UNIVERSIDADE FEDERAL DOS VALES DO JEQUITINHONHA E MUCURI
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Ana Carolina Coelho de Oliveira

EXERCÍCIO DE VIBRAÇÃO DIRETAMENTE SOB AS MÃOS APRIMORA A EFICIÊNCIA NEUROMUSCULAR DE PREENSÃO DAS MÃOS DE MULHERES COM ARTRITE REUMATOIDE: Estudo Randomizado Cruzado

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Orientador: Prof.ª Dr.ª Ana Cristina Rodrigues Lacerda

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Atesto para os devidos fins que no dia 20 de Setembro de 2019, às 09h, nas dependências da UFVJM – em Diamantina, foi realizada a defesa de dissertação/tese do(a) discente Ana Carolina Coelho de Oliveira com o trabalho intitulado ***"EXERCÍCIO DE VIBRAÇÃO DIRETAMENTE SOB AS MÃOS APRIMORA A EFICIÊNCIA NEUROMUSCULAR DE PREENSÃO DAS MÃOS DE MULHERES COM ARTRITE REUMATOIDE: ESTUDO RANDOMIZADO CRUZADO.",*** no Programa de Pós-graduação em Reabilitação e Desempenho Funcional – PPGREAB.

Na qualidade de presidente da banca, atesto que a Profa. Dra. Núbia Carelli Pereira de Avelar (docente da Universidade Federal de Santa Catarina - UFSC), participou através de videoconferência.

Em virtude da participação remota do membro da banca acima indicado, eu, Ana Cristina Rodrigues Lacerda, enquanto servidor público, no gozo de fé pública, assino no lugar desse na Ata de Defesa e na Folha de Aprovação da referida defesa.

Por ser verdade, dou fé e assino o presente atestado.

Diamantina, 20 de Setembro de 2019.

Ana Cristina Rodrigues Lacerda

Presidente da Banca

Drª Ana Cristina R. Lacerda
UFVJM / Professora
Matrícula 1559454

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“Per Aspera Ad Astra”

Até os céus, por caminhos difíceis.

RESUMO

Introdução: A Artrite Reumatoide (AR) é uma doença inflamatória, autoimune, crônica, que promove alterações degenerativas progressivas no sistema musculoesquelético, comprometendo o controle neuromuscular, principalmente das mãos. Estratégias terapêuticas preparatórias que promovem modificações neuromusculares são importantes no contexto da reabilitação. Assim, a vibração de corpo inteiro aplicada diretamente sobre as mãos poderia ser uma alternativa de exercício preparatório para a reabilitação das mãos desta população. **Objetivo:** Investigar o efeito de uma única sessão aguda de vibração na posição *"push up"* modificada na razão neural (RN) durante a preensão manual em mulheres com AR estável. **Método:** Vinte e uma mulheres com AR estável (diagnóstico da doença: 8 $\pm$ 5 anos, velocidade de hemossedimentação: 24,8 $\pm$ 14 mm/h, idade: 54 $\pm$ 11 anos, IMC: 28 $\pm$ 4 $kg.m^{-2}$) receberam três testes experimentais de forma randomizada e balanceada, com intervalo de 48 horas entre os testes, em um estudo clínico cruzado randomizado velado: A) Controle - Posição sentada, com os pés no chão, as costas devidamente apoiadas e as mãos na posição supina apoiada nos membros inferiores. Não houve estímulo vibratório; B) Sham - Posição *"push up"* com as mãos separadas a uma distância de 28 cm na plataforma vibratória que permaneceu desligada, mas com estímulo sonoro mimetizando a vibração; C) Vibração - Posição *"push up"* com as mãos afastadas a uma distância de 28 cm na plataforma vibratória ligada (45 Hz / 2 mm / 159,73 $m.s^{-2}$). Os participantes permaneceram cinco minutos contínuos em cada teste. No início (linha de base) e imediatamente após os três testes experimentais, a RN, ou seja, a razão entre registro eletromiográfico do flexor superficial dos dedos (EMGrms) e força de preensão manual (FPM) da mão dominante foi determinada representando, assim, modificações neuromusculares. Os dados foram analisados utilizando ANOVA two-way com arranjo Split-Plot, em delineamento de blocos casualizados, seguido de post hoc de Tukey. Nível de significância adotado $p < 0,05$. **Resultados:** A RN foi similar na linha de base entre os testes experimentais. Apesar de não ter sido observado efeito intra-testes ($p = 0.0611$, $F = 3.94$, $\eta^2 = 0.66$, Poder = 0.99) e interação ($p = 0.1907$, $F = 1.69$, $\eta^2 = 0.50$, Poder = 0.96), a análise entre-testes ($p = 0.0003$, $F = 8.86$, $\eta^2 = 0.85$, Poder = 1.00) demonstrou que a vibração reduziu a RN comparado com sham e controle. **Conclusão:** O exercício de vibração agudo diretamente sob as mãos promove modificações neuromusculares durante a preensão manual de mulheres com AR estável, podendo, desta forma, ser utilizado na prática clínica como exercício preparatório para a reabilitação das mãos desta população.

Palavras-chave: Exercício preparatório. Modificações neuromusculares. Doença crônica. Força de preensão. EMGrms. Amplitude de movimento.

ABSTRACT

Introduction: Rheumatoid Arthritis (RA) is an inflammatory, autoimmune, chronic disease that causes progressive changes in the musculoskeletal system, compromising neuromuscular control, especially of the hands. Therapeutic strategies that promote neuromuscular changes are important in the context of rehabilitation. Whole-body vibration applied directly to the hands could be an alternative of preparatory exercise for the rehabilitation of the hands of this population. **Objective:** To investigate the effect of a single session of whole-body vibration in the modified push-up position on neural ratio (NR) during handgrip in stable RA women. **Methods:** Twenty-one women with RA (diagnosis of disease: ±8 years, erythrocyte sedimentation rate: ±24.8mm/h, age: 54±11 years, BMI: 28± 4kg.m^{-2}) received three experimental tests in a randomized and balanced cross-over order: A) Control- Seated with feet on the floor and hands supine in the lower limbs without vibratory stimulus; B) Sham-Push-up position with hands apart at a distance of 28 cm on the vibratory platform that remained disconnected, but with sound stimulus mimicking vibration; C) Vibration- Push-up position with hands apart at a distance of 28 cm on vibratory platform turned on (45Hz/2mm/159.73 m.s^{-2}). Participants remained five minutes continuous in each test. At baseline and immediately after the three experimental tests, the HS, the EMGrms, and ROM of the dominant hand were measured. The NR, i.e. ratio between EMGrms of the FDS and HS, was also determinated. Thus, the lower NR represented the greater NE. Data were analyzed using ANOVA two-way with a Split-Plot arrangement in a randomized block design, followed by Tukey's post hoc. Significance level adopted $p < 0.05$. **Results:** The NR was similar at baseline in the three experimental tests. Despite of no within-tests ($p = 0.0611$, $F = 3.94$, $\eta^2 = 0.66$, Poder = 0.99) and interaction effect ($p = 0.1907$, $F = 1.69$, $\eta^2 = 0.50$, Poder = 0.96), vibration exercise reduced the NR compared with the sham and control ($p = 0.0003$, $F = 8.86$, $\eta^2 = 0.85$, Poder = 1.00). **Conclusion:** Acute vibration exercise directly under the hands promotes neuromuscular modifcations during the hand grip of women with stable RA. In this sense, can be used in clinical practice as a preparatory exercise for the rehabilitation of the hands of this population.

Keywords: Preparatory exercise. Neuromuscular modifications. Chronic disease. Handgrip. EMGrms. Range of motion.

LISTA DE ABREVIATURAS

ADM- Amplitude de movimento

AR- Artrite Reumatoide

AVD- Atividade de Vida Diária

EMGrms- Eletromiografia de Superfície

FMCL- Fosforilação da Miosina Regulatória de Cadeia Leve

FPM- Força de Preensão Manual

FSD- Flexor Superficial dos Dedos

IMC- Índice de Massa Corporal

IFP- Interfalângiana Proximal

LAFIEX- Laboratório de Fisiologia do Exercício

MMII- Membros Inferiores

MMSS- Membros Superiores

PV- Plataforma Vibratória

TCLE- Termo de Consentimento Livre e Esclarecido

TNF- Fator de Necrose Tumoral

VCI- Vibração de Corpo Inteiro

VHS- Velocidade de Hemossedimentação

SUMÁRIO

1 INTRODUÇÃO

1.1 Artrite Reumatoide

A Artrite Reumatoide (AR) é uma doença de caráter inflamatório, crônico, de origem autoimune e etiologia ainda desconhecida, que causa danos degenerativos progressivos no sistema musculoesquelético (SANGHA, 2000; PLASQUI, 2008). Geralmente acomete as articulações de forma simétrica, podendo apresentar importante envolvimento extra articular, rigidez matinal, fadiga, dor, redução da força muscular, diminuição da amplitude de movimento e consequente perda funcional, especialmente das mãos. É uma doença caracterizada por poliartrite crônica periférica, simétrica, de grandes e pequenas articulações, que acomete principalmente os tecidos sinoviais de revestimento articular e tendinoso, levando à deformidade e à destruição das articulações (EBERHARDT *et al.*, 1990), bem como redução da mobilidade articular em virtude de erosões ósseas e da cartilagem associada com morbidade severa, perda funcional, incapacidade permanente, alta mortalidade (PINCUS *et al.*, 1994) e rápida progressão na fase precoce da doença (EBERHARDT *et al.*, 1990).

É comumente considerada uma síndrome clínica que abrange vários subconjuntos de doenças (VAN DER *et al.,* 2008). Esses subconjuntos, por sua vez, implicam em várias cascatas inflamatórias (VAN OOSTERHOUT *et al.,* 2008), que conduzem em direção à uma via comum que culmina em ocorrência de inflamação sinovial persistente e danos associados à cartilagem articular e ao osso subjacente. A ativação de uma cascata inflamatória chave na AR resulta em produção e a superexpressão do fator de necrose tumoral (TNF) (FELDMANN, 1996). Esta via conduz à inflamação sinovial e à destruição da cartilagem das articulações. A produção de TNF tem várias causas, incluindo interações entre linfócitos T e B, fibroblastos de tipo sinovial e macrófagos. Este processo leva à superprodução de muitas citocinas, como a interleucina 6, que também desencadeia inflamação persistente e destruição das articulações (CHOY, 2002) (Figura 1).

