UNIVERSIDADE FEDERAL DOS VALES DO JEQUITINHONHA E MUCURI

Programa de Pós-Graduação em Reabilitação e Desempenho Funcional

Ana Lúcia Cristino de Souza

VIBRAÇÃO DE CORPO INTEIRO NA POSIÇÃO ESTÁTICA COM AS MÃOS SOBRE A PLATAFORMA ESTIMULA O SISTEMA NEUROMUSCULAR POTENCIALIZANDO A FORÇA MUSCULAR DE PREENSÃO MANUAL

Diamantina
2017

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Vibração de corpo inteiro na posição estática com as mãos sobre a plataforma estimula o sistema neuromuscular potencializando a força de preensão manual

Dissertação apresentada ao PROGRAMA DE POS-GRADUAÇAO EM REABILITAÇAO E DESEMPENHO FUNCIONAL - STRICTO SENSU, nível de MESTRADO como parte dos requisitos para obtenção do titulo de MAGISTER SCIENTIAE EM REABILITAÇAO E DESEMPENHO FUNCIONAL

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Data da aprovação: 22/09/2017

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DIAMANTINA

Ficha Catalográfica - Sistema de Bibliotecas/UFVJM
Bibliotecária: Jullyele Hubner Costa CRB-6/2972

S729v Souza, Ana Lúcia Cristino de.
Vibração de corpo inteiro na posição estática com as mãos sobre a plataforma estimula o sistema neuromuscular potencializando a força de preensão manual / Ana Lúcia Cristino de Souza. – Diamantina, 2017.
46 p.

Orientadora: Ana Cristina Rodrigues Lacerda
Coorientadora: Vanessa Amaral Mendonça

Dissertação (Mestrado - Programa de Pós-graduação em Reabilitação e Desempenho Funcional) –Universidade Federal dos Vales do Jequitinhonha e Mucuri.

1. Vibração. 2. Desempenho muscular. 3. Força de preensão manual. 4. Eletromiografia. I. Lacerda, Ana Cristina Rodrigues. II. Mendonça, Vanessa Amaral. III. Título.

CDD 612.044

Elaborada com os dados fornecidos pela autora.

MINISTERIO DA EDUCAÇÃO

UNIVERSIDADE FEDERAL DOS VALES DO JEQUITINHONHA E MUCURI - UFVJM

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À Deus, por me permitir mais uma oportunidade de vida e conquista.
Ao meu filho amado, Lucas, por ser sempre parceiro. Acreditar, confiar e me acompanhar,
incondicionalmente, em todas as situações.

AGRADECIMENTOS

À orientadora, Dra Ana Cristina Rodrigues Lacerda, pelo compromisso e dedicação ao ensino, por tornar possível a execução dessa pesquisa e por sua amizade.

À co-orientadora, Dra Vanessa Amaral Mendonça, pelas valiosas contribuições.

Aos professores do PPGReab da UFVJM, pelas importantes contribuições.

À Ana Carolina Ansani, por estar presente, principalmente nos percalços da coleta de dados.

À Ana Carolina de Oliveira, Luciana Martins, Márcia Rocha e Jonathan Senra, pela persistência nas coletas.

Ao José Sebastião Cunha Fernandes e Sueli Ferreira da Fonseca, pela contribuição na estatística.

Ao Professor David Lee, pela revisão do inglês.

Aos colegas de pós-graduação, pelas trocas de experiência em sala de aula.

À equipe do Laboratório de Fisiologia do Exercício (LAFIEX) da UFVJM, pelo apoio e contribuições.

À toda a equipe de profissionais e funcionários do CIPq que direta ou indiretamente colaboraram com a viabilização deste estudo.

Aos meus alunos e pacientes, que impulsionam a busca pelo aprendizado.

Às voluntárias, que se disponibilizaram a participar, bem como fornecer as informações necessárias para a realização desse estudo.

Às amigas e vizinhas Luciana de Freitas Campos e Ivone Moraes, pela receptividade, carinho e amizade.

Ao Alexandre Christófaro, pela amizade e acolhida em Diamantina.

Aos meus tios, tias, primos e primas pelo apoio e incentivo.

Aos meus irmãos, Lu e Guto, pelo carinho e apoio.

Ao meu filho, Lucas Cezar, por compreender a minha ausência em alguns momentos da sua vida.

Aos meus pais, Luiz Carlos e Maria das Graças, responsáveis por todas as minhas conquistas.

Ao meu amor, José Carlos, companheiro de todas as horas.

RESUMO

A vibração do corpo inteiro (VCI) pode ser uma modalidade ergogênica capaz de melhorar o desempenho muscular. Uma vez que a transmissibilidade deste estímulo é reduzida quando aplicado sob os pés, permanece uma lacuna no que tange a potencialização da força de preensão manual (FPM) na posição estática, com as mãos sobre a plataforma, em indivíduos saudáveis. O objetivo deste estudo foi investigar o efeito dose-resposta da exposição à vibração na posição estática, com as mãos sobre a plataforma na FPM e nos registros eletromiográficos (EMG) do músculo flexor superficial dos dedos. Vinte e oito mulheres saudáveis (idade: 27 ± 8 anos, IMC: 23,2 ± 4,5 kg.m-2) foram familiarizadas e submetidas de forma randomizada e aleatorizada a quatro situações experimentais: A). Sentado - mãos supinadas, apoiadas nas pernas, sem estímulo vibratório; B) Placebo – mãos posicionadas sobre a plataforma desligada e estímulo sonoro mimetizando o estímulo de vibração; C). 25Hz / 2mm e D). 45Hz / 2mm - semelhante à posição placebo com estímulo vibratório vertical sinusoidal em diferentes freqüências, com aplicação da amplitude de 2mm. O período de intervenção foi de 5 minutos em todas as situações experimentais. Antes e imediatamente após as intervenções, o desempenho muscular da mão dominante foi avaliado usando o dinamômetro de força manual (Jamar, EUA). Os registros EMG (Miotec, Brasil) ocorreram durante as situações experimentais. A razão neuronal representou a relação entre registros EMG e força de preensão. A análise estatística foi realizada por ANOVA bifatorial, com post hoc (Tukey), sendo considerado p <0,05 significativo. Como resultado, a exposição à vibração de 45Hz / 2mm resultou em um aumento de variação (pós-antes) na FPM em média de 84,6%, 93,7%, 62,6% para controle, placebo e 25Hz / 2mm, respectivamente. Este aumento foi acompanhado por uma menor relação neuronal. Os registros EMG durante o período de intervenção demonstraram que apenas a exposição ao VCI (45Hz / 2mm) aumentou os registros EMG em uma média de 94,8 % e 50,2% em relação ao controle e placebo, respectivamente. Esses achados mostram que a exposição à vibração na posição *push-up* modificada estática potencializou a resposta miogênica da mão de forma dose dependente. O mecanismo parece estar relacionado com a estimulação do sistema neuromuscular e a subsequente potenciação pós-ativação que defende o aprimoramento neural.

Palavras-Chave: vibração, desempenho muscular, força de preensão manual, EMG

ABSTRACT

Because the transmissibility of vibration is lower when applied under the feet, an uncertainty remains as to whether this stimulus could potentiate handgrip strength (HS) in the static modified push-up position. The aim of this study was to investigate the effect of vibration in the push-up position on HS and electromyography (EMG) of the superficial flexor muscle of the fingers. 28 healthy women (age: 27 ± 8 years, BMI: 23.2 ± 4.5 kg.m^{-2}) were familiarized and submitted, to four experimental situations in a balanced, and randomized order: A). Seated supine with hands supported on the legs; B) Placebo – hands on the platform off; C). 25 Hz/2 mm/49.30 m.s^{-2} and, D). 45 Hz/2 mm/159.73 m.s^{-2} similar to the placebo position with vibration turned on. The intervention was 5-minutes in all experimental situations. Muscle performance was evaluated using the HS dynamometer (Jamar, USA). The EMG (Miotec, Brazil) was registered throughout experimental situations. The neuronal ratio represented the ratio between EMG and HS. The 45 Hz exposure resulted in an increase in variation of the HS by 84.6%, 93.7%, 62.6% relative to the control, placebo and 25 Hz, respectively. This augment was accompanied by a lower neuronal ratio. The EMG during the intervention demonstrated that only 45 Hz increased the EMG by an average of 94.8%, and 50.2% compared to the control and placebo, respectively. In conclusion, the vibration in the push-up position potentiated the HS. The mechanism seems to be related to the stimulation of the neuromuscular system and subsequent post-activation potentiation advocating neural enhancement.

