using the formula MDC = 1.96 x√2 x SEM. The magnitude of the ICC and Pearson's coefficient of correlation were classified as follows: very low (≤ 0.25), low (0.26–0.49), moderate (0.50-0.69), high (0.70-0.89) and very high (0.90-1.00) [23]. Significance level was established at $p < 0.05$. BioEstat 5.0 software was used for all statistical analysis.

Ethical approval

The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the authors' institutional review board or an equivalent committee.

The local ethics committee approved this study (CAAE 63883116.1.0000.5147).

Informed consent

All participants were informed about all procedures and signed an informed consent form prior to participation.

Results

Validity

None of the subjects reported any localized muscle pain or fatigue. No differences and high ICC among trials were observed (scaption, p = 0.62 / ICC = 0.75; internal rotation p = 0.70 / ICC = 0.85; external rotation, p = 0.58 / ICC = 0.85). Table 2 shows ST and HHD descriptive results for each test (scaption, internal and external rotation) and the transformed data (tST) using the prediction equations obtained from the linear regression calculations. The coefficient of determination showed the equations as good predictors of values in Kgf from obtained values in mmHg. In systematic bias analysis by paired t-tests, no differences were noted when comparing tST and those obtained from HHD (scaption, p = 0.99; internal rotation, p = 0.98; and external rotation, p = 0.98).

Significant and positive high correlations were noted (Table 3) between the ST and the HHD for all movements. Very high reliability (ICC) between transformed values and HHD results are also shown in Table 3.

Reliability

Pearson's coefficient and ICC values denoted very high intra-reliability, with range above 0.90. For ab-

Table 2. Descriptive data (mean and standard deviation) of scaption, internal and external rotation, regression equation and coefficient of determination

	ST (mmHg)	tST (Kgf)	HHD (Kgf)	regression equation	r^2
Scaption	120 (33)	3.6 (1.37)	3.6 (1.48)	y = 0.0409x - 1.2617	0.85
Internal Rotation	134 (39)	5 (1.66)	5 (2.02)	y = 0.0427x - 0.6777	0.67
External Rotation	108 (31)	3.8 (1.13)	3.8 (1.34)	y = 0.0367x - 0.1373	0.71

ST – sphygmomanometer test, tST – transformed sphygmomanometer, HHD – hand-held dynamometer; r^2 – coefficient of determination

Table 3. Correlation and reliability between hand-held dynamometer and transformed sphygmomanometer data from scaption, internal and external rotation of the shoulder

	r	95%-CI	ICC
Scaption	0.92* (very high)	0.87-0.96	0.89 (high)
Internal Rotation	0.82* (high)	0.70-0.89	0.78 (high)
External Rotation	0.84* (high)	0.73-0.91	0.81 (high)

r – Pearson's coefficient of correlation, 95%-CI – confidence interval, ICC – intra-class correlation coefficient

Table 4. Intra-rater reliability

	ICC	95%-CI	r	95%-CI	CV (%)	SEM	MDC
Scaption	0.95	0.88-0.98	0.96	0.90-0.98	5	3	8
Internal Rotation	0.92	0.82-0.97	0.92	0.81-0.96	5	4	12
External Rotation	0.96	0.90-0.98	0.97	0.93-0.99	3	2	6

r – Pearson's coefficient of correlation, 95%-CI – confidence interval, CV – coefficient of variation, SEM – standard error of measurement, MDC = minimal detectable change

Table 5. Inter-rater reliability

	ICC	95%-CI	r	95%-CI	CV (%)	SEM	MDC
Scaption	0.83	0.64-0.92	0.92	0.82-0.97	9	6	15
Internal Rotation	0.67	0.35-0.84	0.77	0.53-0.90	12	9	26
External Rotation	0.87	0.71-0.94	0.92	0.83-0.97	8	5	14

r – Pearson's coefficient of correlation, 95%-CI – confidence interval, CV – coefficient of variation, SEM – standard error of measurement, MDC – minimal detectable change

solute reliability, the CV variation was above 10%, the SEM of each movement ranged from 2 to 4 mmHg. The lowest MDC was 6, and the highest was 12 mmHg. All results denoted satisfactory intra-rater reliability (Table 4).

The inter-rater reliability showed relative reliability ICC values ranging from moderate – for internal rotation – to high – for scaption and external rotation – with Pearson's coefficient showing high to very high results. The absolute reliability showed internal rotation's CV above 10%, with scaption and external rotation close to the limit. SEM ranged from 5 to 9 mmHg, and the MDC range was 14–26 mmHg. The absolute inter-rater reliability results suggest a systematic bias between the 2 raters.