Sua característica clínica mais evidente, portanto, é a sinovite, que se caracteriza pela inflamação do tecido sinovial, localizado ao redor das articulações, que tem como função lubrificar a articulação. Quando ocorre a sinovite, há desequilíbrio a favor de processos catabólicos com consequente destruição da cartilagem articular e perda da proteção articular (ARAÚJO, 2008).

Figura 1 – Características da Articulação

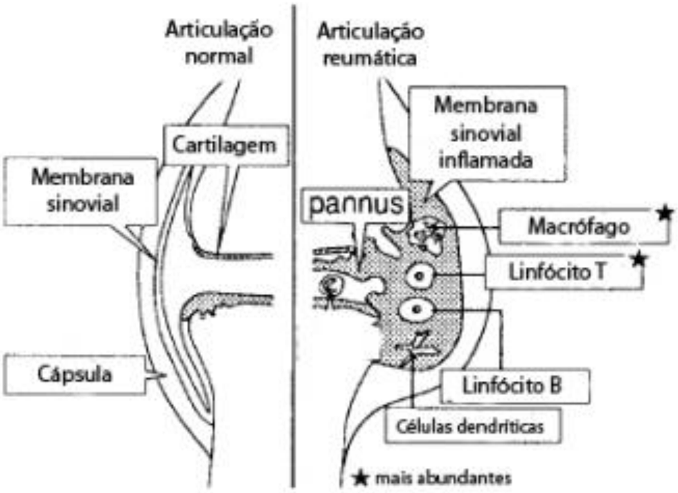

Figura 1: Articulação normal e articulação acometida por AR. Células do sistema imune (células dendríticas, macrófagos, linfócitos T e B) em direção ao líquido sinovial promovendo a destruição da articulação. Fonte: Adaptado de FELDMANN, BRENNAN (1996).

Quanto à gravidade da doença, a AR costuma ser subdividida em leve, moderada e grave. O diagnóstico precoce e o início imediato do tratamento são fundamentais para o controle da atividade da doença e para prevenir incapacidade funcional e lesão articular irreversível (LAURINDO *et al.,* 2004).

1.2 Prevalência e Incidência Artrite Reumatoide

A AR tem prevalência 1-2% na população em geral (MOTA *et al.,* 2011), na população brasileira a prevalência é similar a mundial 1% (BRENOL *et al.,* 2007). Acomete 2 a 3 vezes mais mulheres do que homens (MOTA *et al.,* 2011; FIRESTEIN, 2009), predominantemente entre as idades de 20 e 65 anos (BRENOL *et al.*, 2007; LOUZADA-JUNIOR, 2007), com pico de incidência entre a quarta e quinta década de vida (BRENOL et al., 2007). A prevalência da AR aumenta com a idade, apesar de atingir mulheres a partir de 20 anos (FIRESTEIN, 2009), embora sua prevalência modifique geograficamente, é mais comum em mulheres na pós-menopausa (PLASQUI, 2008). Segundo Pikwer e colaboradores, a menopausa precoce parece ser um preditor independente de artrite reumatoide. Além disso, alterações hormonais inerentes ao período fértil parecem influenciar o desenvolvimento da AR em mulheres pós-menopáusicas. A incidência de AR varia de 5 a 50 por 100000 adultos em países desenvolvidos e também aumenta com a idade, além disso, a doença é capaz de persistir por muitos anos e tipicamente afeta várias articulações ao longo do corpo (PEDERSEN *et al.*, 2009).

O gênero feminino e a idade foram descritos como preditores de disfunção física em pacientes com AR (HAKKINEN *et al.*, 2006; KUIPER *et al.*, 2001; HALLERT *et al.*, 2003). Assim, há evidência de maior prevalência de disfunção física na AR em sujeitos idosos e do gênero feminino.

1.3 Artrite Reumatoide, Características e Sintomas

Os danos articulares são as características mais evidentes, sendo as articulações das mãos metacarpofalângicas (91%), interfalângicas proximais (91%) e dos punhos (78%) as mais acometidas (HARRIS, 2005). Mais de 90% dos pacientes com AR sofrem de disfunções das articulações das mãos (LEFEVRE-COLAU *et al.*, 2001). O acometimento das articulações das mãos na AR causa limitações e até incapacidade para realizar movimentos essenciais na execução da maioria das atividades básicas da vida diária (ABVDs) (SILVA, 2002; VAN LANKVELD 1998 e 2000). De acordo com Ferraz *et al* (1992) e Hallert *et al* (2003), a incapacidade para realizar as ABVDS é habitualmente associada a uma maior dependência física e mental, diminuindo a capacidade para o trabalho e o rendimento financeiro. Em decorrência disso, ocorre aumento da demanda e utilização dos serviços de assistência à saúde, bem como impacto econômico significativo tanto para o paciente como para a sociedade (SAÑUDO *et al.*, 2013).

A evolução da AR resulta no desenvolvimento de incapacidades físicas, com consequente diminuição das habilidades funcionais (CORBACHO & DAPUETO, 2010). Dentre estes comprometimentos, a redução da força muscular e limitação da amplitude de movimento das mãos, com consequente limitação funcional dos membros superiores, têm sido consideradas importantes causas de disfunção na AR (BODUR *et al*., 2006). Newman (2002) menciona que sujeitos com AR com redução da força, dor e deformidades articulares, manifestam repercussões tanto para a sua independência quanto para a sua autoestima. Sendo assim, a progressão da doença impõe dificuldades na realização das atividades de vida diária (AVD) e das atividades profissionais, refletindo nas condições econômicas para o paciente e para a sociedade. Dessa forma, há impacto evidente da AR nas condições físicas, psicológicas e sociais dos indivíduos afetados (AMUR *et al.*, 2012).

Os danos no tecido musculoesquelético causados pela inflamação ocasionada pela AR interferem diretamente na geração de força, já que quando a inflamação se perpetua ela traz destruição dos tecidos, cartilagens, tendões e até ossos, ocasionando a deformação da articulação, perda de mobilidade e, consequente, perda de força muscular (DA SILVA *et al.*, 2003). A força muscular é considerada como necessária e imprescindível para a realização da maioria das AVD; porém, ela pode sofrer declínio ao longo dos anos. (LENHARDT *et al.,* 2014). As articulações instáveis não mantêm as forças atuantes para a estabilização durante os movimentos, prejudicando suas funções normais, como pinça e preensão, com isso as articulações deformam em sentidos patológicos, provocando a subluxação ou até luxação articular (ARAÚJO, 2008). O processo destrutivo observado na doença pode resultar em deficiência de tendões, músculos e nervos, levando a deformidades articulares e, consequentemente, diminuição da mobilidade e diminuição funcional nas atividades de vida diária, trabalho e lazer (BIANCHIN *et al.*, 2010).

Nesses indivíduos, portanto, a força de preensão manual (FPM) é uma medida de avaliação útil (FERRAZ *et al.*, 1992) uma vez que a fraqueza muscular é um sinal comum (HAKKINEN *et al.*, 2006). Sabe-se que existem diferenças de força de preensão entre a mão dominante e a não dominante. Estudos demonstram que a mão dominante apresenta maior força em comparação com a não dominante (INCEL *et al.*, 2002). O movimento de preensão manual, portanto, promove intensa atividade dos músculos superficial e profundo dos dedos, pois fornece um índice da integridade funcional dos membros superiores, incluindo atividades manipulativas, força e movimento das mãos (MOURA *et al.,* 2008). No âmbito clínico, a FPM apresenta diversas finalidades, sendo recomendada para auxiliar no diagnóstico clínico, na avaliação e na comparação de técnicas cirúrgicas, na documentação do progresso durante a reabilitação, na resposta ao tratamento e para avaliar o nível de incapacidade após a lesão (SHIRATORI *et al.,* 2014). A FPM também pode ser utilizada como um indicador de força global e estado geral de saúde (MASSY-WESTROPP *et al.*, 2004).

Com relação ao declínio funcional, a AR geralmente acomete pacientes em idade produtiva no trabalho e pode determinar importante limitação na capacidade funcional e perda de capacidade laboral (MACHADO C; RUPERTO N, 2005). Essa limitação pode ser temporária e reversível quando é devida à presença de inflamação aguda. Logo que o processo inflamatório é controlado, a capacidade funcional é recuperada. No entanto, conforme a

Sociedade Brasileira de Reumatologia 2000, quando o processo inflamatório não é controlado de forma adequada, ocorre evolução para lesão permanente da articulação e surgimento de deformidades articulares. Essas limitações podem se instalar de forma permanente e irreversível.

Como a AR é altamente simétrica, a doença pode diminuir a função bimanual, ou seja, a destreza. A deficiência relacionada à mão afeta negativamente a capacidade de autocuidado do paciente (VAN LANKVELD *et al.,* 1996). Isso é observado em pacientes que não conseguem vestir e lavar-se como resultado de uma destreza reduzida. A incapacidade de cuidar de si mesmo pode causar dependência de outros, sendo percebida pelos sujeitos com AR como um dos fatores estressores mais importantes da doença (VAN LANKVELD *et al.*, 1993; TAAL E *et al.*, 1993).