Keywords: exposure to vibration, muscular performance, grip strength, EMG records

LISTA DE ILUSTRAÇÕES

LISTA DE TABELAS

LISTA DE ABREVIATURAS E SIGLAS

VCI – Vibração de todo o corpo
WBV - Whole Body Vibration
FPM – Força de Preensão Manual
EMG – Electromyography
SFF - superficial flexor of the finger
LAFIEX - Laboratório de Fisiologia do Exercício
HS – Hand Strength
RN – Neuronal Innervation
EN – Eficiência Neuronal

SUMÁRIO

CAPÍTULO 1 – REFERÊNCIAL TEÓRICO

1 INTRODUÇÃO

A vibração do corpo inteiro (VCI) surgiu em 1998 como modalidade de atividade preparatória antes da prática esportiva. Bosco e colaboradores partiram do princípio de que a gravidade normalmente fornece a maior parte do estímulo mecânico responsável pelo desenvolvimento da estrutura do músculo durante o dia-a-dia e durante treinamento (BOSCO *et al.,* 1998).

O estímulo vibratório, em um sentido físico, é definido como a força da oscilação onde a energia é transferida de um dispositivo de vibração para o corpo humano ou parte dele. Desta forma, o estímulo vibratório tem sido investigado na última década como uma alternativa ou até mesmo um complemento aos métodos tradicionais já existentes de treinamento, com o objetivo de potencializar os benefícios destes programas (GUTIÉRREZ; RHEA; MARÍN, 2014).

Perchthaler (2015) relatou que a magnitude da atividade eletromiográfica (EMG) de um músculo específico depende da carga de vibração, que é determinada pelos parâmetros biomecânicos como: aceleração, frequência, amplitude de deslocamento pico a pico e angulação da articulação. A carga vibratória é quantificada calculando a aceleração transmitida ao corpo inteiro, de acordo com a seguinte equação: aceleração = A x $(2\pi f)^2$. Nesta equação, “A” representa a amplitude de oscilação e “f” representa a frequência. Sendo assim, alterações na frequência ou na amplitude determinam a magnitude da vibração transmitida ao corpo (DI GIMINIANI *et al.*, 2014).

Considerando sujeitos saudáveis, a literatura vigente evidencia que a força e potência muscular, equilíbrio pode ser aumentada (BOSCO *et al.,* 1999 e 2000; JACOBS e BURNS, 2009; TORVINEN *et al.,* 2002a), diminuída (DERUITER *et al.,* 2003) ou inalterada (DERUITER *et al.,* 2003; TORVINEN *et al.,* 2002b) dependendo do volume e da intensidade do estímulo de VCI, da forma de execução e posicionamento do indivíduo sobre a plataforma, bem como do tipo de plataforma utilizada (estímulo sincrônico ou assincrônico, uniplanar ou triplanar).

Segundo Asmussen e Boje (1945), o aumento em torno de 1ºC na temperatura muscular resultou em incremento de 4% no desempenho muscular. Assim, a aplicação do estímulo vibratório também tem sido utilizada por treinadores durante sessões de treinamento e em competições esportivas baseando-se na premissa de promover "*aquecimento muscular ativo*" (COCHRANE *et al*., 2008; COCHRANE *et al*., 2010) e aumento no fluxo sanguíneo da pele durante exercício vibratório. Acredita-se que o fluxo sanguíneo parece intensificar devido ao aumento da demanda de energia exigida pelo estímulo de vibração, resultando em produção de calor e aumento na demanda de perfusão muscular (RITTWEGER, 2010).

De acordo com Rittweger (2010), durante o processo de geração de calor e, consequentemente, aquecimento muscular, é necessário considerar a forma que as vibrações mecânicas são transmitidas da plataforma para os segmentos corporais. Assim, o local onde o estímulo é aplicado, a rigidez artificial do corpo humano, o posicionamento adotado sobre a plataforma vibratória, a realização de exercícios dinâmicos, os parâmetros de aceleração do estímulo vibratório são fatores que influenciam a magnitude do aquecimento muscular.

A literatura também aponta a facilitação neuromuscular como outro possível mecanismo responsável pelo aumento da força e/ou potência muscular imediatamente após a aplicação de vibração de corpo inteiro. Segundo Matthews e Watson (1981), as oscilações da plataforma vibratória estimulam fibras aferentes Ia, resultando na facilitação homônima dos motoneuronios-alfa, induzindo a contração reflexa em ambos os músculos (primários e secundários) envolvidos na *performance* do exercício. Assim, uma potenciação neuromuscular, conhecida como potenciação pós-ativação, resultante da contração muscular antes do teste de desempenho ou da prática esportiva, parece induzir a excitabilidade do motoneurônio e, consequentemente, a fosforilação dos elementos contráteis (i.e., cabeça leve regulatória da miosina) e/ou promover o aumento do recrutamento de maior número de unidades motoras (BOSCO; CARDINALE; TSARPELA, 1999; MCBRIDE *et al*., 2010).

Rassier e Macintosh (2000) definem potenciação pós-ativação (PAP) como o aumento do torque de uma contração muscular causado por uma contração condicionante em função da provável fosforilação da miosina regulatória de cadeia leve (BAUDRY & DUCHATEAU, 2007). Assim, esta fosforilação alteraria a conformação das pontes cruzadas, colocando as cabeças globulares da miosina em posição mais próxima dos filamentos de actina. Esta aproximação, por sua vez, aumentaria a probabilidade de interação entre as proteínas contráteis, o que implicaria em maior quantidade de conexões entre os filamentos e, consequentemente, maior desenvolvimento de tensão (BATISTA *et al*., 2010; BAUDRY; KLASS; DUCHATEAU, 2005; O'LEARY; HOPE; SALE, 1997; MORANA & PERREY, 2009; RASSIER & MACINTOSH, 2000). Além disso, Hamada *et al.* (2000) afirmaram que uma ação condicionante prévia poderia acarretar maior liberação do cálcio pelo retículo sarcoplasmático aumentando, desta forma, a sua concentração no sarcoplasma. O aumento na concentração de cálcio no sarcoplasma levaria a uma maior taxa de formação das pontes cruzadas devido a um aumento da sensibilidade das proteínas contráteis ao cálcio, aumentando consequentemente a força de contração muscular e a taxa de desenvolvimento de força.

Cardinale *et al.* (2010) investigaram os efeitos na concentração plasmática de cortisol, testosterona, hormônio do crescimento e fator de crescimento como insulina tipo 1 (IGF-1), de uma sessão de 5 minutos em plataforma vibratória, utilizando como parâmetros 30 Hz de frequência e 4 mm de amplitude (aceleração de 141,98 m/s²), posição de semi-agachamento, em idosos antes, imediatamente após, 1 e 2h após intervenção. Como achados, estes autores apesar de não terem observado efeito do estímulo vibratório na concentração plasmática dos hormônios testosterona e hormônio de crescimento, demonstraram efeito nas concentrações plasmáticas de IGF-1 e cortisol. Com base nestes achados, os autores concluíram que o estímulo de vibração de corpo inteiro aplicado de forma aguda na população idosa parece ser um estímulo a favor de eventos anabólicos. Assim, a aplicação deste estímulo como modalidade de treinamento poderia gerar adaptações musculares a favor do incremento da força e trofismo muscular.