Discussion

The results suggest that the fixed, non-adapted ST is a valid and intra-rater reliable alternative to measure muscle strength compared to the HHD technique during scaption, internal rotation and external rotation of the shoulder in healthy adults. Souza et al. [20] assessed the non-adapted sphygmomanometer as a tool able to provide valid muscle strength measurements for elbow flexion, knee extension and trunk flexion. However, the same authors reported difficulties with stabilizing the equipment during the MVIC for knee extension. This type of limitation is often reported in the literature using the HHD, with higher reliability achieved only when the rater is stronger than the subject [26, 27]. Studies using the HHD showed that the proficiency of the raters affects the results, and anchoring the HHD could avoid rater interference [15, 28, 29]. Both enhanced reliability and validity – as compared to the isokinetic dynamometer – were noted when the HHD was fixed compared to non-fixed trials [14]. The present study did not assess the same muscles, but the use of an inelastic belt provided stability and consistent results during ST compared to HHD tests. It is assumed that, when the belt was folded around the sphygmomanometer, its borders helped to secure the equipment, decreasing the point of contact against the limb's force compared to holding the equipment with hands. A uniform pressure was obtained when the belt was correctly folded around the center of the sphygmomanometer, leading to increased test stability, and avoiding air displacement under the belt. Thus, the anchoring procedure avoided rater interference as a potential source of bias.

Previous studies reported stability across ST results with no recalibration other than that recommended by the manufacturer [11, 20]. The current study checked the air content after each participant's tests and found air loss after every three measurements. As the calibration procedure is essential for valid and reliable values, our results suggest that new calibration for each patient is necessary to avoid wrong measurements. The adopted pre-inflation value (40 mmHg) also diverges from other studies. The most used value is 20 mmHg, but another study also suggested different pre-inflation values [30]. Tests performed prior to data collection also showed better results with 40 mmHg. The non-adapted sphygmomanometer has a larger area of contact with the limb, providing lower pressure values when an external force is applied [20].

This issue became more evident using the anchored inelastic belt due to the enhanced stabilizing force applied through the surrounding area of contact and not only against the limb's counterforce. Higher pressure value was then necessary for proper calibration.

Reliability studies are essential to assess the variability of an instrument to avoid misinterpretation of variables before and after interventions [17]. A previous study showed excellent test-retest reliability of the ST for shoulder internal and external rotator strength in healthy subjects (ICC > 0.90) [21]. However, a literature search found no studies that assessed the reliability of the ST for scaption. Six scapular muscles are fired to increase the stability of the humeral head during scaption [31]. In this movement, the arm is elevated with full elbow extension and glenohumeral external rotation, i.e., the "full can" position, as opposed to the "empty can" position in which the thumb points to the ground (shoulder in internal rotation). It has been shown that elevating the arm in shoulder external rotation is associated with less middle deltoid muscle activity and higher supraspinatus muscle activity, reducing the superior-anterior subluxation of the humeral head. Also, external rotation moves the greater tuberosity away from the undersurface of the acromion, increasing the width of the subacromial space. These actions decrease the risk of impingement [32]. Intra-rater reliability confirmed the consistency when the same evaluator performed the procedure on different days of data collection. The inter-rater agreement, when assessed using the SEM and MDC, showed larger MDC values than the intra-rater results. The assessments performed at different times in the same individual would have variations ranging from 5 to 9 mmHg (SEM), depending on the movement, and related to measurement errors as opposed to changes in the strength status. Compared to intra-rater variations (2 to 4 mmHg) and considering the 2-mmHg scale, the range was larger but not too discrepant. Also, the CV showed acceptable levels of variation, ranging from 5 to 9% among the results, not very different when compared to intra-rater trials (3 to 5%). However, the MDC showed ranges from 14 to 26 mmHg. The results indicate that changes greater than 14 to 26 mmHg, depending on the movement, has a probability of 5% of occurrence due to a random error or a random variation, very different when comparing the intra-rater results, with a range from 6 to 12 mmHg. The absolute reliability demonstrated that when assessing the shoulder movements by different raters, there is great variation with low agreement and important measurement error. Results should be interpreted with caution if the goal is to compare different rater assessments.

The present study used means from two last trials for statistical analysis – as more repetitions could reduce errors [33] – and longer resting time (1 minute among trials) compared to other studies (15–20 seconds on average) [19, 20, 23] to allow recovery after MVIC. No differences between trials were observed. Other studies also noted no difference among measurements considering multiple trials, recommending one trial after familiarization to avoid fatigue and/or pain [20, 23]. Nevertheless, participants did not report fatigue or discomfort after the experiment (familiarization + 2 trials). We recommend two or more trials due to subject's adaptation to the task. Two participants were excluded due to their lack of control during all trials, suggesting the need for more familiarization. Some subjects also tried to compensate by elevating the scapula or bending the trunk to increase the generated force, mainly during scaption. The examiner was aware about compensations and instructed all participants to correct their postures. Although the current shoulder and body positions for strength assessment have been studied and standardized, the assessment of shoulder strength performed with the sphygmomanometer is not free from common issues described during other strength assessments. The equipment stabilization with a belt, the required attention to prevent air displacement and the frequent recalibration are potential disadvantages of the ST. However, the method provided a valid, intra-rater reliable, low cost and portable method for shoulder strength assessment. These advantages should be considered to include the ST in clinical practice to replace manual muscle testing.