Adicionalmente, a AR pode levar a alterações em todas as estruturas das articulações, como ossos, cartilagens, cápsula articular, tendões, ligamentos e músculos que são os responsáveis pelo movimento articular. Dentre os achados tardios da AR e que levam à incapacidade física para as atividades do dia a dia, podemos citar diversas alterações em diferentes articulações: – desvio ulnar dos dedos ou "dedos em ventania": resultado de múltiplos fatores (ex. deslocamento dos tendões extensores dos dedos, subluxações das metacarpofalangeanas) – deformidades em "pescoço de cisne": hiperextensão das interfalangeanas proximais – IFPs - e flexão das distais - IFDs) – deformidades em "botoeira": flexão das IFPs e hiperextensão das IFDs) – "mãos em dorso de camelo": aumento de volume do punho e das articulações metacarpofalangeanas com atrofia interóssea (MOTA *et al.,* 2011). Estas alterações consequentemente levam a uma redução amplitude de movimento (ADM) articular dos indivíduos com AR.

1.4 Artrite Reumatoide e a Reabilitação

A AR representa um importante desafio aos médicos clínicos, reumatologistas, fisioterapeutas e pesquisadores, não só pelo aumento da mortalidade em longo prazo, mas pela incapacidade para o trabalho, pelas evidências de lesões articulares, fraqueza, fadiga e declínio funcional (OKEN *et al.*, 2008; SPEED & CAMPBELL R, 2012).

Nas últimas décadas, houve significativa progressão no tratamento da AR, incluindo o uso de fármacos antireumáticos que controlam a doença (O'DELL JR, 2004). Entretanto, em grande parte dos pacientes com AR, estes fármacos não atuam na causa da doença de forma satisfatória ou promovem toxicidade suficiente levando à sua suspensão. Adicionalmente, o impacto destas terapias em longo prazo ainda é desconhecido (KAVANAUGH &

KEYSTONE, 2003). Dentre as estratégias de tratamento não farmacológicas da AR, destaca-se a prática de exercícios físicos e reabilitação que abordem o desenvolvimento da amplitude do movimento, da funcionalidade, da capacidade cardiovascular e da força muscular (DE SANTANA et al., 2014).

1.5 Vibração de Corpo Inteiro e Artrite Reumatoide

A literatura vigente aponta possíveis benefícios do treino com vibração de corpo inteiro sobre amplitude articular, e fadiga muscular (ALENTORN-GELI *et al.,* 2009), estado de saúde, função física, qualidade de vida, marcha, equilíbrio, mobilidade e força muscular (SAÑUDO *et al.*, 2012; CHANOU *et al.,* 2012; ADSUAR *et al.*, 2012) em pacientes com doença inflamatória crônica (ALENTORN-GELI, 2009). Prioreschi e colaboradores (2014, 2016) evidenciaram que a Vibração de Corpo Inteiro (VCI) parece ser um recurso promissor para aprimorar a capacidade e desempenho funcional, promover mudanças na atividade da doença, melhora na qualidade de vida, aumento nos níveis habituais de atividade física e composição corporal, atenuar a perda de massa óssea bem como diminuir a fadiga em pacientes com AR diagnosticada.

Durante a vibração, os estímulos mecânicos são transmitidos ao corpo e estimulam as terminações primárias dos fusos musculares, ativando o reflexo tônico vibratório (BRISHOP, 2003; CARDINALE E BOSCO, 2003). Os fusos, por sua vez, desencadeiam a ativação reflexa de motoneurônios alfa, aumentando o recrutamento de unidades motoras, como demonstrado por estudo que utilizou eletromiografia de superfície (CARDINALE E BOSCO, 2003). Além disso, a literatura vigente apresenta evidências de aumento da potenciação pós-ativação por meio do estímulo vibratório, com consequente incremento transitório no desempenho contrátil do músculo (AVELAR *et al.*, 2014).

Contudo, a aplicação do estímulo de VCI como estratégia terapêutica aguda e modalidade de exercício de baixo impacto, podendo ser utilizada como atividade preparatória antes da sessão de reabilitação, visando modificações neuromusculares e seus consequentes benefícios em atividades subsequentes à vibração, em pacientes com doença reumática, inflamatória, crônico-degenerativa não foi investigada.

1.6 Vibração, Sistema neuromuscular e Eficiência Neuromuscular

No contexto da saúde, alguns dos possíveis mecanismos que poderiam ajudar a explicar efeitos positivos do estímulo de VCI seriam as mudanças proporcionadas no padrão de ativação neuromuscular a favor de maior eficiência neuromuscular (BOSCO, 1999).

Neste sentido, Perchthlaer *et al.* (2015) e Ashnagar *et al.* (2016) demonstraram em seus respectivos estudos que o estímulo de VCI, aplicado de forma aguda, ativa padrões do sistema neuromuscular por um mecanismo fisiológico chamado de reflexo tônico vibratório. Este mecanismo é caracterizado pela a ativação de motoneurônios e recrutamento de unidades motoras, contribuindo, desta forma, com o incremento das contrações musculares subsequentes à aplicação do estímulo vibratório.

Além disso, acredita-se que a VCI por aumentar a atividade do fuso neuromuscular, desencadeando resposta de estiramento-reflexo e, consequentemente, mudança rápida e de pequena magnitude no comprimento do músculo, possa ser estratégia terapêutica coadjuvante no tratamento de indivíduos com disfunção musculoesquelética (COCHRANE, 2010).

Outro mecanismo que também poderia explicar um incremento na ativação neuromuscular e, consequente incremento transitório no desempenho contrátil e neuromuscular seria o complexo potenciação pós - ativação (BATISTA *et al.,* 2010; HAMADA *et al.,*2000; AVELAR *et al*., 2014).

Segundo Baudry e Duchateau (2007), potenciação pós ativação pode ser definida como o aumento do torque de uma contração muscular causado por uma contração condicionante, que ocorre em função da provável fosforilação da miosina regulatória de cadeia leve (FMCL). Assim, a FMCL alteraria a conformação das pontes cruzadas colocando as cabeças globulares da miosina em uma 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 *et al.,* 2005, MORANA, C. & PERREY, S, 2009).

Já Hamada *et al*. (2000) demonstraram que uma ação condicionante prévia poderia acarretar em maior liberação do cálcio pelo retículo sarcoplasmático aumentando, desta forma, a sua concentração no sarcoplasma. Este 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 (METZER *et al*., 1989).

A eletromiografia de superfície (EMG) tem sido utilizada como uma ferramenta útil para avaliar indiretamente a atividade neuromuscular dos músculos submetidos a estímulo de vibração (BOSCO, 1990). Assim, o uso desta ferramenta tem sido fundamental em estudos que objetivam avaliar diferentes variáveis de treinamento, tais como magnitude do estímulo de vibração, influência da posição corporal dos sujeitos na plataforma vibratória na ativação neuromuscular (transmissibilidade do estímulo) (AVELAR, 2013; DI GIMINIANI, 2013).

Bosco (1999), ao realizar estudo com atletas de boxe utilizando a vibração mecânica durante o movimento de flexão de braço, evidenciou em análises dos registros eletromiográficos, antes e durante o tratamento, aumento significativo da atividade neuronal durante a vibração de até duas vezes mais que os valores basais; o que sugere que este tipo de tratamento é capaz de estimular o sistema neuromuscular.

Experimentos realizados com a eletromiografia de superfície apontam que as mulheres com AR tendem a usar níveis mais altos de ativação muscular em tarefas diárias do que mulheres saudáveis (BRORSSON, 2014).

Estudo prévio do nosso grupo com mulheres adultas jovens hígidas evidenciou que a atividade de EMGrms do músculo flexor superficial dos dedos potencializou a força de preensão manual durante a exposição à vibração em alta intensidade na posição *push-up* modificada estática. Além disso, houve concomitantemente ao incremento na força manual, menor razão neural e, consequentemente, maior eficiência neuromuscular, após a aplicação do estímulo de vibração. Estes achados demonstraram que o estímulo de vibração na posição *push-up* modificada estática potencializou a resposta miogênica da mão de forma dependente da dose. O mecanismo parece estar relacionado à estimulação do sistema neuromuscular e à posterior potenciação pós-ativação que defende o aprimoramento neural.

1.7 Relevância do Estudo

Partindo do pressuposto teórico de que o estímulo vibratório agudo poderia ser uma ferramenta útil capaz de promover aumento transitório na amplitude de movimento articular e no desempenho contrátil muscular, bem como um menor registro eletromiográfico, influenciando, a favor de ocorrer modificações neuromusculares, é interessante que terapeutas que atuam com reabilitação de membro superior conheçam os efeitos do exercício vibratório, especialmente nas mãos de grupos especiais como pacientes com AR estável.

No contexto da reabilitação de pacientes com AR estável, vale destacar que os estudos em geral avaliaram o efeito do treinamento com estímulo de VCI no desempenho físico funcional e outros desfechos, e tiveram como foco os membros inferiores (PRIORESCHI *et al.,* 2016 e 2014). Além disso, com relação a posição na plataforma vibratória, considerando que a transmissibilidade do estímulo vibração aplicado sob os pés, ou seja, com o paciente posicionado em ortostatismo e pés apoiados diretamente sobre a plataforma vibratória, parece ser atenuada até chegar aos membros superiores (AVELAR *et al*., 2013), poucos estudos investigaram o efeito do exercício de vibração aplicado sob as mãos, na posição "*push up*" modificada, na atividade elétrica de músculos do membro superior, incluindo o flexor superficial dos dedos, o principal grupo muscular usado durante as habilidades manuais envolvendo o movimento de preensão (ASHNAGAR *et al.,* 2016; MOREL *et al.,* 2018). Apenas um estudo evidenciou a vibração aplicada nos membros superiores nas respostas neuromusculares (DI GIMINIANI *et al.,* 2014); no entanto, como a maioria dos estudos foram realizados com população saudável, a realização de um estudo que investigue os efeitos agudos (uma única sessão) do exercício de vibração, aplicado diretamente sob as mãos, em parâmetros relacionados com a estrutura e função das mãos de pacientes com AR estável se torna relevante, uma vez que se trata de uma inovação terapêutica, com baixo impacto nas articulações, boa aderência pelos usuários, podendo auxiliar no controle neuromuscular de atividades que envolvem preensão manual em pacientes com AR estável.