A simulação da situação de supergravidade, como por exemplo, utilizando uma vestimenta com carga, era utilizada visando ganhos musculares explosivos em humanos (BOSCO *et al.,* 1998). No entanto, considerando que mudanças gravitacionais poderiam ser promovidas por aplicação de variações mecânicas aplicadas em todo corpo, Bosco *et al.* (1998) levantaram a hipótese da possível influência da vibração de corpo inteiro nos comportamentos mecânicos dos músculos extensores de membros inferiores em sujeitos ativos, influenciando a força e a potência muscular. Assim, 14 indivíduos fisicamente ativos foram divididos em dois grupos (grupo experimental e grupo controle), onde no grupo experimental os participantes foram submetidos à vibração de corpo inteiro com 5 séries de 2 minutos por dia, durante 10 dias. Os sujeitos foram avaliados no início e ao final do treinamento com testes de saltos específicos em uma plataforma resistiva. Os resultados foram positivos apenas no grupo experimental onde houve melhora significativa na altura e na potência do salto.

Evidências recentes demonstraram que após a aplicação aguda de vibração de corpo inteiro com estímulo sob os pés, associando agachamentos dinâmicos, houve melhora do desempenho muscular de alta intensidade em membros inferiores e maior potência muscular e cadência de pedalada (AVELAR *et al.*, 2014; TELES *et al.*, 2015). Outros estudos corroboram este achado, também evidenciando o efeito ergogênico muscular quando se aplica estímulo vibratório previamente à atividade física (CORMIE *et al.,* 2006; BULLOCK *et al*., 2008; COCHRANE *et al*., 2008; COCHRANE *et al*., 2010; DI GIMINIANI *et al.,* 2014).

Mileva, Bowtell e Kossev (2009) utilizaram o estímulo agudo de vibração de corpo inteiro, parâmetros em 30 Hz de frequência e 1,5 mm de amplitude (aceleração de 53,24 m/s^2), em posição de agachamento estático. Como resultado, estes autores observaram o aumento da excitabilidade córtico-espinhal e alteração na excitabilidade em processos intra-corticais, sugerindo, desta forma, que a aplicação de estímulo de vibração de corpo inteiro em sujeitos hígidos poderia influenciar o estado de excitabilidade do sistema nervoso central e periférico, facilitando, consequentemente, a eficácia de movimentos voluntários subsequentes.

Gimianini *et al.* (2014) realizaram estudo com 20 indivíduos do gênero masculino, utilizando plataforma vibratória que emite ondas sincrônicas, subdivididos em 3 grupos: controle, alta intensidade (40 Hz de frequência e 0,9 mm de amplitude e com aceleração de 56,79 m/s^2) e baixa intensidade (20 Hz de frequência e 0,2 mm de amplitude (aceleração de 3,16 m/s^2), em posição de flexão de braço na plataforma e avaliaram a atividade eletromiográfica dos músculos peitoral maior, tríceps braquial, deltóide anterior e flexor radial do carpo. Além disso, aplicaram testes de desempenho muscular como o teste de preensão palmar e exercício no aparelho “supino”. Como resultado, houve redução na atividade eletromiográfica do músculo tríceps braquial no grupo de alta intensidade e redução na atividade eletromiográfica dos músculos flexor do carpo e no deltóide no grupo de baixa intensidade. Assim, estes autores levantaram a hipótese de possível efeito de fadiga, reduzindo, desta forma, a atividade eletromiográfica na postura adotada na plataforma vibratória. Com relação ao desempenho muscular, os autores não evidenciaram efeito do estímulo nos testes de desempenho muscular.

Segundo Perchthaler (2015), qualquer aumento na pré-ativação muscular, como por exemplo, aplicação de estímulo de vibração de corpo inteiro, promoveria aumento sensitivo no fuso muscular por meio da co-ativação alfa-gama. Além disso, este aumento seria amplificado quanto mais próximo o estímulo (sistema indutor) estiver do músculo.

A literatura vigente exibe escassez de estudos que investigaram tanto o efeito ergogênico agudo quanto do treinamento com utilização de vibração de corpo inteiro em membros superiores. A razão para isto parece ser pautada na atenuação que a vibração sofre até atingir os membros superiores (MMSS) quando o estímulo é aplicado sob os pés.

Estudos utilizaram diferentes estratégias para transmitir a vibração de modo seguro e eficaz aos membros superiores. Segundo (ASHNAGAR *et al.,* 2016), as propriedades do tecido mole do corpo humano, combinados com a atividade neuromuscular desempenhada pelo cérebro para controlar a exposição da vibração, resultariam em menor transmissão do estímulo vibratório aos membros superiores quando este é aplicado sob os pés.

Pesquisadores variaram desde a utilização de halteres vibratórios à realização de semi agachamentos (HAZELL; JAKOBI; KENNO, 2007; MISCHI & CARDINALE, 2009). Alguns estudos mencionaram que a posição de flexão de braço com as mãos posicionadas diretamente na plataforma vibratória teria como vantagem a facilitação da transmissão do estímulo vibratório aos músculos da cintura escapular visto que as mãos estariam próximas ao estímulo (ASHNAGAR *et al.,* 2016).

Ashnagar e colaboradores (2016) utilizaram a posição estática de flexão de braço sobre a plataforma vibratória para avaliar o efeito da vibração de corpo inteiro na atividade eletromigráfica de músculos do manguito rotador. Eles argumentaram que esta posição teria como vantagem a facilitação da transmissão do estímulo vibratório aos músculos da cintura escapular visto que as mãos estariam próximas ao estímulo. Os achados desse estudo demonstraram que o estímulo aplicado na posição adotada aumentou a atividade eletromiográfica de músculos dos membros superiores (trapézio superior, serrátil anterior, bíceps braquial e tríceps braquial). Entretanto, mais sessões de aplicação de estímulo vibratório seriam necessárias para este estudo, haja visto que foi utilizada apenas a frequência de 30 Hz / 5 mm (aceleração de 177,47 m/s^2), e a eletromiografia foi mensurada em músculos do membro dominante.

Gutiérrez, Rhea e Marín (2014), realizaram estudo com 28 sujeitos hígidos objetivando mensurar os efeitos do estímulo vibratório no desempenho neuromuscular de membros superiores durante exercício isométrico em posição de semi agachamento (30 graus de flexão de joelhos) na intensidade 50 Hz de frequência e 2,51 mm de amplitude (aceleração de 247,48 m/s^2), tendo como desfecho primário a mensuração da força de preensão manual por meio de dinamômetro e como desfecho secundário a atividade eletromiográfica dos músculos flexor radial do carpo, bíceps braquial, gastrocnêmio medial e extensor radial longo do carpo, onde cada participante passava por 3 situações experimentais, em um mesmo dia, com intervalo de 10 minutos entre as seguintes situações experimentai: vibração de corpo inteiro associada à vibração do membro superior contralateral por meio de uma alça de mão diretamente conectada a vibração da plataforma; vibração apenas do membro superior; sem vibração de membro superior ou de corpo inteiro. Como resultado, não houve diferença na força de preensão manual entre as situações experimentais. A análise dos dados da eletromiografia demonstrou diferença significativa na atividade apenas dos músculos extensores do carpo, indicando que a vibração de corpo inteiro associada com a vibração do braço contralateral produziu baixa co-ativação nos músculos avaliados durante a tarefa de preensão manual. Portanto, houve redução na ativação do músculo antagonista sem mudança na ativação do músculo agonista durante a realização do exercício de preensão manual. Os autores sugeriram que a aplicação da vibração de corpo inteiro associada à vibração do membro superior, aplicados de forma aguda, parece aprimorar a coordenação muscular e diminuir a co-ativação do músculo extensor do carpo sem mudança na força de preensão manual.

Avelar et al (2013), verificou melhora no desempenho de alta intensidade em membros inferiores pelo estímulo vibratório, sem aumento na atividade eletromiográfica. Assim, outra possível explicação para a melhora na capacidade de rendimento muscular (potência e/ou força muscular) pode estar relacionada com a **Potenciação pós–ativação (PPA)** (Rassier & Macintosh, 2002). Baudry & Duchateau (2007), define a PPA como o aumento do torque de uma contração muscular causado por uma contração condicionante em função da provável fosforilação da miosina regulatória de cadeia leve (FMCL).