A limitation of the present study includes that the results were read and recorded by an independent assistant to ensure the internal validity of the study by blinding the principal examiner, although Martins et al. [19] adopted the same procedure. The sample also included only young, healthy participants. Further studies must include samples with different ages and pathologies to confirm the outcome. Additional limitations include not testing the equipment against the gold standard isokinetic dynamometer and testing only on upper extremities.

In conclusion, we recommend measuring shoulder strength using the sphygmomanometer which provides objective, low-cost and similar strength measurement results to those obtained from the HHD. The results from the non-adapted sphygmomanometer presented significant positive correlation and similar magnitude to those obtained by using an HHD in young, healthy subjects with valid predictive models. These models showed similar results to those obtained using the HHD. Inter-rater comparisons should be interpreted with caution.

The sphygmomanometer is a convenient, portable, valid, and intra-rater reliable tool for measuring muscle strength during scaption, internal rotation and external rotation of the shoulder. This information may assist coaches and physical therapists with exercise program planning and outcomes assessments. The strength protocol can be monitored at a low cost to establish the MVIC and its prescribed percentage to enhance strength, endurance and/or motor control. The present study used an inextensible belt anchored to a fixed ladder which provided stabilization of the sphygmomanometer during the strength tests. The stabilization of test instruments seemed to play an important role in providing reliable measurements. Also, the present study clarifies necessary actions to take when performing the ST including subject's familiarization, examiner's attention to prevent air and equipment displacement, and recalibration between tests.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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ANEXO I - MINI EXAME DO ESTADO MENTAL

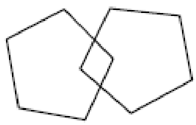
Identificação do cliente

Nome:____

Data de nascimento/idade: ______ Sexo:_____________

Escolaridade: Analfabeto ( ) 0 à 3 anos ( ) 4 à 8 anos ( ) mais de 8 anos ( )

Avaliação em: ____/____/____ Avaliador: ___________________.

Orientação Temporal Espacial 1. Qual é o (a) Dia da semana?__ 1 Dia do mês?______ 1 Mês?_______ 1 Ano?______ 1 Hora aproximada?___ 1 2. Onde estamos? Local?______ 1 Instituição (casa, rua)?___ 1 Bairro?______ 1 Cidade?_______ 1 Estado?______ 1	**Linguagem** 5. Aponte para um lápis e um relógio. Faça o paciente dizer o nome desses objetos conforme você os aponta ______ 2 6. Faça o paciente. Repetir "nem aqui, nem ali, nem lá". ______ 1 7. Faça o paciente seguir o comando de 3 estágios. "Pegue o papel com a mão direita. Dobre o papel ao meio. Coloque o papel na mesa". _____ 3
Registros 1. Mencione 3 palavras levando 1 segundo para cada uma. Peça ao paciente para repetir as 3 palavras que você menciou. Estabeleça um ponto para cada resposta correta. -Vaso, carro, tijolo ________ 3	8. Faça o paciente ler e obedecer ao seguinte: FECHE OS OLHOS. _____ 1 09. Faça o paciente escrever uma frase de sua própria autoria. (A frase deve conter um sujeito e um objeto e fazer sentido). **(Ignore erros de ortografia ao marcar o ponto)** _____ 1
3. **Atenção e cálculo** Sete seriado (100-7=93-7=86-7=79-7=72-7=65). Estabeleça um ponto para cada resposta correta. Interrompa a cada cinco respostas. Ou soletrar apalavra MUNDO de trás para frente. ________ 5	10. Copie o desenho abaixo. Estabeleça um ponto se todos os lados e ângulos forem preservados e se os lados da interseção formarem um quadrilátero. ________ 1
4. **Lembranças (memória de evocação)** Pergunte o nome das 3 palavras aprendidos na questão 2. Estabeleça um ponto para cada resposta correta. ________ 3	

ANEXO II – IPAC

Para responder as questões lembre-se que: Atividades físicas VIGOROSAS são aquelas que precisam de um grande esforço físico e que fazem respirar MUITO mais forte que o normal. Atividades físicas MODERADAS são aquelas que precisam de algum esforço físico e que fazem respirar UM POUCO mais forte que o normal.

Para responder as perguntas pense somente nas atividades que você realiza por pelo menos 10 minutos contínuos de cada vez.

1a Em quantos dias da última semana você CAMINHOU por pelo menos 10 minutos contínuos em casa ou no trabalho, como forma de transporte para ir de um lugar para outro, por lazer, por prazer ou como forma de exercício?