Diante do exposto, o objetivo do presente estudo foi investigar o efeito de uma única sessão de vibração na posição *"push up"* modificada em mulheres com AR nas variáveis: razão neural (RN), força de preensão manual (FPM), registro eletromiográfico (EMGrms) do músculo flexor superficial dos dedos (FSD) e amplitude de movimento (ADM) do punho da mão dominante desta população. Acreditamos que a exposição ao estímulo de VCI, na posição "*push up"* modificada, promoveria modificações neuromusculares em mulheres com AR estável. Assim, estes pacientes apresentariam ganhos na ADM de flexo-extensão de punho e na FPM, bem como concomitante redução na ativação EMGrms muscular, como por exemplo do músculo flexor superfical dos dedos que é o principal grupo muscular para atividades manuais (LONG et al 1970).

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1.9 OBJETIVOS

1.9.1 Objetivo Geral

Investigar o efeito de sessão única de exercício de vibração na posição "*push-up*" modificada estática nas modicações neuromusculares durante a preensão manual da mão dominante em mulheres com AR estável.

1.9.2 Objetivos Específicos

- Investigar o efeito de sessão única de exercício de vibração na posição "*push-up*" modificada estática na força de preensão manual da mão dominante em mulheres com AR estável.
- Investigar o efeito de sessão única de exercício de vibração na posição "*push-up*" modificada estática na atividade eletromiográfica do músculo flexor superficial dos dedos durante a preensão manual da mão dominante em mulheres com AR estável.
- Investigar o efeito de sessão única de exercício de vibração na posição "*push-up*" modificada estática na amplitude de movimento ativa de flexo-extensão do punho da mão dominante em mulheres com AR estável.

2. ARTIGO-

Title: Acute vibration exercise directly under the hands promotes favourable handgrip neuromuscular modifications in women with Rheumatoid Arthritis: a cross-over randomized clinical trial.

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Abbreviated title: Whole-body vibration in hand’s women with Rheumatoid Arthritis

Keywords: preparatory exercise, neuromuscular modifications, chronic disease, handgrip, EMGrms, range of motion.

2.1 ABSTRACT

Background. Rheumatoid Arthritis (RA) causes progressive changes in the musculoskeletal system and compromising neuromuscular control especially in the hands. Whole-body vibration (WBV) applied directly to the hands could be an alternative for the rehabilitation of the hands in this population.

Objective. To investigate the effect of WBV while in the modified push-up position on neural ratio (NR) in a single session during handgrip (HS) in stable women with RA.

Methods. Twenty-one women with RA (diagnosis of disease: ±8 years, erythrocyte sedimentation rate: ±24.8, age: 54±11 years, BMI: 28±4kg.m^{-2}) received three experimental tests for five minutes in a randomized and balanced cross-over order: A) Control- Seated with hands at rest without vibratory stimulus B) Sham- Push-up position with hands on the vibratory platform that remained disconnected, but with sound stimulus mimicking vibration C) Vibration- Push-up position with hands on vibratory platform turned on (45Hz/2mm/159.73 m.s^{-2}). At the baseline and immediately after the three experimental tests, the HS, the electromyographic records (EMGrms), and range of motion (ROM) of the dominant hand were measured. The NR, i.e. ratio between EMGrms of the flexor digitorum superficialis muscle (FDS) and HS, was also determined. The lower NR represented the greater NE.

Results. The NR was similar at baseline in the three experimental tests. Despite of no within-tests ($p = 0.0611$, $F = 3.94$, $\eta2 = 0.66$, Power = 0.99) and interaction effect ($p = 0.1907$, $F = 1.69$, $\eta2 = 0.50$, Power = 0.96), vibration exercise reduced the NR compared with the sham and control ($p = 0.0003$, $F = 8.86$, $\eta2 = 0.85$, Power = 1.00).

Conclusions. Acute vibration exercise under the hands promotes neuromuscular modifications during the handgrip of women with stable RA. Thus, vibration exercise can be used as a preparatory exercise for the rehabilitation of the hands in this population.

Trial Registration. 2.544.850. ReBEC - RBR-2n932c.

Keywords: preparatory exercise, neuromuscular modifications, chronic disease, handgrip, EMGrms, range of motion.

2.2 INTRODUCTION

Rheumatoid arthritis (RA) is a chronic disease that causes progressive damage to the musculoskeletal system. This disease compromes neuromuscular control especially in hands [1,2,3,4]. It usually affects the joints in a symmetrical way and it may be associated with a muscle strength reduction, progressively leading to the development of physical disabilities, with consequent reduction of hand functional abilities (i.e. manipulate objects and other activities with hands) [5]. The prevalence is 1-2% in the world and two to three times higher in women [6], predominantly between 20 and 65 years old [7].

As the pathological process of RA, the individual may experience difficulties while performing daily tasks induced by pain, stiffness, and deterioration of the joint structure and function. Damage to musculoskeletal tissue caused by RA's inflammation interferes directly with mobility, generation muscle strength and neuromuscular control [8,9]. Neuromuscular control is necessary and essential for most daily tasks [10]. Thus, women with RA tend to use higher levels of neuromuscular activation in daily tasks than healthy women [11].

Exercise programs are commonly used to improve hand structure and function, but the gap remains on types of exercises that are most effective for this population [11]. Whole-body vibration (WBV) exercise is a neuromuscular stimulus method which can represents a preparatory exercise because it might promote lower joint impact and greater neuromuscular modifications [12].

In the context of rehabilitation of patients with stable RA, it is noteworthy that studies generally evaluated the effect of WBV focused on the lower limbs [4,13]. Moreover, few investigations used the static modified push-up position to assess the effects of WBV on healthy subjects [14,15]. Other studies examined the effect of WBV exposure on neuromuscular activity of the flexor digitorum superficialis muscle (FDS) [15,16], the main muscle group used during manual skills involving the handgrip [17].

Some of the possible mechanisms that could help explain the positive effects of WBV exercise are represented by the changes provided in the neuromuscular activation pattern in favor of greater neuromuscular modifications [18]. Thus, the study by Bosco (1999), wich included boxing athletes using vibration during arm flexion movement, evidenced by analysis of electromyographic recordings performed before and during vibration. An increase in neuronal activity was up to two times higher than baseline values, suggesting that this type of treatment can stimulate the neuromuscular system and improve the neuromuscular modifications, i.e., the ratio between electromyographic records and mechanical power, during handgrip activities.

The objective of this work was to investigate the effect of WBV exercise in a single session on the static modified push-up position on the handgrip neuromuscular modifications in women with stable RA. As secondary outcomes, the researchers of this study aimed to evaluate the handgrip strength (HS), and concomitant neuromuscular electrical activity of the FDS muscle. Then, followed by the wrist flexion-extension range of motion (ROM) of the dominant hand of this population. We believe that the exposure to WBV exercise directly under the hands would promote an increase in handgrip neuromuscular modifications in women with stable RA. Hence, these patients would have increased wrist flexion-extension ROM and HS, in addition to a concomitant reduction in neuromuscular electromyography (EMGrms) record.

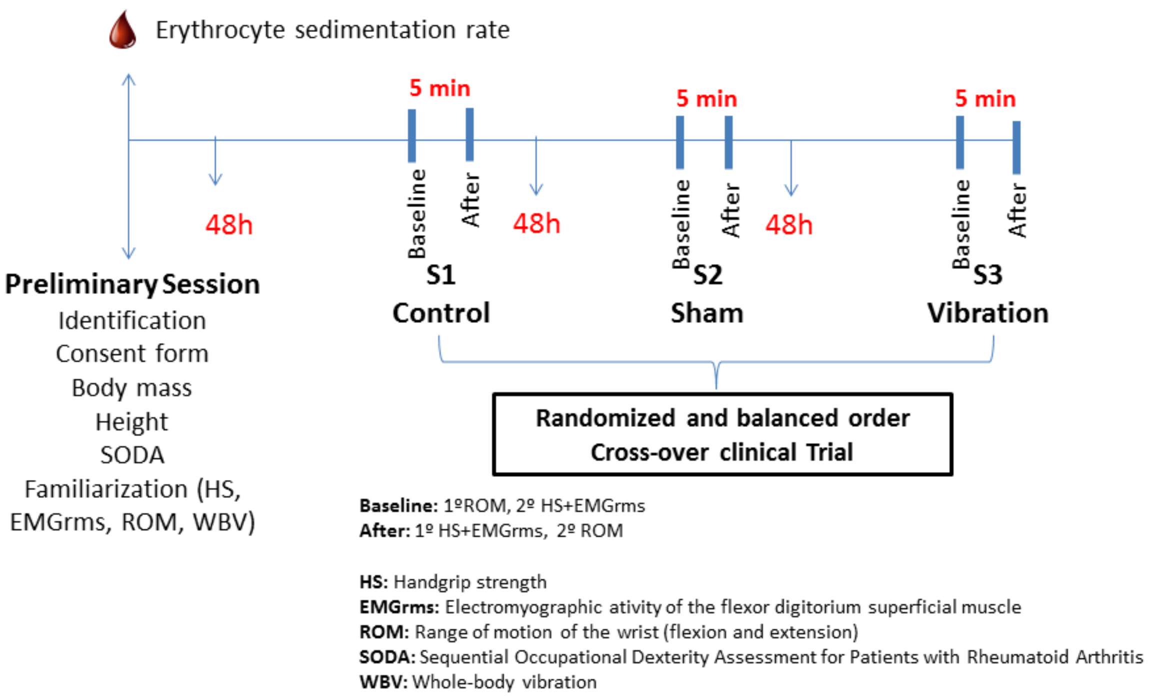
2.3 METHODS

Study Design

The study design was a crossover clinical trial (i.e. all volunteers performed all three experimental tests in a randomized order) with seven balanced blocks, three by three. Experimental tests were randomized by sortition, and the participants were blinded. There was a previous familiarization session, and interventions were performed during the consecutive of one-week period. There was a 48-hour recovery period among the three investigated tests. The familiarization session was performed 48 hours prior the beginning of the experimental tests, and included a physical examination, anthropometric measurements (height and body mass), and familiarization with the vibrating platform, HS, EMGrms, and ROM (procedures performed during the three investigated tests). On the day of familiarization, a blood sample was also performed to check the inflammatory activity of the disease through the erythrocyte sedimentation rate (Fig. 1).