Bosco *et al.* (1999), relataram que a atividade eletromiográfica dos músculos parece ser potencializada durante o estímulo vibratório, com a razão neuronal (atividade EMG / desempenho muscular) reduzida após exposição ao estímulo vibratório; promovendo, desta forma, aumento paralelo na potência muscular, resultando em maior eficiência neuronal. Eficiência neuronal representa a razão entre a atividade do motoneurônio pela força muscular (RN= % EMG / Força Kgf). Portanto, quanto menor a razão neuronal representa maior eficiência neuronal (EN)

Acredita-se, no presente estudo, que a vibração de corpo inteiro, pode: (1) não modificar a razão neuronal (RN) e a eficiência neuronal (EN), quando ocorre o aumento da ativação EMG e aumento de força; (2) aumentar a RN, reduzindo a EN, quando ocorre o aumento da EMG, sem alteração da força; (3) reduzir a RN aumentando a EN, quando ocorre o aumento da força, sem alteração da EMG.

A vibração do corpo inteiro (VCI) pode ser um possível estímulo ergogênico capaz de melhorar a força de preensão manual no contexto da reabilitação. A relevância desse estudo é pautada na necessidade de se estudar alternativas terapêuticas que potencializam a resposta miogênica dos membros superiores em mulheres saudáveis. Como possíveis justificativas, (1) maior inserção do gênero feminino no mercado de trabalho exercendo atividades que requerem força e potência manual; (2) levantamento de peso e atividades que requerem “carregar” peso são exemplos de exercícios realizados no cotidiano e em atividades laborais; (3) maior incidência de lesões musculotendíneas e ocorrência de doenças crônicodegenerativas no gênero feminino, poderiam ser justificadas por problemas hormonais, dupla jornada de trabalho, e baixo preparo muscular para certas tarefas; (4) há associação positiva entre a força de preensão manual e a densidade mineral óssea pós-menopausa; (5) não há estudo que investigou o efeito agudo da exposição à vibração na posição push up estática modificada na força de preensão manual, como desfecho primário e a atividade eletromiográfica, como desfecho secundário, do músculo flexor superficial dos dedos, que é o motor primário em atividades que envolvem preensão manual; (6) o presente estudo serve de base para estudos futuros que investiguem a exposição da vibração de corpo inteiro como atividade preparatória, visando aumento da força muscular dos membros superiores no contexto da reabilitação em mulheres. (Hakkinen, 2001; Kritz, 1994 Lowe, 2010; Nestle, 2017).

2 OBJETIVOS

Objetivo geral

Investigar o efeito de diferentes intensidades de estímulo agudo de vibração de corpo inteiro, aplicado na posição *push up* estática modificada, na força de preensão manual (desfecho primário), na atividade eletromiográfica (desfecho secundário) do músculo flexor superficial dos dedos e na razão neuronal (desfecho secundário) em mulheres saudáveis não treinadas.

Objetivos específicos

- Avaliar o efeito de diferentes combinações de aceleração de vibração, aplicada diretamente sob as mãos, comparado com placebo e controle na força de preensão manual do membro superior dominante.

- Avaliar o efeito de diferentes combinações de aceleração de vibração, aplicada diretamente sob as mãos, comparado com o placebo e controle na atividade eletromiográfica do músculo flexor superficial dos dedos do membro superior dominante, bem como na razão neuronal.

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CAPÍTULO 2 – ARTIGO CIENTÍFICO

RESUMO

WHOLE BODY VIBRATION IN THE STATIC MODIFIED PUSH-UP POSITION STIMULATES NEUROMUSCULAR SYSTEM POTENTIATING HANDGRIP MYOGENIC RESPONSE

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Funding: Fundação de Amparo à pesquisa de Minas Gerais (Fapemig), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Comissão de Aperfeiçoamento de Pessoal do Nível Superior (Capes), Universidade Federal do Vales do Jequitinhonha e Mucuri (UFVJM)

WHOLE BODY VIBRATION IN THE STATIC MODIFIED PUSH-UP POSITION STIMULATES NEUROMUSCULAR SYSTEM POTENTIATING HANDGRIP MYOGENIC RESPONSE

ABSTRACT

Because the transmissibility of vibration is lower when applied under the feet, an uncertainty remains as to whether this stimulus could potentiate handgrip strength (HS) in the static modified push-up position. The aim of this study was to investigate the effect of vibration in the push-up position on HS and electromyography (EMG) of the superficial flexor muscle of the fingers. 28 healthy women (age: 27$\pm$ 8 years, BMI: 23.2 $\pm$ 4.5 kg.m^{-2}) were familiarized and submitted, to four experimental situations in a balanced, and randomized order: A). Seated supine with hands supported on the legs; B) Placebo – hands on the platform off; C). 25 Hz/2 mm/49.30 m.s^{-2} and, D). 45 Hz/2 mm/159.73 m.s^{-2} similar to the placebo position with vibration turned on. The intervention was 5-minutes in all experimental situations. Muscle performance was evaluated using the HS dynamometer (Jamar, USA). The EMG (Miotec, Brazil) was registered throughout experimental situations. The neuronal ratio represented the ratio between EMG and HS. The 45 Hz exposure resulted in an increase in variation of the HS by 84.6%, 93.7%, 62.6% relative to the control, placebo and 25 Hz, respectively. This augment was accompanied by a lower neuronal ratio. The EMG during the intervention demonstrated that only 45 Hz increased the EMG by an average of 94.8%, and 50.2% compared to the control and placebo, respectively. In conclusion, the vibration in the push-up position potentiated the HS. The mechanism seems to be related to the stimulation of the neuromuscular system and subsequent post-activation potentiation advocating neural enhancement.

Keywords: exposure to vibration, muscular performance, grip strength, EMG

INTRODUCTION

Whole body vibration (WBV) has received a lot of attention for augmenting the acute effects of strength and power in the lower body (3, 37, 11), whereas only a few studies investigate the effects of upper-body vibration (7, 18, 32).

The mechanism that causes strength and power increases from acute vibration is still being debated. However, the current proposal is that vibration provides a mechanical stimulus that causes the muscle fibers to stretch, thereby evoking a natural stretch, which enhances the neuromuscular function through neurogenic excitability and recruitment (7, 18). Nevertheless, further research is required at the neuromuscular level to validate this proposition.

Because the transmissibility of this stimulus is lower when applied under the feet (4, 10, 28), it remains unknown whether it could promote an improvement in handgrip strength when the stimulus is applied directly on the upper-body. Cochrane's study (9) demonstrated that an acute WBV exposure did not promote the expected potential neuromuscular enhancements of the handgrip strength in climbers during a static modified push-up position. Well-trained athletes are believed to have no margin for further performance improvement because they are close to their genetic potentials and already have highly developed muscular characteristics, such as high levels of reflex sensitivity, fast-twitch fibre recruitment, motor neuron excitability, and stiffer muscle-tendon units (22). Therefore, it is not known whether the magnitude of the stimulus was sufficient to promote a myogenic response whereas there was only one stimulus intensity, limiting the interpretation and extrapolation of the results. Although several WBV studies have been conducted on well-trained/elite athletes (22), the generalizability of the results of these studies to healthy, untrained subjects is impossible. Finally, it remains uncertain whether the EMGrms activity of muscles has been potentiated during vibration because no EMG data was collected. The ratio of EMGrms to power was lower after vibration and increases that were parallel to muscular power were observed, which advocates neural enhancement.

However, whole body vibration (WBV) can be a possible ergogenic stimulus that is able to improve the handgrip strength in the context of rehabilitation. This higher incidence in the female gender is justified by hormonal issues, the double working day, and the lack of muscle preparation for certain tasks (27, 31). In addition, current literature indicates a positive association between handgrip strength and postmenopausal bone mineral density (15, 20) Therefore, it is relevant to study therapeutic alternatives that potentiate the myogenic muscle response of upper limbs in healthy women. This knowledge can serve as a basis for future studies investigating WBV exposure for muscle strength enhancement of upper limbs in the context of rehabilitation.

To our understanding, no study has examined the acute dose-response effect of WBV exposure in the static, modified push-up position on handgrip strength and electromyographic (EMG) records of the superficial flexor muscle of the fingers, which is the main muscle group utilized during manual activities involving the handgrip (26) in healthy, untrained women.