_____ dias por SEMANA ( ) Nenhum

1b Nos dias em que você caminhou por pelo menos 10 minutos contínuos quanto tempo no total você gastou caminhando por dia?

horas: ______ Minutos: _____

2a. Em quantos dias da última semana, você realizou atividades MODERADAS por pelo menos 10 minutos contínuos, como por exemplo pedalar leve na bicicleta, nadar, dançar, fazer ginástica aeróbica leve, jogar vôlei recreativo, carregar pesos leves, fazer serviços domésticos na casa, no quintal ou no jardim como varrer, aspirar, cuidar do jardim, ou qualquer atividade que fez aumentar moderadamente sua respiração ou batimentos do coração (POR FAVOR NÃO INCLUA CAMINHADA)

_____ dias por SEMANA ( ) Nenhum

2b. Nos dias em que você fez essas atividades moderadas por pelo menos 10 minutos contínuos, quanto tempo no total você gastou fazendo essas atividades por dia?

horas: ______ Minutos: _____

3a Em quantos dias da última semana, você realizou atividades VIGOROSAS por pelo menos 10 minutos contínuos, como por exemplo correr, fazer ginástica aeróbica, jogar futebol, pedalar rápido na bicicleta, jogar basquete, fazer serviços domésticos pesados em casa, no quintal ou cavoucar no jardim, carregar pesos elevados ou qualquer atividade que fez aumentar MUITO sua respiração ou batimentos do coração.

dias _____ por SEMANA ( ) Nenhum

3b Nos dias em que você fez essas atividades vigorosas por pelo menos 10 minutos contínuos quanto tempo no total você gastou fazendo essas atividades por dia?

horas: ______ Minutos: _____

Estas últimas questões são sobre o tempo que você permanece sentado todo dia, no trabalho, na escola ou faculdade, em casa e durante seu tempo livre. Isto inclui o tempo sentado estudando, sentado enquanto descansa, fazendo lição de casa visitando um amigo, lendo, sentado ou deitado assistindo TV. Não inclua o tempo gasto sentando durante o transporte em ônibus, trem, metrô ou carro.

4a. Quanto tempo no total você gasta sentado durante um dia de semana?

______horas ____minutos

4b. Quanto tempo no total você gasta sentado durante em um dia de final de semana?

______horas ____minutos

ANEXO III – FES-I-BRASIL

	Nem um pouco preocupado 1	Um pouco preocupado 2	Muito preocupado 3	Extremamente preocupado 4
1. Limpando a casa (ex: passar pano, aspirar ou tirar a poeira)	1	2	3	4
2. Vestindo ou tirando a roupa	1	2	3	4
3. Preparando refeições simples	1	2	3	4
4. Tomando banho	1	2	3	4
5. Indo às compras	1	2	3	4
6. Sentando ou levantando de uma cadeira	1	2	3	4
7. Subindo ou descendo escadas	1	2	3	4
8. Caminhando pela vizinhança	1	2	3	4
9. Pegando algo acima de sua cabeça ou do chão	1	2	3	4
10. Indo atender o telefone antes que pare de tocar	1	2	3	4
11. Andando sobre superfície escorregadia (ex: chão molhado)	1	2	3	4
12. Visitando um amigo ou parente	1	2	3	4
13. Andando em lugares cheios de gente	1	2	3	4
14. Caminhando sobre superfície irregular (com pedras, esburacada)	1	2	3	4
15. Subindo ou descendo uma ladeira	1	2	3	4
16. Indo a uma atividade social (ex: ato religioso, reunião de família ou encontro no clube)	1	2	3	4

APÊNDICE I – DECLARAÇÃO DE INFRAESTRUTURA

Ministério da Educação

Universidade Federal de Juiz de Fora

Governador Valadares, 22 de Novembro de 2016.

A/C: Prof. Dr. Alexandre C. Barbosa

Ref.: Declaração de infraestrutura e concordância para realização de pesquisa

Prezado Professor,

A Clínica Escola de Fisioterapia da Universidade Federal de Juiz de Fora - Campus Governador Valadares conta com toda a infra-estrutura necessária para a realização do projeto de pesquisa intitulado “Equilíbrio e ativação da musculatura da perna pré e pós fadiga de membros inferiores em mulheres com diabetes tipo 2”, contando com salas devidamente preparadas para as avaliações e intervenções do projeto, garantindo a segurança e a privacidade dos participantes.

A mesma se encontra à disposição, conforme cronograma apresentado e devidamente autorizado o uso das instalações pelo pesquisador e sua equipe.

Atenciosamente,

____

Profª. Drª. Alessa Brugiolo

Chefe do Departamento de Fisioterapia

Universidade Federal de Juiz de Fora

Campus Gov. Valadares

APÊNDICE II – TCLE

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

O Sr. (a) está sendo convidado (a) como voluntário (a) a participar da pesquisa “**Equilíbrio e ativação da musculatura da perna pré e pós fadiga de membros inferiores em mulheres com diabetes tipo 2**”. Nesta pesquisa pretendemos “**investigar o equilíbrio e a atividade muscular durante atividade de fadiga em mulheres idosas com e sem diabetes tipo 2**”. O motivo que nos leva a estudar “**mulheres idosas com diabetes tipo 2 apresentam maior risco de quedas e perda do equilíbrio e o estudo da fadiga poderá auxiliar na prescrição de exercícios mais eficazes no combate ao risco de quedas**”.