This study was conducted in accordance with the ethical principles for research involving humans' subjects (principles of the Declaration of Helsinki) and received approval from the Ethics Committee of the *Universidade Federal dos Vales do Jequitinhonha e Mucuri* (Nº 2.544.850). Furthermore, was submitted to the Registry of Clinical Trials (ReBEC) (RBR-2n932c).

Fig. 1.



The participants were recruited between March of 2018 and May of 2019, at the medical clinic by the rheumatologists of the Regional Polyclinic, Basic Health Units and the radio ads in Diamantina, MG, Brazil. Inclusion criteria were included: women ages between 20 and 70 years, with confirmed diagnosis of RA by a rheumatologist according to the criteria of the American College of Rheumatology [19]. Participants were ineligible, if they presented: sensory disturbances; active infections; alcohol or drug abuse; pregnancy or breastfeeding; anticoagulant treatment; any concomitant disease that would prevent the execution of the experimental tests; any other rheumatological disease; serious complications of RA; non-stable disease; intra-articular infiltrations or other procedures, such as physical therapy or corrective surgeries, and some contraindication vibrating platform. Throughout the study, participants were oriented to avoid adjust drug therapy, and the use of analgesics for pain.

Intervention

Experimental Tests

All the volunteers performed the three experimental tests at the same time of each day, in a controlled thermoneutral environment (means of 22±1 ^{0}C and 53±2 % relative humidity).

Control. Participants remained for five minutes continuously at rest in seating position with feet on the floor and hands in the supine position on the lower limbs. There was no vibration stimulus (Fig. A.2).

Sham. The participants were positioned for five minutes continuously in the push-up position with their hands apart at a distance of 28 cm on the vibrating platform that remained disconnected, but with a sonorous stimulus mimicking the vibration (Fig. B.2).

Vibration. The participants were positioned for five minutes continuously in the push-up position with their hands apart at a distance of 28 cm on the vibrating platform turned on, using the vibratory stimulus intensities of 45 Hz/2 mm/159.73 $m.s^{-2}$. The study used a vibrating platform (FitVibe, GymnaUniphy NV, Bilzen, Belgium) that produces vertical sinusoidal vibrations. This is while the platform moves predominantly in the vertical direction, resulting in a simultaneous and symmetrical movement on both sides of the body during exposure. A horizontal bar at shoulder height was used to avoid trunk flexion during the intervention and to guarantee an elbow flexion of 10º (Fig. B.2). All vibration parameters (frequency: 45 Hz; amplitude: 2 mm) were selected in agreement with previous studies [20,21].

Fig. 2. Experimental tests positions. (A) – control position and (B) - push up position adopted during sham or vibration exercise tests.

Procedures

Prior to all three experimental tests, each participant rested for fifteen minutes in seated position with their hands in a supine position on the lower limbs, with these arrangements we verified that lower muscle's electrical activity of the FDS muscle, indicative of rest. Thereafter, each participant was positioned in one of the experimental tests described previously. At the baseline and immediately after the intervention, the muscle performance of the dominant hand was evaluated using the HS dynamometer (Jamar, Warrenville, USA). The neuromuscular electromyographic record of the FDS muscle of the dominant hand was simultaneously recorded using portable electromyography data log instrument (Miotec, Porto Alegre, Brazil). Following the ROM of the wrist, flexion-extension of the dominant hand was measured using a universal goniometer (Fibra Cirúrgica, Joinville, Brazil). All the evaluations were performed by a single blinded researcher whom always followed the same order of procedures.

Outcomes Measures

Handgrip Strength (HS).: Participants seated with feet on the floor, with the arm in adduction and elbow flexed at 90°, forearm in a neutral position, with wrist extension between 0° and 30°. The dominant hand performed three repetitions of 3-second maximum HS. There were a 60-second recovery period scheduled among the repetitions. HS was determined by the average of the three peak values [22].

Electromyography (EMGrms).: Electromyography of the FDS muscle of the dominant hand was recorded using a one-channel portable electromyography. Two passive Ag/AgCl electrodes (Meditrace, Ludlow Technical Products, Gananoque, Canada) were positioned on the muscle belly of the FDS muscle with a fixed distance of 20 mm, arranged perpendicular to the direction of muscle fibers. One ground electrode was attached to the lateral epicondyle of the humerus according to the position described by SENIAM - Surface Electromyography for the Non-Invasive Assessment of Muscles [23]. The recorded signals were treated with a 10-480 Hz band pass butterworth filters for signal amplitude analysis and to avoid noise. The analog-to-digital conversion of the signals was performed with a 14-bit input A/D hardware resolution, sampling frequency of 2 kHz, common rejection module greater than 100 dB, signal-to-noise ratio less than 3 μV and system impedance of 109 Ohms. The signal was captured by surface-active differential sensors and recorded as the Root Mean Square (RMS), a quantitative indicator in the recruitment of motor units, in μV and the mean frequency in Hz [24]. Thus, the electromyography signals were collected in μV, normalized by peaks (peak-to-peak) and transformed into %RMS by software (MiotecSuite 1.0.1065) for data analysis [23].

Both HS and EMGrms were determined concomitantly by the average of the three repetitions performed before and after the experimental tests. The HS frequency was of 3000 ms (i.e., 3 s) with simultaneous and synchronized EMGrms registration. As the EMGrms record pattern considers, the discard of the first and the last contraction second, was used only the middle contraction second by us, within the interval range of 1000-2000 ms. Thus, all EMGrms record was performed inside 3000 ms (i.e. time of HS contraction), however the duration of the signal used to analyze the sliding window of the EMGrms was actually 1000 ms.

Neural Ratio (NR): With the values obtained with electromyography and HS, it was possible to determine the NR, calculated by the RMS electromyogram (flexor digitorum superficialis muscle electromyography) divided by the mechanical power (HS). A lower NR represents greater neuromuscular modifications [18].

Range of motion (ROM). The ROM was measured in degrees, with a universal goniometer, by a previously trained evaluator. The fixed arm of the goniometer was placed parallel to the longitudinal axis of the proximal end. The movable arm was positioned parallel to the longitudinal axis of the distal end, with the fulcrum at the axis of the joint. Measurements were made of wrist flexion and extension of the dominant hand [25].

Data analysis

Data were reported as means ± 95% confidence intervals (CIs). Intraclass correlation coefficients assessed the test-retest reliability of the HS and electromyography measures.

Shapiro-Wilk's test for normality and Levene for homogeneity revealed that data were normally distributed and homogeneous.

The effects of the tests were compared by Split-Plot arrangement in a randomized block design and Tukey (5%) test for means comparison (within-test, between-test and interaction).

All measurements were obtained at the local institutional *Laboratório de Fisiologia do Exercício* by trained researchers. The statistical significance level was set up at $p < 0.05$. The effect size (eta squared: η2) < 0.25 represented small effect, between 0.25-0.4 moderate effect and > 0.4 high effect [26].

This study was based and is in accordance with checklists for randomized controlled and clinicals trials CONSORT and SPIRIT.

Sample size

The sample size was calculated using the G-Power® software (Franz Faul, Universitat Kiel, Germany), based on a previous study of our group evaluating the dose-response effect of WBV exercise in the push-up position on NR (primary outcome). Thus, a sample size of eighteen participants was required for a power value equal to 80% and a two-tailed α-value = 0.05 for the NR. Nevertheless, once we considered a lost around 15%, the sample size had twenty-one (7 blocks of 3 x 3 participants) participants. There was no drop-out, so it was not necessary to analyze the data by Intention to Treat.

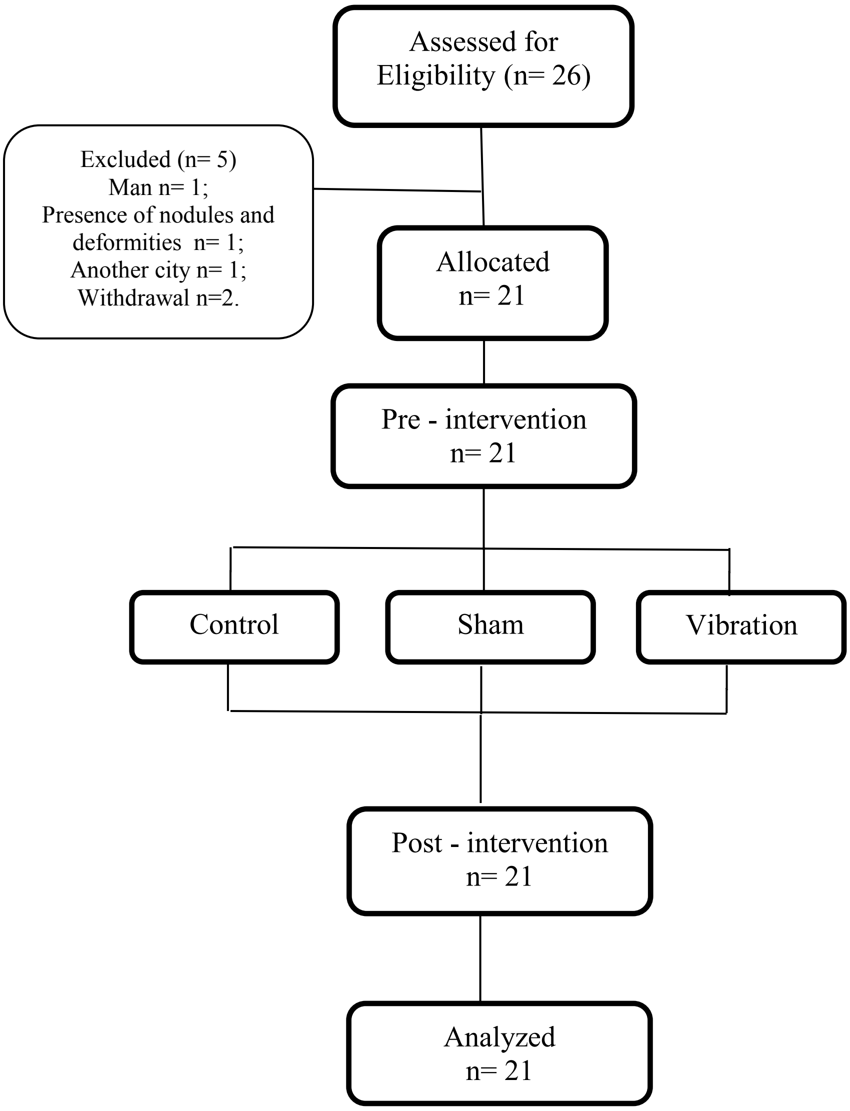
RESULTS

The ICC test-retest reliability of HS, EMG activity of the FDS muscle and ROM were 0.984, 0.778 and 0.899, respectively.