Thus, the aim of this study was to investigate the dose-response effect of vibration exposure in the static modified push-up position on handgrip strength and electromyographic (EMG) records of the superficial flexor muscle of the fingers in healthy, untrained women. It was hypothesized that acute UBV would cause the desired neuromuscular responses for enhancing handgrip strength. In parallel, activation of tonic-vibratory reflex would occur, and consequently, reduction in the neuronal innervation ratio of the main muscle involved in handgrip activities, which could provide an additional method for improving strength training.

METHODS

Experimental Approach to the Problem

Whole-body vibration training has received a lot of attention in the areas of athletic conditioning, health, and rehabilitation. Our previous studies have demonstrated the effectiveness of WBV in improving high-intensity performance during cycle exercise for athletes immediately before competition or training (38). Many competitors are now using this modality as part of their conditioning regimes as they try to enhance their lower limb neuromuscular potential from the post-activation potentiation that occurs from WBV (2).

Because the transmissibility of this stimulus is lower when applied under the feet (2, 28, 10), we believe that muscles directly exposed to vibration would show more pronounced performance enhancement than indirectly vibrated muscles. Depending on the purpose of the study, forearm muscles were directly exposed to different intensities of vibration. The values for handgrip strength (primary outcome) were obtained before and after experimental conditions, and electromyography (secondary outcome) was measured during all the data collection. The target audience of this study was healthy, untrained women because this group has a higher incidence of work-related, occupational, and chronic degenerative diseases, such as rheumatoid arthritis, that are justified by hormonal issues, the double working day, and the lack of muscle preparation for certain tasks (27, 31). Additionally, this knowledge can serve as a basis for validating the benefits of exposure to vibration in the context of health and rehabilitation.

Subjects

Twenty-eight healthy, untrained women, aged 27 ± 8 years, height: 1.61 ± 6 m, weight: 60.5 ± 13.3 kg, volunteered to participate in the study. They had no contraindications to WBV (i.e., acute inflammations, joint problems, back problems, diabetes, epilepsy, or metabolic or neuromuscular disease). The subjects were asked to report the use of any medications. Furthermore, they were instructed to refrain from participation in strenuous physical activity for 24 hours, the consumption of caffeine for 48 hours, alcoholic beverages for 24 hours and food for two hours before testing. The participants were asked to maintain the same dietary habits, obtain 8 hours of sleep, and consume 500 ml of water two hours before each experimental condition. This study was approved by an the Human Ethics Committee of the Universidade Federal dos Vales do Jequitinhonha e Mucuri, Diamantina, MG (1.814.218). All subjects were informed of the benefits and risks of the investigation prior to signing the approved informed consent document to participate in the study.

Procedures

This study design included one familiarization session followed by four balanced, randomized, and blinded experimental situations over a consecutive one-week period, which was separated by at least 24 hours. The familiarization session included a physical examination, anthropometric measurements (height and weight), experience with handgrip strength and with procedures performed during subsequent experimental situations.

<<<<Figure 1>>>>

Experimental Situations

The study consisted of four experimental conditions : (a) control; (b) placebo; (c) WBV (25 Hz/2 mm/49.30 m.s^{-2}); (d) WBV (45Hz/2 mm/159.73 m.s^{-2}). To minimize the circadian influence, the participants performed all four interventions at the same time each day. The trials took place in a thermoneutral environment (22 ± 1 ^{0}C and 53 ± 2% relative humidity).

Control. The volunteers remained at rest while reclining on a stretcher, feet on the floor and hands in the supine position on the lower limbs, in the supine position without vibration stimulus for 5-minutes.

Placebo. The participants postured themselves in the push-up position on the vibrating platform, with their hands apart at a distance of 28 cm on the vibratory platform that remained disconnected, but with a sonorous stimulus mimicking the vibrating platform for 5-minutes. A horizontal bar at shoulder height was used to avoid trunk flexion and to guarantee an elbow flexion of around 10º.

WBV (25 Hz/2 mm/49.30 $\mathrm{m.s^{-2}}$ *or 45 Hz/2 mm/*159.73 $\mathrm{m.s^{-2}}$*)*. In both experimental situations, the participants postured themselves in the push-up position on the vibrating platform, with their hands apart at a distance of 28 cm on a shaking platform at one of the vibratory stimulus intensities for 5-minutes. A horizontal bar at shoulder height was used to avoid trunk flexion during the intervention and to guarantee an elbow flexion of around 10º.

The WBV stimulation was conducted using a vibrating platform (FitVibe, GymnaUniphy NV, Bilzen, Belgium) that produces vertical sinusoidal vibrations, while the platform moves predominantly in the vertical direction, resulting in a simultaneous and symmetrical movement on both sides of the body during exposure.

Physiological Measurements

Before all the experimental situations, each volunteer rested for 10 minutes in a supine position. Thereafter, the subject was allocated to one of the experimental situations. Before and immediately after the experimental situations, the muscle performance of the dominant hand was evaluated using the handgrip strength dynamometer (Jamar, USA). The EMG records (Miotec, Brazil) was registered throughout experimental situations.

Handgrip Strength. Participants were in a seated position, with the arm in adduction and 90° forward at the elbow joint, forearm in neutral position, with an extension between 0 and 30°. The dominant hand performed three repetitions of maximum 3-second handgrip strength using a dynamometer (Jamar, USA). There was a 60-second recovery period between repetitions. Handgrip strength was determined by the average of the three repetitions. The analysis of handgrip strength were determined by the variation (delta) representing the difference between the averages obtained after and before the vibratory stimulus.

Electromyography (EMG). Upper limb muscle activity was recorded by using a 1-channel portable surface EMG data log instrument (Miotec Equipaments Biomédicos Ltda, Brasil). The EMG data was band-pass filtered with a low cutoff frequency of 480 Hz and a high cutoff frequency of 10 Hz. Input impedance of 1015 Ohms, Analog/digital converter with 16-bit resolution; filters and integrated rechargeable battery; sampling frequency of 2000 Hz; 10 Hz high pass filter; Low-pass filter of 480 Hz. For the capture of

EMG signals, disposable surface electrodes and simple differentials were used (Data Hominis Technology Ltda., Brazil). The participants' preparation consisted of two reference electrodes on the muscle belly of the superficial flexor of the fingers and one electrode ground wire attached to the lateral epicondyle of the humerus (1). Before electrode placement, the subject's arms were also shaved and cleaned with alcohol to avoid high impedances in the signals. The EMG signals from the superficial flexor of the finger (SFF), muscles of the dominant limb was recorded during all the experimental situations. The electrodes were placed according to the surface EMG for non-invasive assessment of muscles (SENIAM) recommendations (17). To maintain consistent electrode positioning across the inter-day EMG recordings, the skin positions of the subjects were marked with indelible ink.

The electromyography was connected to a battery-powered notebook. Electromyographic signals were collected and processed later using a Myosystem Br1 software application (version 3.5.6). The root mean square (RMS) was calculated from the EMG recording that was performed during all the data collection. The RMS was used in this study because it is often used as a quantitative indicator of changes in the recruitment of motor units (36).

Statistical Analyses

Data are reported as means ± standard deviation. This is an experiment with two times each (before and after the vibratory stimulus) and four experimental situations (control, placebo, vibration at 25 Hz/2 mm/49.30 m.s^{-2}

and vibration at 45 Hz/2 mm/159.73 $m.s^{-2}$) conducted in only one group (n=28). The Tukey test was used to compare the means with a 5% significance level.

The ANOVA model used was: yijk = m + ai + bj +abij rk +eijk, where:

m = general mean

ai = effect of vibration (before and after) i;

bj = effect of experimental situations (control, placebo, vibration at 25 Hz/2 mm/49.30 $m.s^{-2}$, vibration at 45 Hz/2 mm/159.73 $m.s^{-2}$) j;

abij = effect of the interaction between these two factors;

rk = effect on subjects (repetitions) within group;

eijk(j) = weighted average error.