Para esta pesquisa adotaremos os seguintes procedimentos: “a sra. ficará em pé sobre um pé por 20 segundos em cima de uma plataforma de força. para a avaliação da fadiga dos músculos da região de tornozelo o sra. ficará na ponta dos pés, o maior tempo possível. serão colocados alguns eletrodos sobre a sua pele para coletar as informações musculares esse procedimento não causará nenhum desconforto à sra.”

Os riscos envolvidos na pesquisa consistem em “mínimo risco de corte ao raspar os pelos da perna no local onde serão colocados os eletrodos, a lâmina de barbear será descartável e o pesquisador receberá treinamento prévio; risco de cair durante a avaliação do equilíbrio, no entanto o participante estará preso por um cinto ao teto e haverá um fisioterapeuta experiente próximo ao participante para evitar qualquer queda que possa acontecer; risco de estresse psicológico para responder o questionário, no entanto a sra. responderá ao questionário em local privativo, e suas respostas serão sigilosas”.

A pesquisa contribuirá para “diagnosticar previamente o risco de quedas e você receberá um relatório sobre sua condição de equilíbrio, bem como orientações para atividades simples com o objetivo de prevenir a ocorrência de quedas durante suas atividades diárias”.

Para participar deste estudo a Sra. não terá nenhum custo nem receberá qualquer vantagem financeira. Apesar disso, caso sejam identificados e comprovados danos provenientes desta pesquisa, a Sra. tem assegurado o direito a indenização. A Sra. terá o esclarecimento sobre o estudo em qualquer aspecto que desejar e estará livre para participar ou recusar-se a participar. Poderá retirar seu consentimento ou interromper a participação a qualquer momento. A sua participação é voluntária e a recusa em participar não acarretará qualquer penalidade ou modificação na forma em que a Sra. será atendida. O pesquisador tratará a sua identidade com padrões profissionais de sigilo. Os resultados da pesquisa estarão à sua disposição quando finalizada. Seu nome ou o material que indique sua participação não será liberado sem a sua permissão. O (A) Sr (a) não será identificado (a) em nenhuma publicação que possa resultar.

Este termo de consentimento encontra-se impresso em duas vias originais, sendo que uma será arquivada pelo pesquisador responsável, na "clínica escola de fisioterapia da universidade federal de juiz de fora - campus Governador Valadares" e a outra será fornecida ao Sr. (a). Os dados e instrumentos utilizados na pesquisa ficarão arquivados com o pesquisador responsável por um período de 5 (cinco) anos, e após esse tempo serão destruídos. Os pesquisadores tratarão a sua identidade com padrões profissionais de sigilo, atendendo a legislação brasileira (Resolução Nº 466/12 do Conselho Nacional de Saúde), utilizando as informações somente para os fins acadêmicos e científicos.

Eu, ____, fui informado (a) dos objetivos da pesquisa "Equilíbrio e ativação da musculatura da perna pré e pós fadiga de membros inferiores em mulheres com diabetes tipo 2" de maneira clara e detalhada e esclareci minhas dúvidas. Sei que a qualquer momento poderei solicitar novas informações e modificar minha decisão de participar se assim o desejar.

Declaro que concordo em participar. Recebi uma via original deste termo de consentimento livre e esclarecido e me foi dada à oportunidade de ler e esclarecer as minhas dúvidas.

Governador Valadares, __________ de ____________________________ de 20 .

________________________________ ________________________________

Assinatura do Participante Assinatura do (a) Pesquisador (a)

Pesquisador Responsável: Ilha Gonçalves Fernandes

Fone: (32) 34225121

E-mail: ilha.fernandes@hotmail.com

APÊNCICE III – CARTA DE APROVAÇÃO COMITÊ DE ÉTICA E PESQUISA

UFJF - UNIVERSIDADE FEDERAL DE JUIZ DE FORA - MG

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Análise do equilíbrio e da ativação muscular em idosos diabéticos pré e pós fadiga de membros inferiores

Pesquisador: Alexandre Wesley Carvalho Barbosa

Área Temática:

Versão: 2

CAAE: 62606616.2.0000.5147

Instituição Proponente: UNIVERSIDADE FEDERAL DE JUIZ DE FORA UFJF

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 1.891.492

Apresentação do Projeto:

Esse é um estudo observacional de corte transversal não randomizado, a amostra será composta por idosos da cidade de Governador Valadares. As avaliações para recrutamento seguirão até atingirmos um n=42 idosos, que serão divididos com taxa de alocação de 1:1 em dois grupos: grupo sem e com diabetes. Apresentação do projeto esta clara, detalhada de forma objetiva, descreve as bases científicas que justificam o estudo, de acordo com as atribuições definidas na Resolução CNS 466/12 de 2012, item III.