Flow of participants through the study

A total of twenty-six women diagnosed with RA were initially screened for eligibility. A sample of twenty-one (n=21) eligible RA women enrolled the study (Fig. 3).

Fig. 3. Flow of participants through the study.



Characteristics of participants.

Table 1 presents the volunteers characteristics concerning age, anthropometric parameters, identification of the medical diagnosis's time frame, and Erythrocyte Sedimentation Rate test to verify the inflammatory activity disease.

Table 1. Characteristics of participants.

Characteristic	Mean (CI 95%)	MIN	MAX
Age *(yr)*	54 (48.99-59.01)	33	66
Weight *(kg)*	72.9 (66.98-78.82)	52	108
Height *(m)*	1.59 (1.56-1.62)	1.46	1.71
BMI* *(kg/m²)*	28.6 (26.69-30.51)	21.9	37.8
Diagnostic time *(yr)*	8 (5.36-10.64)	2	18
Erythrocyte sedimentation rate *(mm/h)*	24.8 (18.43-31.17)	10	61
SODA*	106 (104.97-107.03)	100	108

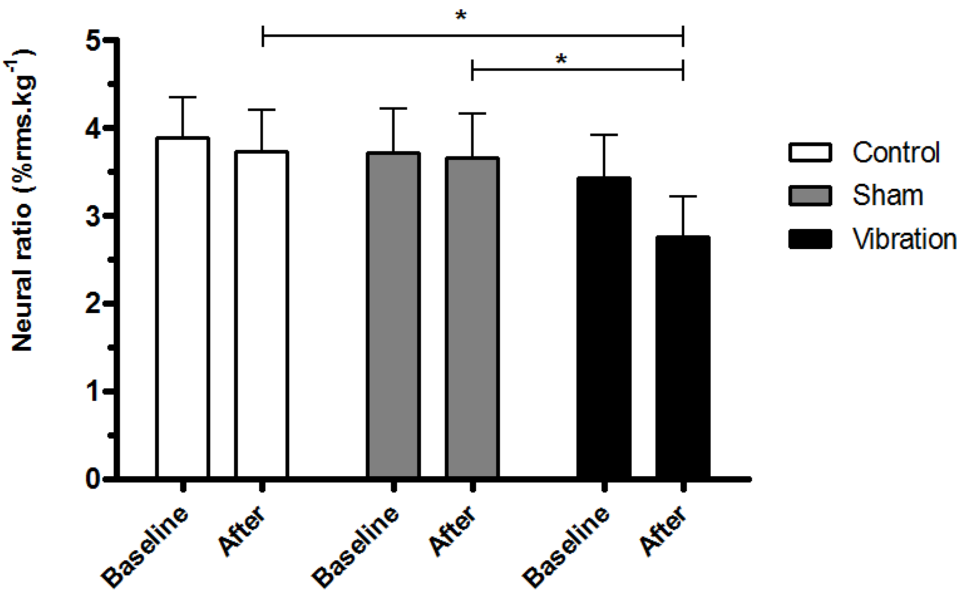
SODA*: Sequential Occupational Dexterity Assessment for Patients with Rheumatoid Arthritis.
BMI*: Body Mass Index.

Primary outcome

NR. NR was similar in the three experimental tests at baseline [Baseline - Sham: 3.68 (CI 95% 2.67-4.68), Control: 3.88 (CI 95% 2.91-4.85), Vibration: 3.42 (CI 95% 41-4.43). Despite of no within-tests (p = 0.0611, F = 3.94, η^2 = 0.66, Power = 0.99) and interaction (p = 0.1907, F = 1.69, η^2 = 0.50, Power = 0.96) effect, between-tests analyses (p = 0.0003, F = 8.86, η^2 = 0.85, Power = 1.00) showed that vibration exercise reduced the NR compared with the sham and control.

[After - Sham: 3.63 (CI 95% 2.58-4.67), Control: 3.71(CI 95% 2.74-4.68), Vibration: 2.74 (CI 95% 1.79-3.69)] (Fig. 4).

Fig. 4. Neural ratio at baseline and after the experimental tests in the three experimental tests.



N = 21 subjects in each experimental test. Difference (after – baseline) Control= (CI 95% -0.78 – 0.44); Sham= (CI 95% -0.22 - 0.82) and Vibration = (CI 95% -1.52 - -0.30).

Secondary outcomes

HS. HS was similar in the three experimental tests at baseline. Despite of no between-tests effect, there was interaction effect and within-tests analyses it showed that immediately after the vibration exercise, the HS augmented was around 11% compared with the baseline, and the others experimental tests (sham and control). (Table 2).

EMGrms. EMGrms was similar in the three experimental tests at baseline. Despite of no within-tests and interaction effect, the between-tests analyses demonstrated that vibration exercise decreased significantly the EMGrms activity of FDS muscle compared with sham and control (Table 2).

ROM. Wrist flexion-extension ROM was similar in the three experimental tests at baseline. Within and between-tests, as well as interaction analyses showed that vibration exercise increased both wrist ROM compared with baseline and the others experimental tests (sham and control). (Table 2).

Table 2. Effect of whole-body vibration exposure on handgrip strength, electromyographic records of the flexor digitorum superficialis muscle, and wrist range of motion.

Variable	Control	Sham	Vibration	Within-tests				Between-tests				Interaction			
				p	F	η^2	Power	p	F	η^2	Power	p	F	η^2	Power
HS															
Baseline (kg)	20.03(16.52-23.54)	20.68(17.29-24.07)	19.38(16.18-22.58)	**0.0014**	13.70	0.86	1.00	0.3667	1.02	0.37	0.82	**0.0178**	4.24	0.73	0.99
After (kg)	20.45(16.79-24.11)	20.95(17.40-24.50)	21.77(18.06-25.48)$^{*\#}$												
EMGrms															
Baseline (% rms)	64.53(57.77-71.29)	62.82(56.83-62.81)	53.84(46.93-60.79)	0.1821	1.91	0.34	0.76	**0.0002**	9.29	0.87	1.00	0.7403	0.30	0.17	0.39
After (% rms)	62.86(55.64-70.08)	62.76(56.81-68.71)	48.92(39.34-58.50)$^{\#}$												
FLEXION ROM															
Baseline (º)	79.48(75.70-83.26)	77.71(73.58-81.84)	77.28(73.36-81.20)	**0.0059**	9.48	0.77	0.99	0.6424	0.44	0.22	0.49	**0.0086**	5.05	0.76	0.99
After (º)	77.67(73.62-81.72)	81.10(77.17-85.03)	81.57(76.91-86.23)$^{*\#}$												
EXTENSION ROM															
Baseline (º)	49.00 (41.37-56.63)	52.71(44.50-60.92)	50.10(42.86-57.34)	**0.0064**	9.28	0.84	1.00	**0.0218**	4.01	0.62	0.99	**0.0404**	3.34	0.58	0.99
After (º)	51.86(46.19-57.53)	53.95(45.18-62.72)	58.10(51.85-64.35)$^{*\#}$												

HS (handgrip strength); EMGrms (electromyographic records); ROM (range of motion); Whole-body vibration 45Hz/2mm. Measures performed at baseline and after the experimental tests. Data are presented as Mean (Confidence Interval 95%). F values. Eta partial η^2. N = 21 subjects in each experimental test. $^{*}p<0.05$ to baseline. $^{\#}p<0.05$ to experimental tests.

2.5 DISCUSSION

Our results suggest that acute vibration exercise directly under the hands promotes favourable handgrip neuromuscular modifications in women with RA. Thus, WBV therapy represents a preparatory activity to be used prior to rehabilitation session of stable RA patients. Therefore, to understand the neuromuscular modifications provided by this exercise, first the effects of vibration exercise on HS muscular performance concomitant with the neuromuscular activity of the FDS muscles should be understood.

The HS of the participants was around 20.03 kg at baseline in all experimental tests, representing 62% of the predicted HS in middle-aged and elderly Brazilians. Thus, the disease resulted in a 33 to 37% impact on HS [27]. Considering the measurement properties of the HS assessment, the minimum clinically important difference (MCID) scores for women with carpometarcarpal osteoarthritis, a chronic disease which results in deterioration of the joint surfaces bone reformation such as RA, is around 0.84 kg (affected side) and 1.12 kg (unaffected side) [28,29]. Although the MCID was estimated for another chronic disease group, the score obtained in our study, 2.39 (1.88 – 2.90) kg with a vibration test, suggests an important clinical change. Accordingly, our finding is in line with the study by Brorsson et al. (2014), who found that patients suffering from arthritis are weaker than healthy individuals in terms of flexion-extension strength. However, our results, as well as Speed & Campbell (2012), showed that increases of muscle strength in individuals with RA may be due to neural adaptation and, consequently, greater efficiency creates motor unit activation. Experiments with surface electromyography showed that women with RA tend to use higher levels of neuromuscular activation in daily tasks than healthy women [11], especially during manual skills involving handgrip. Thus, in the present work we opted in evaluating the EMGrms of the FDS muscles. This decision was based on the major muscle group which is responsible for handshake activity since it helps to provide balance for the finger flexion arc [15,16,31]. Moreover, we decided for the static push-up position on the vibration platform, as there is evidence of greater muscle activation in the upper limb muscles during vibration stimulation of this position [15,16]. However, in our study, vibration stimulation reduced muscle activation levels immediately after the vibration test, suggesting that fewer motor units were required to perform the same handgrip activity.