Intraclass correlation coefficients (ICCs) assessed the test-retest reliability of comparing the mean of the dependent variables between experimental situations. The Pearson test (symmetric distribution) was used to verify the correlation between the variables.

A sample size of 28 participants was required to a power equal to 80% and a two-tailed α-value = 0.05 for the handgrip strength (primary outcame). A minimum difference of 0.8 before and after vibration exposure, and a standard deviation of 1.6 for handgrip strength score were considered (9).

RESULTS

All the possible confounding variables were accounted for. The ICC test-retest reliability of handgrip strength (0.96) and electromyographic activity of the superficial flexor of the fingers (0.92) reported a significant correlation ($p < 0.0001$), indicating very little variability; thus, a high degree of consistency was attained.

The handgrip strength was similar before the experimental situations (baseline). The WBV stimulus at the 45 Hz frequency, 2 mm amplitude, and 159.73 $m.s^{-2}$ increased handgrip strength compared to other experimental situations. The EMG activity of the superficial flexor of the fingers was similar before the experimental situations (baseline). The WBV stimulus did not modify the EMG activity of this muscle at the two intensities evaluated. There was a reduction in the EMG activity of this muscle after the placebo relative to the baseline. The neuronal innervation ratio was similar before the experimental situations (baseline). This ratio decreased relative to the other experimental situations only when the WBV stimulus at the 45 Hz frequency, 2 mm amplitude, and 159.73 $m.s^{-2}$ was employed (Table 1).

<<< Table 1>>>

The highest vibratory stimulus (45 Hz, 2 mm, 159.73 $m.s^{-2}$) resulted in an increase in variation (delta = after - before) of the handgrip strength by an average of 62.6%, 93.7%, and 84.6% compared to the lowest vibratory exposure (25 Hz, 2 mm, 49.3 $m.s^{-2}$), placebo (0 Hz, 0 mm, 0 $m.s^{-2}$), and control, respectively. During experimental situations, only the highest vibratory stimulus increased the EMG activity of the superficial flexor digitorum muscle by an average of 94.8%, and 50.2% relative to the control and placebo, respectively (Figure 2).

<<<Figure 2>>>

There was a moderate to strong negative correlation between handgrip strength and neuronal innervation ratio (Figure 2).

<<<Figure 3>>>

DISCUSSION

The findings of the present study indicated that EMGrms activity of the superficial flexor digitorum muscle was potentiated during exposure to vibration (45 Hz, 2 mm, 159.73 $m.s^{-2}$) in the static, modified push-up position, with a lower neuronal innervation ratio after vibration, providing parallel increases in handgrip strength, which advocates neural enhancement in healthy, untrained women.

In the present study, we opted for the modified static push-up position on the vibratory platform because muscle groups less proportionally exposed to vibration do not exhibit physiological changes that potentiate muscular performance (7), and there is evidence of greater transmissibility of the vibration stimulus to the upper limb muscles in this position (1).

According to Barut and colleagues (5), different sports use the hands as important body segments involved with physical performance. As examples of sports modalities we highlight judo, sneakers, sailing, rowing, boxing, and weight lifting. During practice of sports that require the use of hands, the interaction between ability, strength and muscular endurance is determinant for the sporting advantage. In addition, handgrip strength, along with other physical variables and abilities, is an important element in the general physical condition of the athlete and may help to identify talent in sports (25). In the clinical and rehabilitation scenario, handgrip strength can be used for clinical-functional assessment and diagnosis, evolution and progression of the treatment (35). Handgrip strength can also be used as an indicator of overall strength and general health status (29). There is evidence that the reduction in handgrip strength is related to the low bone mineral density of the femoral neck and spine, as well as to the increased risk of postmenopausal fractures in korean women (19). Thus, in clinical practice, handgrip strength measurement has been used for screening for sarcopenia and as an indication of functional impairment when less than 30 kgf for men and 20 kgf for women is tested (23).

In the present study, nineteen healthy women were randomly assigned to four experimental situations: a triplanar synchronous vibratory stimulus in high-intensity (45 Hz, 2 mm, 159.73 $m.s^{-2}$, 5 min), low-intensity (25 Hz, 2 mm, 49.30 $m.s^{-2}$, 5 min), platform turned off (0 Hz, 0 mm, 0 $m.s^{-2}$, 5 min), or sitting position with supine hands resting on the legs (control). The results of our study demonstrated that only the high vibratory stimulus resulted in pre-post intervention interaction for the handgrip strength test. This increase in handgrip strength at high vibratory stimulus is in agreement with the study of Kurt and colleagues (22), which investigated the effect of exposure to asynchronic whole body vibration on maximal handgrip strength of well-trained combat athletes. Whole body vibrations consisted of four isometric exercises targeting forearm, leg and trunk muscles (26 Hz, 4 mm, 106.64 $m.s^{-2}$). The results also showed an interaction with pre-post intervention for the handgrip test, indicating that the whole body vibration protocol used potentiated handgrip strength. Although we did not use trained individuals in our study, the fact that Kurt's (22) study found results in favor of the effect of the vibratory stimulus on handgrip strength indicates that the genetic potential of muscle training adaptations does not seem to influence the acute myogenic response inherent to the vibratory stimulus.

In contrast, other studies have reported that vibrational stimulus does not demonstrate the expected potential neuromuscular enhancements on the handgrip strength. In the study of Cochrane and colleagues (9), twelve healthy active climbers were randomly assigned to upper-body vibration, non-upper body vibration, and arm cranking. Upper-body vibration consisted of performing upper-body exercises for five minutes in association with vibration (26 Hz, 3 mm, 79.98 $m.s^{-2}$) to shoulder and arms from an electric-powered dumbbell. The non-upper body vibration was performed exactly like the upper-body vibration; however, the vibratory dumbbell was set at 0 Hz and 0 mm. The third treatment consisted of arm cranking, which was performed at 75 $k.min^{-1}$ for 5 minutes. Giminiani and colleagues (12) also observed no significant difference in handgrip strength. Thirty male students were randomly assigned to a high vibration group (40 Hz, 0.9 mm, 56.79 m.s^{-2}), a low vibration group (20 Hz, 0.2 mm, 3.16 m.s^{-2}), or a control situation and were exposed to a series of 20 10-s trials of synchronous whole-body vibration with a 10-s pause between each trial and a 4-min pause after the first 10 trials. The control group assumed an isometric push-up position without whole body vibration. The comparison between our study and the studies by Cochrane (9) and Giminiani (9, 12) reveals that the magnitude of the vibratory stimulus acceleration seems to actually influence the results. Thus, regardless of the level of physical conditioning, a subliminal vibrational stimulus intensity (acceleration less than 80 m.s^{-2}) does not seem to potentiate muscular performance, even if applied close to the muscles tested. This finding indicates that acceleration seems to be the most appropriate parameter to be evaluated, and different magnitudes of vibration stimulus are compared.

Regarding the volume of the vibratory stimulus, the mean stimulus time of the studies was 4 min (3.33 min – 5 min) minutes. Thus, we believe that the results do not seem to be influenced by the volume of the stimulus because it is of short duration. Both the present study and the Giminianni (12) study used triplanar synchronous platforms. The Cochrane study (9) used an electric-powered dumbbell. The study by Kurt (22) used an asynchronous platform. The type of vibratory stimulus employed could be another factor that influenced muscle performance (13, 14, 28) because the type of vibratory stimulus varied between studies

.

In the present study, the electromyography of the superficial flexor digitorum muscle of the upper limb was evaluated as a secondary outcome to help explain the primary outcome that was the handgrip strength. Thus, the fact that the superficial flexor digitorum muscle was positioned directly on the origin of the vibratory stimulus justified the need to analyze its electromyographic activity during the vibratory stimulus, as well as before and in the follow up concomitant to the measurement of the handgrip strength. In addition, this muscle is the primary motor responsible for increasing muscle power during the execution of tasks involving handgrip strength. The efficiency of the central nervous system in handgrip strength control can be studied by changes in strength in performing complex tasks involving multiple muscles.