Objetivo da Pesquisa:

Comparar a capacidade de manutenção de equilíbrio e a ativação muscular em idosos com diabetes tipo 2 e idosos sem diabetes pré e pós protocolo de fadiga muscular distal de membros inferiores. O Objetivo da pesquisa está bem delineado, apresenta clareza e compatibilidade com a proposta, tendo adequação da metodologia aos objetivos pretendido, de acordo com as atribuições definidas na Norma Operacional CNS 001 de 2013, item 3.4.1 - 4.

Avaliação dos Riscos e Benefícios:

Os riscos são considerados mínimos, de corte ao realizar a tricotomia para melhor aderência dos eletrodos para a coleta do sinal eletromiográfico, que serão minimizados através de treinamento para o terapeuta a coletar os dados sobre como realizar o procedimento com segurança. Além

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disso, os instrumentos utilizados para o procedimento serão todos descartáveis. Haverá também o risco de alguma queda durante os procedimentos de avaliação de equilíbrio será minimizado com a presença de um fisioterapeuta experiente,
bem como uso de cinto de segurança afixado no teto. É improvável que o questionário utilizado nesse estudo cause algum estresse psicológico, entretanto os voluntários serão entrevistados em local privativo, resguardando o sigilo de seus dados. A avaliação de equilíbrio corporal será importante para ajudar os fisioterapeutas a identificar os pacientes com maior risco de quedas na comunidade
do município de Governador Valadares. Como benefício direto de participação neste projeto de pesquisa todos idosos identificados com risco aumentado de queda (caidores) receberão orientação sobre como prevenir quedas com atividades físicas baseado no protocolo domicilar de Otago, que é eficaz em reduzir em 33% o risco de queda (CAMPBELL et al, 1997). Para os fisioterapeutas os resultados dos procedimentos de avaliação do equilíbrio e da fadiga serão importantes para identificar se a fadiga de Tibial Anterior e Gastrocnêmio Medial e sua possível associação ao diabetes tipo 2 é fator predisponente para queda. O risco que o projeto apresenta é caracterizado como risco mínimo e estão adequadamente descritos, considerando que os indivíduos não sofrerão qualquer dano ou sofrerão prejuízo pela participação ou pela negação de participação na pesquisa e benefícios esperados adequadamente descritos. A avaliação dos Riscos e Benefícios estão de acordo com as atribuições definidas na Resolução CNS 466/12 de 2012, itens III; III.2 e V.

Comentários e Considerações sobre a Pesquisa:
O projeto está bem estruturado, delineado e fundamentado, sustenta os objetivos do estudo em sua metodologia de forma clara e objetiva, e se apresenta em consonância com os princípios éticos norteadores da ética na pesquisa científica envolvendo seres humanos elencados na resolução 466/12 do CNS e com a Norma Operacional Nº 001/2013 CNS.

Considerações sobre os Termos de apresentação obrigatória:
O protocolo de pesquisa está em configuração adequada, apresenta FOLHA DE ROSTO devidamente preenchida,com o título em português, identifica o patrocinador pela pesquisa, estando de acordo com as atribuições definidas na Norma Operacional CNS 001 de 2013 item 3.3 letra a; e 3.4.1 item 16. Apresenta o TERMO DE CONSENTIMENTO LIVRE ESCLARECIDO em linguagem clara para compreensão dos participantes, apresenta justificativa e objetivo, campo para identificação do participante, descreve de forma suficiente os procedimentos, informa que uma das vias do TCLE será entregue aos participantes,assegura a liberdade do participante recusar

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Continuação do Parecer: 1.891.492

ou retirar o consentimento sem penalidades,garante sigilo e anonimato, explicita riscos e desconfortos esperados, indenização diante de eventuais danos decorrentes da pesquisa,contato do pesquisador e do CEP e informa que os dados da pesquisa ficarão arquivados com o pesquisador pelo periodo de cinco anos, de acordo com as atribuições definidas na Resolução CNS 466 de 2012, itens:IV letra b; IV.3 letras a,b,d,e,f,g e h; IV. 5 letra d e XI.2 letra f. Apresenta o INSTRUMENTO DE COLETA DE DADOS de forma pertinente aos objetivos delineados e preserva os participantes da pesquisa. O Pesquisador apresenta titulação e experiência compatível com o projeto de pesquisa, estando de acordo com as atribuições definidas no Manual Operacional para CPEs. Apresenta DECLARAÇÃO de infraestrutura e de concordância com a realização da pesquisa de acordo com as atribuições definidas na Norma Operacional CNS 001 de 2013 item 3.3 letra h.

Conclusões ou Pendências e Lista de Inadequações:

Diante do exposto, o projeto está aprovado, pois está de acordo com os princípios éticos norteadores da ética em pesquisa estabelecido na Res. 466/12 CNS e com a Norma Operacional Nº 001/2013 CNS. Data prevista para o término da pesquisa:Julho de 2017.