According to our findings, a single WBV exercise session directly under the hands, in a modified static push-up position, was able to promote neuromuscular changes in handgrip in women with RA. Firmly, we can observe that the NR of the participants was about 3.66% at the baseline in all experimental tests. After exposure to the vibration test, they found a reduction of approx 24.5% was found in handgrip NR compared with that observed after the sham and control tests. These results evidenced that a single session of vibration stimulus, directly under the hands, promotes greater neuromuscular modifications.

Although there are few publications in the context of the rehabilitation of patients with stable RA involving WBV and upper limbs. It is noteworthy that studies generally evaluated the effect of training with vibration, focused on the lower limbs [4,13]. Regarding the changes and consequent neuromuscular modifications about of the hands, we found no studies with this special population thus far. However, Krol and colleagues (2011) demonstrated an increase in the neuromuscular efficiency and concluded that vibration exercise can be useful to stimulate the neuromuscular system in healthy women [14].

Our results are in line with the idea that the vibration exercise potentiates the neural response. The following protocol description reproduces information already reported elsewhere [15]. WBV exercise is reported to represents an alternative exercise for the treatment of RA due to its ability in promoting lower joint impact and greater neuromuscular modifications. Most of studies that found satisfactory results of vibration training used the range from 24 Hz, 2 mm acceleration [45.43 $m.s^{-2}$] to 30 Hz, 3 mm, acceleration [106.48 $m.s^{-2}$]. Moreover, the stimulus duration varied from 10½ minutes to 15 minutes intermittent [13,33,34]. Nevertheless, the vibration parameters (frequency: 45 Hz; amplitude: 2 mm, acceleration 159.73 $m.s^{-2}$) during 5 minutes continuous of vibratory stimulus used in the present study were selected in agreement with previous research [20,21]. Additionally, the time of 5 minutes of tests did not generate discomfort, thus allowing to finish the test and a good adherence by the participants.

As far as the joint damage in patients with RA is concerned, one of the most affected is the wrist (78%) [35]. Thus, usually joint in hand's present reduction in muscle contraction, firing rate of motor units, ROM and mobility, as well as change in the muscle fiber type [36]. In the current study, the wrist flexion ROM in the RA group was on average 11.8º lower than normal values, [25] and after vibration exposure there was an increase around 4.29º (compared with sham test showing an increase around 3.39º). Regarding the wrist extension ROM, the RA group presented a 19.4º value lower than the predicted values [25], which increased after vibration of around (compared with sham test showing an increase around 4.15º).

The rationale for vibration exercise as a preparatory activity before training or rehabilitation sessions is based on the premise of promoting "active muscle warm-up" [20,21]. Active warm-up consists of low intensity movements that are effective in raising body temperature, promoting tissue warm-up and producing a variety of improvements in physiological functions [37]. Therefore, warm-up activities are necessary to prepare the body for vigorous physical activity since they increase performance and decrease the risk of muscle injury. Moderate intensity of active warming and passive warming can increase muscle performance by 3 to 9% [37]. In addition, WBV exercise seems to increase neuromuscular spindle activity, triggering a reflex-stretch response and consequently creates a small and rapid change in muscle length.

In the literature, few studies have investigated the effects of vibration on ROM with focused mainly on the lower limbs, involving flexibility [38,39]. According to Oliveira et al. (2015), joint ROM is related to functionality and is a determinant factor of morbidity and mortality predictor in RA patients. Thus, we considered relevant to investigate the effect of vibration exercise applied directly to the hand on the ROM of the wrist flexion-extension. Our data pointed out that vibratory exercise significantly improved the wrist ROM, probably triggering small and rapid modifications in muscle length. However, this supposition is beyond the scope of this study.

Inevitably, this work had some inherent shortcomings. As this investigation was only performed with RA women, a certain degree of wariness should be taken before spreading the conclusions. However, statistical analyses demonstrated a large effect size within- between-tests, as well as interaction for NR. The blood analysis of Erythrocyte Sedimentation Rate and the SODA instrument demonstrated that the studied population was not in the inflammatory activity phase of the disease and presented satisfactory manual dexterity. Moreover, because specific conditions were evaluated, such as: platform position, stimulus duration, frequency and amplitude, EMGrms analyzes of only one muscle group, were evaluated, therefore the findings of this study cannot be extrapolated to other parameters of vibration and cannot be generalized to another population.

Finally, as perspective, it is relevant to perform a study to evaluate the effect of accumulated acute vibration exercise directly under the hands, i.e., vibration training, in neuromuscular performance during handgrip activities in RA patients. Since a single session of vibration exercise has promoted handgrip neuromuscular modifications, probably adaptations due to training may occur as a result of the sum of acute sessions. Thus, it is possible that vibration training under the hands may also result in greater efficiency in motor unit's activation during handgrip activities in RA patients.

In conclusion, acute vibration exercise, directly under the hands, in the push up position, promotes neuromuscular modifications, suggesting positive impact on neuromuscular performance and wrist ROM, with concomitant reduction in handgrip NR in women with stable RA. As clinical relevance, vibration exercise under the hands of stable RA patients suggests positive effects on aspects of structure and function related to manual activities that involve object manipulation. Thus, vibration exercise may be a complementary and alternative preparatory exercise for the treatment of patients with musculoskeletal dysfunction.

2.7 ACKNOWLEDGMENTS

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2.8 ABBREVIATIONS

CI- Confidence intervals

EMGrms – Electromyography activity

FDS – Flexor digitorum superficialis muscle

HS – Handgrip strength

ICC – Intraclass correlation coefficients

LAFIEX – Laboratório de Fisiologia do Exercício

MCID – Minimum Clinically Important Difference

NE – Neuromuscular efficiency

NR – Neural ratio

RA – Rheumatoid Arthritis

RMS – Root mean square

ROM – Range of motion

UFVJM – Universidade Federal dos Vales do Jequitinhonha e Mucuri

WBV – Whole-body vibration

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2.10 DECLARATIONS

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles for research involving humans' subjects (principles of the Declaration of Helsinki), received approval from the Ethics Committee of the *Universidade Federal dos Vales do Jequitinhonha e Mucuri* (Nº 2.544.850), and was registered in the Brazilian Registry of Clinical Trials on March 1, 2019 (ReBEC) (RBR-2n932c).

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(Coordenador)

Consent for publication

All participants were informed about the study procedures and provided their written consent to participate in this study. The researchers of this study confirm that they have given due consideration to protect the intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations of Interests

The authors declare none interests.

Authors' contributions

Conceived and designed the experiments: AC, AL, VA, ACR. Performed the experiments: AC, AL, LM. Analyzed the data (interpreted results of experiments, prepared figures, drafted manuscript, edited and revised manuscript): AC, LM, SF, JM, VR, PH, HR, VA, FM, RG, DC, MB, RT, AS, ACR. Contributed materials/analysis tools: AC, SF, JS, HR, VA, ACR. All authors read and approved the manuscript.

2.11 – NORMAS DE SUBMISSÃO DA REVISTA

Annals of Physical and Rehabilitation Medicine (APRM)

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GUIDE FOR AUTHORS

INTRODUCTION

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This journal operates a single blind review process. All contributions will be initially assessed by the editor for suitability for the journal. Papers deemed suitable are then typically sent to a minimum of two independent expert reviewers to assess the scientific quality of the paper. The Editor is responsible for the final decision regarding acceptance or rejection of articles. The Editor's decision is final. More information on types of peer review.

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It is important that the file be saved in the native format of the word processor used. The text should be in single-column format. Keep the layout of the text as simple as possible. Most formatting codes will be removed and replaced on processing the article. In particular, do not use the word processor's options to justify text or to hyphenate words. However, do use bold face, italics, subscripts, superscripts etc. When preparing tables, if you are using a table grid, use only one grid for each individual table and not a grid for each row. If no grid is used, use tabs, not spaces, to align columns. The electronic text should be prepared in a way very similar to that of conventional manuscripts (see also the Guide to Publishing with Elsevier). Note that source files of figures, tables and text graphics will be required whether or not you embed your figures in the text. See also the section on Electronic artwork To avoid unnecessary errors you are strongly advised to use the 'spell-check' and 'grammar-check' functions of your word processor.

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Subdivision - unnumbered sections
Divide your article into clearly defined sections. Each subsection is given a brief heading. Each heading should appear on its own separate line. Subsections should be used as much as possible when crossreferencing text: refer to the subsection by heading as opposed to simply 'the text'.
Introduction
State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.
Material and methods
Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.

Theory/calculation
A Theory section should extend, not repeat, the background to the article already dealt with in the Introduction and lay the foundation for further work. In contrast, a Calculation section represents a practical development from a theoretical basis.
Results

Results should be clear and concise.

Discussion

This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

Appendices

If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

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• Author names and affiliations. Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. You can add your name between parentheses in your own script behind the English transliteration. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lowercase superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.
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Abstract

A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

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Reference to a book:
[3] Strunk Jr W, White EB. The elements of style. 4th ed. New York: Longman; 2000.
Reference to a chapter in an edited book:
[4] Mettam GR, Adams LB. How to prepare an electronic version of your article. In: Jones BS, Smith RZ, editors. Introduction to the electronic age, New York: E-Publishing Inc; 2009, p. 281–304.
Reference to a website:
[5] Cancer Research UK. Cancer statistics reports for the UK, http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/; 2003 [accessed 13 March 2003].
Reference to a dataset:
[dataset] [6] Oguro M, Imahiro S, Saito S, Nakashizuka T. Mortality data for Japanese oak wilt disease and surrounding forest compositions, Mendeley Data, v1; 2015. https://doi.org/10.17632/xwj98nb39r.1.
Note shortened form for last page number. e.g., 51–9, and that for more than 6 authors the first 6 should be listed followed by 'et al.' For further details you are referred to 'Uniform Requirements for Manuscripts submitted to Biomedical Journals' (J Am Med Assoc 1997;277:927–34) (see also Samples of Formatted References).