During the handgrip strength test, the flexor muscles of the hand and the forearm are the agonists, whereas the wrist extensors assist in stabilizing the wrist. The superficial flexor of the fingers is the main agonist in the grasping movement, whereas the radial flexor of the carpal is responsible for the flexion of the wrist, reach support in the explosive movements and the hold in bulged talons (26).

Electromyographic records during the vibrational stimulus demonstrated the higher neuromuscular activity of the superficial flexor digitorum muscle in the static modified push-up position. The vibration-stimulus mechanics applied to the muscles and tendons during the vibrational stimulus is characterized by a cyclical transition between the eccentric and concentric muscle contractions resulting from the reflex alpha-gamma activation (33). The possibility that the vibrational stimulus might elicit excitatory inflow through muscle spindle-α-motoneuron connections in the overall motoneuron inflow has been also suggested by Lebedev and Peliakov (24). It has been demonstrated that vibration drives the α-motoneuron via a Ia neuron loop to produce force without diminishing the motor drive (34). The study of Bosco and colleagues (7) demonstrated that an increase in neural activity up to more than twice the baseline values during vibration occurred during the analysis of EMGrms recorded before the treatment and during the treatment itself. This increase would indicate that this type of treatment is able to stimulate the neuromuscular system more than other treatments used to improve neuromuscular properties (21).

Moreover, according to Cardinale (8), increases in electromyographic activity induced by vibrational stimulus and the consequent degree of synchronization of motor units are dependent on the magnitude of the vibration stimulus. Ashnagar et al. (1) corroborated this finding because they found increased electromyographic activity in muscles of the shoulder complex (upper trapezius, anterior serratus, biceps, brachial biceps, and brachial triceps) during exposure to the vibrational stimulus (30 Hz, 5 mm, 246.49 $m.s^{-2}$) in the modified static push-up position (5 series of 30 seconds of vibration, with intervals of 1 minute) in healthy women. Other studies also showed an increase in the electromyographic activity of the triceps and biceps brachii muscles with the vibratory stimulus in healthy subjects (30).

Due to the diversity of vibrational stimulus parameters present in the literature, it is difficult to delimit an ideal intensity range to increase the electromyographic activity; However, we observed that the range between 92.29 $m.s^{-2}$ - 319.45 $m.s^{-2}$ of vibrational stimulus appeared to result in an increase in electromyographic neuromuscular activity (32, 16). This result is in line with our findings because there was an increase in muscle activity only at the highest intensity of vibratory stimulus (45 Hz, 2 mm, 159.73 $m.s^{-2}$) compared to the placebo and control.

The follow-up analysis did not show a change in the electromyographic activity concomitant to the increase in the handgrip strength and the lower neuronal innervation ratio. These findings together substantiate the hypothesis that the increase in tonic-vibratory reflex activation during vibration stimulus seems to have promoted post-activation potentiation in handgrip strength and greater neuronal enhancement (2). According to Baudry & Duchateau (6), post-activation potentiation can be defined as the increase in torque of a muscle contraction caused by a contraction conditioning resulting from the probable phosphorylation of the myosin regulatory light chain.

The increase in handgrip strength after vibration stimulus was accompanied by a reduction in the neuronal innervation ratio. This finding is in line with Bosco's study (7), which demonstrated that the EMGrms activity of muscles was potentiated during vibration, and the ratio of EMGrms to power was lower after vibration, providing parallel increases in muscular power, which advocates neural enhancement.

In conclusion, the vibrational stimulus in the static, modified push-up position potentiated handgrip myogenic responses in a dose-dependent fashion. The mechanism seems to be related to the stimulation of the neuromuscular system and subsequent post-activation potentiation advocating neural enhancement.

PRACTICAL APPLICATIONS

Health professionals can expect enhancement of handgrip performance by acute vibration stimulus on the basis of the protocol and high intensity parameters used in this study for healthy and untrained females; the vibration seems to advocates neural enhancement.

ACKNOWLEDGMENTS

We thank the Universidade Federal dos Vales do Jequitinhonha e Mucuri for institutional support, the CNPq, FAPEMIG, and CAPES for financial support and scholarships. The authors are in debt to David Lee Nelson for kindly reading the manuscript.

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ANNEXES

TABLE 1.

Parameters	**Control**	**Placebo (0Hz, 0mm, 0m.s^{-2})**	**WBV$_{25Hz}$ (25Hz, 2mm, 49.3m.s^{-2})**	**WBV$_{45Hz}$ (45Hz, 2mm, 159.73m.s^{-2})**
HS before (N)	19.18±4.44^{ab}	19.50±4.25^{ab}	18.29±4.77^{b}	18.92±4.10^{b}
HS after (N)	18.55±4.72^{b}	18.65±4.85^{b}	18.19±5.02^{b}	20.33±4.10^{a}
EMG before (% rms)	67.42±5.44^{a}	61.37±14.16^{abc}	60.38±11.12^{abc}	61.93±13.09^{abc}
EMG after (% rms)	64.29±5.55^{ab}	55.36±13.80^{c}	58.49±9.68^{bc}	60.35±12.73^{abc}
NR before (% rms.N^{-1})	3.70±0.93^{a}	3.28±0.98^{abc}	3.55±1.17^{abc}	3.39±0.93^{abc}
NR after (% rms.N^{-1})	3.68±0.94^{ab}	3.13±1.00^{bc}	3.52±1.31^{abc}	3.06±0.82^{c}

Table 1. Effect of whole body vibration exposure on HS (handgrip strength), EMG (eletromiography) and NR (neuronal innervation ratio).Measures performed before and after 4 experimental situations. Data are presented as Mean + Standard Deviation. N= 28 subjects in each experimental situation.

FIGURE LEGENDS

Figure 1. Study flow chart. Preliminary session: physical examination, anthropometric measurements. CON = control; WBV_{25Hz} = whole-body vibration 25Hz, 2mm; PLAC = placebo; WBV_{45Hz} = whole-body vibration 45Hz, 2mm. Pre: Evaluation (HS, EMG) before experimental situation. Post: Evaluation (HS, EMG) immediately after experimental situation.

Figure 2. (Δ) Delta values of handgrip strength after-before (A) and Eletromiography during experimental situations (B). Data are plotted as the Mean±Standard Deviation (n = 28). Horizontal bars indicate differences between experimental situations. WBV_{25Hz} = whole-body vibration (25 Hz, 2 mm, 49.3 $m.s^{-2}$); WBV_{45Hz} = whole-body vibration (45 Hz, 2 mm, 159.73 $m.s^{-2}$).

Figure 3. Correlation between handgrip strength and neuronal innervation ratio. Data are plotted as the Mean±Standard Deviation (n = 28). Horizontal bars indicate differences between experimental situations. WBV_{25Hz} = whole-body vibration (25 Hz, 2 mm, 49.3 $m.s^{-2}$); WBV_{45Hz} = whole-body vibration (45 Hz, 2 mm, 159.73 $m.s^{-2}$).

FIGURE 1.

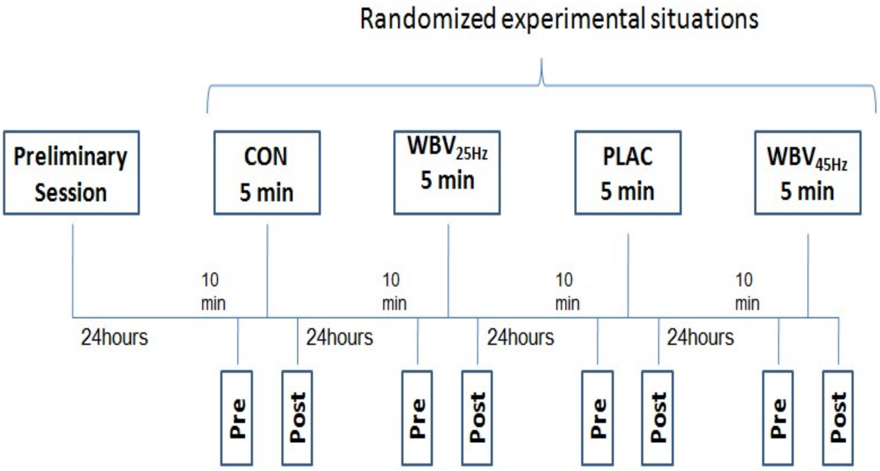

Randomized experimental situations
Preliminary Session
CON 5 min
WBV$_{25Hz}$ 5 min
PLAC 5 min
WBV$_{45Hz}$ 5 min
10 min
10 min
10 min
10 min
24hours
24hours
24hours
24hours
Pre
Post
Pre
Post
Pre
Post
Pre
Post

FIGURE 2 (A).