Considerações Finais a critério do CEP:

Diante do exposto, o Comitê de Ética em Pesquisa CEP/UFJF, de acordo com as atribuições definidas na Res. CNS 466/12 e com a Norma Operacional Nº001/2013 CNS, manifesta-se pela APROVAÇÃO do protocolo de pesquisa proposto. Vale lembrar ao pesquisador responsável pelo projeto, o compromisso de envio ao CEP de relatórios parciais e/ou total de sua pesquisa informando o andamento da mesma, comunicando também eventos adversos e eventuais modificações no protocolo.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_830202.pdf	10/01/2017 12:25:00		Aceito
Folha de Rosto	scan.pdf	10/01/2017 12:24:15	Alexandre Wesley Carvalho Barbosa	Aceito
Declaração de Instituição e	DEC.pdf	22/11/2016 18:00:53	Alexandre Wesley Carvalho Barbosa	Aceito

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Infraestrutura	DEC.pdf	22/11/2016 18:00:53	Alexandre Wesley Carvalho Barbosa	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE.docx	22/11/2016 17:23:17	Alexandre Wesley Carvalho Barbosa	Aceito
Outros	ANEXO_3.docx	22/11/2016 17:12:25	Alexandre Wesley Carvalho Barbosa	Aceito
Outros	ANEXO_2.docx	22/11/2016 17:12:11	Alexandre Wesley Carvalho Barbosa	Aceito
Outros	ANEXO_1.docx	22/11/2016 17:11:54	Alexandre Wesley Carvalho Barbosa	Aceito
Projeto Detalhado / Brochura Investigador	PROJETO.doc	22/11/2016 16:55:08	Alexandre Wesley Carvalho Barbosa	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

JUIZ DE FORA, 16 de Janeiro de 2017

Assinado por:
Vânia Lúcia Silva
(Coordenador)

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APÊNDICE IV - MINI CURRÍCULO

DADOS PESSOAIS

Nome: Ilha Gonçalves Fernandes
Data de nascimento: 06/02/1990
Endereço: Rua Joaquim Faria Salgado, 337
Bairro: Morada do Vale
Cidade: Governador Valadares-MG
Endereço eletrônico: ilha.fernandes@hotmail.com
Link para Lattes: http://lattes.cnpq.br/1561872198268400

FORMAÇÃO ACADÊMICA

2016 – 2018 - Mestrado em Ciências da Reabilitação e Desempenho Físico Funcional.
Universidade Federal de Juiz de Fora, UFJF, Governador Valadares, Brasil.
Orientador: Prof. Dr. Alexandre Wesley Carvalho Barbosa

2015 – 2016 - Especialização em cinesiologia, biomecânica e treinamento físico.
Universidade Estácio de Sá, UNESA, Rio De Janeiro, Brasil.
Orientador: Wilson Pereira Lima

2010 – 2014 - Graduação em Fisioterapia. Faculdade Sudamérica, Cataguases, Brasil.
Orientador: Prof. Dr. Daniel Raul Santúrio Basile

CURSO DE CURTA DURAÇÃO

2017 - Adaptação transcultural e criação de escalas de medida. (Carga horária: 2h). Núcleo de Investigação Músculo-Esquelética - NIME.
2016 - Curso Prático de Análise de Dados. (Carga horária: 10h). Apollo Trainer gestão em saúde.
2015 - Curso Prático de Análise de Dados. (Carga horária: 10h). Apollo Trainer gestão em saúde.
2014 - Kabat Funcional. (Carga horária: 20h). Power Life, POWER LIFE, Brasil.
2014 - Mobilzação Neural. (Carga horária: 20h). Power Life, POWER LIFE, Brasil.
2014 - Mobilização Visceral. (Carga horária: 20h). Power Life, POWER LIFE, Brasil.
2014 - Quiropraxia. (Carga horária: 40h). Power Life, POWER LIFE, Brasil.
2013 - Pilates. (Carga horária: 120h). Universidade Presidente Antônio Carlos, UNIPAC, Brasil.
2012 - Quiropraxia. (Carga horária: 30h). Power Life, POWER LIFE, Brasil.
2012 - Primeiros Socorros. (Carga horária: 2h). Unimed Cataguases, UNIMED, Brasil.
2012 - Drenagem Linfática Manual Corporal e Facial. (Carga horária: 30h).

EXPERIÊNCIA PROFISSIONAL

2017 – 2017 - Universidade Federal de Juiz de Fora. Professora Substituta departamento de fisioterapia, UFJF-GV.
2016 – 2017 - Faculdade Sudamérica. Professora curso de fisioterapia.

2016 – 2016 - Prefeitura Municipal de Cataguases. Servidor Público, Fisioterapeuta.
2015 – 2016 - Fisioterapeuta na empresa Academia Corpus.
2015 – 2015 - Fisioterapeuta na empresa Fisiofitniss.

EXPERIÊNCIA ACADÊMICA

2018 - III Integrafisio UFJF-GV.
2017 - I Congresso Internacional e II congresso Brasileiro da Abrafito.
2017 - IX Congresso de Geriatria e Gerontologia de Minas Gerais.
2016 - I Seminário Internacional de Reabilitação do mestrado em Ciências da Reabilitação/UFJF.
2013 - VII Semana de Fisioterapia da Faculdade Sudamérica.
2012 - VI Semana de Fisioterapia da Faculdade Sudamérica.