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2.12 APÊNDICE I

MINISTÉRIO DA EDUCAÇÃO
Universidade Federal dos Vales do Jequitinhonha e Mucuri
Comitê de Ética em Pesquisa

Termo de consentimento livre e esclarecido (TCLE) para sujeitos com Artrite Reumatoide

Você está sendo convidada a participar de uma pesquisa intitulada: "**EFEITO AGUDO DA VIBRAÇÃO NA DOR E NO DESEMPENHO FÍSICO-FUNCIONAL DOS MEMBROS SUPERIORES EM PACIENTES COM ARTRITE REUMATÓIDE**", por ser mulher, com idade entre 40 a 70 anos, com diagnóstico confirmado de Artrite Reumatoide há, no mínimo, 1 ano. Esta pesquisa será coordenada pela Professora Ana Cristina Rodrigues Lacerda e contará ainda com a aluna de mestrado Ana Carolina Coelho de Oliveira

A sua participação não é obrigatória sendo que, a qualquer momento da pesquisa, você poderá desistir e retirar seu consentimento. Sua recusa não trará nenhum prejuízo para sua relação com o pesquisador e com a UFVJM.

Os objetivos desta pesquisa são: Estudar os efeitos do estímulo vibratório na dor e desempenho físico-funcional em membros superiores de pacientes com artrite reumatoide.

Caso você decida aceitar o convite, será submetida aos seguintes procedimentos: no primeiro momento, você deverá comparecer ao Laboratório de Fisiologia do Exercício localizado no Campus JK da UFVJM, para avaliação de medidas do seu peso corporal, da sua altura, do seu percentual de gordura e mineralização óssea. Você será encaminhada para uma sala reservada para esta finalidade, e ficará descalço, vestindo roupas leves. As medidas do seu peso corporal e altura serão feitas em uma balança equipada com um medidor de estatura e o percentual de gordura corporal será medido por meio de um aparelho chamado DEXA, você ficará deitada em silêncio realizando o mínimo de movimentos possível, por aproximadamente 5 minutos.

Para as avaliações você deverá utilizar roupas leves (short, tênis e camiseta) e será orientado a evitar prática de atividade extenuante e de longa duração, além de não ingerir bebidas alcoólicas e cafeína nas 24 horas antecedentes ao teste, dormir no mínimo 8 horas na noite anterior, realizar uma refeição leve e ingerir 500ml de água no mínimo duas horas antes do teste. O dia e horário desse teste serão marcados com o pesquisador.

De acordo com o resultado dessas avaliações, considerando sua idade, variáveis antropométricas e medicamentos em uso, serão aplicados vários questionários em uma sala reservada com um pesquisador. As perguntas serão sobre seu estado geral de saúde, como é a dor que sente, o quanto essa dor tem interferido na sua vida, como você se sente em relação a outras pessoas, como tem sido o seu sono e quais atividades do dia a dia você consegue realizar. Ao responder os questionários, caso alguma pergunta que lhe traga algum constrangimento, você terá o direito de deixar de responder. Será também coletada uma amostra de sangue na parte anterior do seu cotovelo (fossa cubital). Estes procedimentos (questionários, testes e exame laboratorial) serão aplicados na UFVJM em Diamantina e logo após você será familiarizada com o estímulo de vibração de corpo inteiro.

No dia do procedimento experimental, você deverá chegar a UFVJM no horário previamente combinado com a pesquisadora e ficará em repouso, na posição sentada por 15 minutos. Será realizada assepsia (algodão e álcool) e serão colocados 3 eletrodos no seu braço da mão dominante para coletar a atividade de um determinado músculo. Em seguida, iniciaremos o procedimento experimental. Antes e após o procedimento experimental, será medida a amplitude de movimento dos seus dedos e punho, a força muscular das suas mãos, a dor e um teste de destreza manual. Para medir a amplitude de movimento, você deverá fechar a mão ao máximo e um aparelho será colocado externamente nas articulações de cada dedo e do punho, medindo o seu ângulo de movimento; a força muscular será medida com um Dinamômetro, que consiste num aparelho que você irá apertar com o máximo de força que conseguir, por três vezes consecutivas; o teste de dor, basta você dizer de zero a dez (0 à 10) o quanto está sentindo naquele momento e o teste de destreza manual consiste em você realizar algumas tarefas do dia a dia (espremer uma pasta de dente, lavar as mãos, abotoar uma blusa, dentre outras), com uma ou duas mãos, utilizando os materiais que estarão disponíveis para você na sala. Em seguida você irá realizar um dos três procedimentos citados: (1) Controle. Você deverá ficar sentado, com as mãos viradas para cima e apoiadas nas pernas, durante 5 minutos, com os olhos vendados; (2) Vibração 45Hz/2mm. Você deverá ficar posicionado em posição de *push-up*, com as palmas das mãos a uma distância de 28 cm, em contato com a plataforma, vibrando por 5 minutos, com os olhos vendados; (3) Sham. Você deverá ficar posicionado em posição de *push-up*, com as palmas das mãos a uma distância de 28 cm, em contato com a plataforma, sem vibrar, ouvindo o som da plataforma vibratória, durante 5 minutos, com os olhos vendados. Após o término da sessão experimental, você passará pelas mesmas avaliações que realizou antes da sessão e em seguida, poderá ir para casa.

O tempo total previsto para a sua participação no estudo é de 04 dias, comparecendo ao local do experimento 1 vez, na primeira semana, para a realização do exame que irá avaliar seu peso, altura, percentual de gordura e mineralização óssea no Laboratório de Fisiologia do Exercício no Campus JK da UFVJM e serão aplicados questionários; você conhecerá a plataforma vibratória e será familiarizada com as possibilidades de estímulos, totalizando o tempo de duração de aproximadamente 1 hora. Após o primeiro encontro, serão mais três encontros, em dias alternados, para a realização do protocolo experimental propriamente dito, na UFVJM, com duração de aproximadamente 1 hora.

Os riscos relacionados com sua participação são riscos gerais relacionados ao incômodo e dor, decorrentes da coleta de sangue e desconforto local, o que é normal no procedimento, mas tende a desaparecer em um curto espaço de tempo. Porém, uma vez que estas serão realizadas por pessoa tecnicamente capacitada para tal e utilizando-se materiais descartáveis, estes riscos serão minimizados.

A exposição à vibração poderá, eventualmente, provocar algum incômodo, como cansaço, coceira, náuseas, entre outros. Nestes casos, você poderá interromper o experimento quando quiser. Essas alterações tendem a desaparecer após a finalização da sessão experimental do dia. Além disso, estes eventos ocorrem em baixa frequência nas condições estabelecidas no laboratório, o que diminui o risco de acidentes, em condições estritamente controladas, exclusivamente sob supervisão e orientação dos pesquisadores responsáveis.

A avaliação da composição corporal realizada por meio da absormetria radiológica de dupla energia (DEXA) poderá provocar algum desconforto pela permanência em silêncio e sem realizar movimentos, no entanto destacamos que o escaneamento corporal é rápido.

Todas as medidas serão realizadas pelo mesmo avaliador, sempre acompanhado por outro pesquisador, em sala reservada.

Deve-se ressaltar que as condições de controle da realização dos procedimentos, pesquisadores treinados, equipamentos modernos, material descartável, diminuem a probabilidade de ocorrer problemas para você durante todas as etapas do estudo, bem como permitirá a detecção de alterações precoce que possam trazer prejuízos, permitindo se necessária, a interrupção do procedimento.

Os benefícios decorrentes da realização desta pesquisa estão relacionados ao conhecimento da saúde física e emocional, composição corporal, mineralização óssea, bem como, contribuirão para a construção do conhecimento sobre vibração em pacientes com Artrite Reumatoide.

Os resultados desta pesquisa poderão ser apresentados em seminários, congressos e similares, entretanto, os dados/informações obtidos por meio da sua participação serão confidenciais e sigilosos, não possibilitando sua identificação. A sua participação é de caráter voluntário, não havendo ressarcimento de gastos, tais como o transporte para o local da pesquisa.

Não está previsto indenização por sua participação, mas em qualquer momento se você sofrer algum dano, comprovadamente decorrente desta pesquisa, terá direito à indenização.

Você receberá uma cópia deste termo onde constam o telefone e o endereço do pesquisador principal, podendo tirar suas dúvidas sobre o projeto e sobre sua participação agora ou em qualquer momento.

Coordenadora do Projeto: Ana Cristina Rodrigues Lacerda
Endereço: Rodovia MGT 367 – Km 583, nº 5000 - Alto da Jacuba 39100-000 Diamantina/MG
Telefone: (38) 35321239 – (38) 35321284

Declaro que entendi os objetivos, a forma de minha participação, riscos e benefícios da mesma e aceito o convite para participar. Autorizo a publicação dos resultados da pesquisa, a qual garante o anonimato e o sigilo referente à minha participação.

Nome do sujeito da pesquisa: ____

Assinatura do sujeito da pesquisa: ____

Informações – Comitê de Ética em Pesquisa da UFVJM: Rodovia MGT 367 - Km 583 - nº 5000 - Alto da Jacuba – Diamantina/MG CEP39100000 Tel.: (38)3532-1240 – Coordenador: Prof. Dr. Disney Olivier Sivieri Júnior
Email: cep.secretaria@ufvjm.edu.br e/ou cep@ufvjm.edu.br.

3. CONSIDERAÇÕES FINAIS

O exercício de vibração agudo, diretamente sob as mãos, na posição “push up” promove modificações neuromusculares, sugerindo impacto positivo no desempenho neuromuscular de preensão manual e amplitude de movimento de punho de mulheres com AR estável. Assim, acreditamos que o estímulo de vibração poderia ser uma terapia coadjuvante preparatória, utilizada antes das sessões de reabilitação das mãos em pacientes com AR estável.