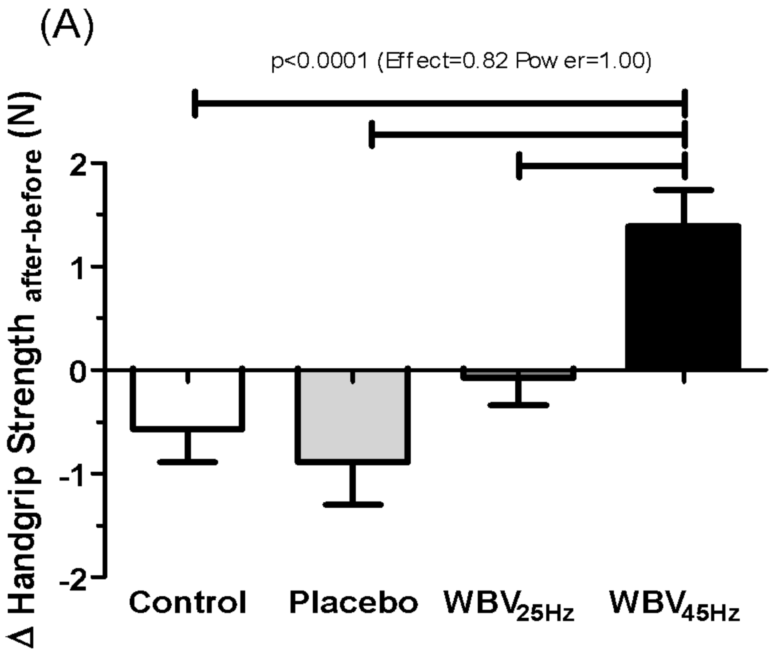

(A)
p<0.0001 (Effect=0.82 Power=1.00)
Δ Handgrip Strength after-before (N)
2
1
0
-1
-2
Control
Placebo
WBV25Hz
WBV45Hz

FIGURE 2 (B).

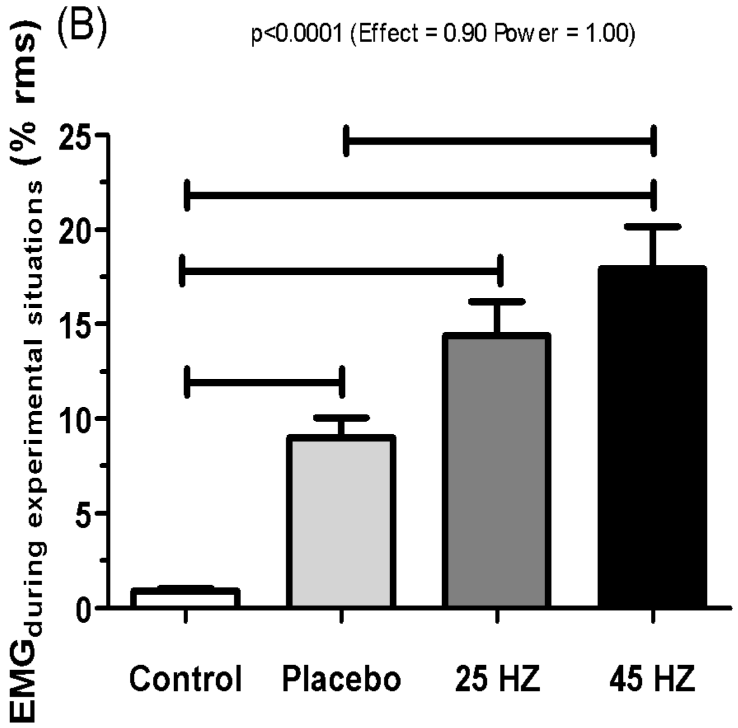
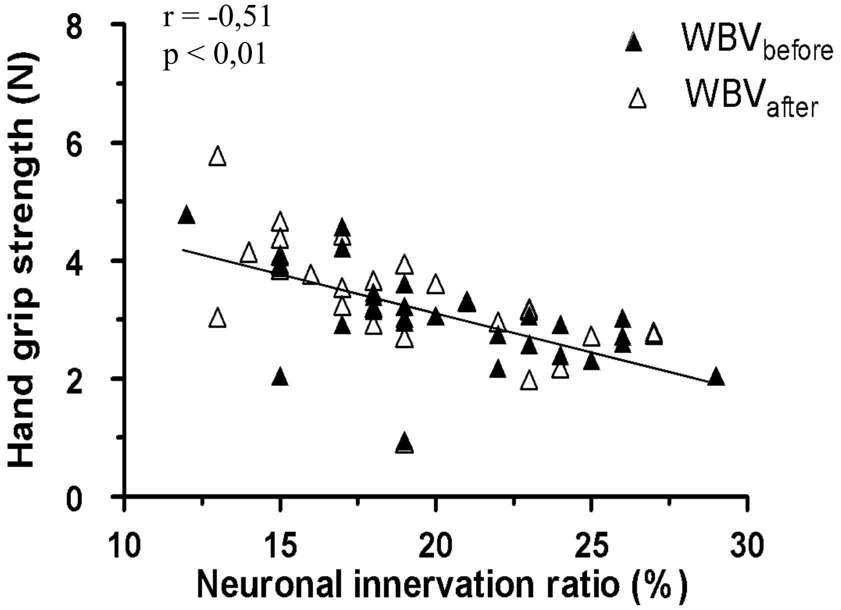

(B)
p<0.0001 (Effect = 0.90 Power = 1.00)
EMGduring experimental situations (% rms)
0
5
10
15
20
25
Control
Placebo
25 HZ
45 HZ

FIGURE 3.


r = -0,51
p < 0,01
WBV$_{before}$
WBV$_{after}$
Hand grip strength (N)
0
2
4
6
8
10
15
20
25
30
Neuronal innervation ratio (%)

Journal of Strength and Conditioning Research

Whole Body Vibration In The Static Modified Push-Up Position Stimulates Neuromuscular System Potentiating Handgrip Myogenic Response

--Manuscript Draft--

Manuscript Number:	JSCR-08-9795
Full Title:	Whole Body Vibration In The Static Modified Push-Up Position Stimulates Neuromuscular System Potentiating Handgrip Myogenic Response
Short Title:	Vibration exposure and upper-body muscular performance
Article Type:	Original Research
Keywords:	Whole Body Vibration; Grip Strength; Electromyography
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Manuscript Region of Origin:	BRAZIL
Abstract:	Because the transmissibility of vibration is lower when applied under the feet, an uncertainty remains as to whether this stimulus could potentiate handgrip strength (HS) in the static modified push-up position. The aim of this study was to investigate the effect of vibration in the push-up position on HS and electromyography (EMG) of the superficial flexor muscle of the fingers. 28 healthy women (age: 27± 8 years, BMI: 23.2±4.5 kg.m^2) were familiarized and submitted, to four experimental situations in a balanced, and randomized order: A). Seated supine with hands supported on the legs; B) Placebo - hands on the platform off; C). 25 Hz, 2 mm, 49.30 m/s^2 and, D). 45 Hz, 2 mm, 159.73 m/s^2 similar to the placebo position with vibration turned on. The intervention was 5 minutes in all experimental situations. Muscle performance was evaluated using the HS dynamometer (Jamar, USA). The EMG (Miotec, Brazil) was registered throughout experimental situations. The neuronal ratio represented the ratio

	intervention demonstrated that only 45 Hz increased the EMG by an average of 94.8%, and 50.2% compared to the control and placebo, respectively. In conclusion, the vibration in the push-up position potentiated the HS. The mechanism seems to be related to the stimulation of the neuromuscular system and subsequent post-activation potentiation advocating neural enhancement.
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