ATIVIDADES DE EXTENSÃO

2018 – Palestra: "Trajetória Profissional: Relatos de um caminho em construção". III Integrafisio.

ATIVIDADES COMPLEMENTARES

2014 – 2014 - Monitoria. Clínica e Fisioterapia Neurológica, Carga horária: 10 h/s
2013 – 2013 - Monitoria. Cinesioterapia, Carga horária: 10 h/s
2012 – 2012 - Monitoria. Eletroterapia, Carga horária: 10 h/s
2011 – 2011 - Monitora de Anatomia, Carga horária: 10 h/s
2011 – 2011 - Iniciação Científica. Projeto: Saúde da Gestante.
Orientador: Andrês Valente Chiapeta

ARTIGOS PUBLICADOS

BARBOSA, A. C.; VIEIRA, E. R.; BARBOSA, M. C. S. A.; FERNANDES, I. G.; DAMAZIO, M.; BADARO, B. Gluteal activation and increased frontal plane projection angle during a step-down test in young women. Human Movement, v. 19 (1), p. 64-70, 2018.

BARBOSA, A. W. C.; INTELANGELO, L.; BORDACHAR, D.; FERNANDES, I. G.; CARDOSO, D.; FELICIO, D. C.; PORFIRIO, W. Validity and reliability of anchored non-modified sphygmomanometer to assess shoulder strength during scaption, internal and external rotation. Human Movement, v. 19 (2), p. 90-98, 2018.

ARTIGO SUBMETIDO

RESUMOS EM PERIÓDICOS E ANAIS DE CONGRESSOS

FERREIRA, I. C.; BARBOSA, A. W. C.; FERNANDES, I. G.; FERREIRA, D. C. CA; SANTOS, P. F.; BARBOSA, M. C. S. A. Equilíbrio e a ativação dos músculos da perna em mulheres idosas diabéticas. In: IX Congresso de Geriatria e Gerontologia, Belo Horizonte. Envelhecer no século XXI: demandas, desafios e limites, 2017.

SANTANA, F. L.; FERREIRA, D. C. CA; OLIVEIRA, M. L.; BARBOSA, A. W. C.; BARBOSA, M. C. S. A ; FERNANDES, I. G. Ativação dos músculos da perna em idosos diabéticos

durante equilíbrio monopodal semi-estático. In: IX Congresso de Geriatria e Gerontologia, Belo Horizonte. Envelhecer no século XXI: demandas, desafios e limites, 2017.

BARBOSA, A. W. C.; FERNANDES, I. G.; SANTOS, P. F.; OLIVEIRA, M. L.; SANTANA, F. L.; BARBOSA, M. C. S. A. Equilíbrio e eletromiografia de tibial anterior pós-fadiga em idosos com alto medo de queda. In: IX Congresso de Geriatria e Gerontologia, Belo Horizonte. Envelhecer no século XXI: demandas, desafios e limites, 2017.

BARBOSA, A. W. C.; BRAGA, S.; FERNANDES, I. G.; REZENDE, R.; BARBOSA, M. C. S. A. Vibração corporal e treino de marcha no equilíbrio, preensão manual e parâmetros de marcha em paciente com atrofia de múltiplos sistemas: estudo de caso. In: II Congresso Brasileiro de Gerontecnologia, Ribeirão Preto. Revista da Faculdade de Medicina de Ribeirão Preto e do Hospital das Clínicas da FMRP-USP, 2017. v. 50. p. 156-156.

BARBOSA, A. W. C.; FORECHI, L.; FERNANDES, I. G.; BARBOSA, M. C. S. A. Benefícios de um set-up portátil, de baixo custo e validado para coleta de dados biomecânicos em idosos: relato de experiência em grupo de pesquisa. In: II Congresso Brasileiro de Gerontecnologia, Ribeirão Preto. Revista da Faculdade de Medicina de Ribeirão Preto e do Hospital das Clínicas da FMRP Universidade, 2017. v. 50. p. 113-114.

BARBOSA, A. C.; FERNANDES, I. G.; VIEIRA, E. R.; BADARO, B.; DAMÁZIO, M.; BARBOSA, M. C. S. A. Gluteal activation and increased unilateral frontal plane projection angle during step-down test in young healthy woman. In: I Congresso Internacional e II Congresso Brasileiro da ABRAFITO, Brasília. Revista Inspirar - movimento e saúde, 2017. v. 9. p. 86-86.

FERNANDES, I. G.; FERNANDES, I.; CARDOSO, D.; INTELANGELO, L.; BORDACHAR, D.; BARBOSA, A. C. Validade do esfignomanômetro para avaliação de força de flexão no plano escapular, rotações interna e externa de ombro. In: I Congresso Internacional e II Congresso Brasileiro da ABRAFITO, Brasília. Revista Inspirar - movimento e saúde, 2017. v. 9. p. 85-85.