UNIVERSIDADE FEDERAL DE CIÊNCIAS DA SAÚDE DE PORTO ALEGRE – UFCSPA

CURSO DE PÓS-GRADUAÇÃO EM CIÊNCIAS DA REABILITAÇÃO

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Efeito da fotobiomodulação associada ao treinamento de força em homens idosos: um ensaio clínico randomizado duplo-cego placebo-controlado

Porto Alegre

2018

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Dissertação de Mestrado apresentada ao Programa de Pós-Graduação em Ciências da Reabilitação da Universidade Federal de Ciências da Saúde de Porto Alegre, como requisito parcial para a obtenção do título de Mestre em Ciências da Reabilitação.

Orientador: Bruno Manfredini Baroni

Porto Alegre

2018

Catalogação na Publicação

Fritsch, Carolina Gassen
Efeito da fotobiomodulação associada ao treinamento de força em homens idosos: um ensaio clínico randomizado duplo-cego placebo-controlado / Carolina Gassen Fritsch. -- 2018.
73 p. : 30 cm.

Dissertação (mestrado) -- Universidade Federal de Ciências da Saúde de Porto Alegre, Programa de Pós-Graduação em Ciências da Reabilitação, 2018.

Orientador(a): Bruno Manfredini Baroni.

1. Fototerapia. 2. Laser de baixa potência. 3. Treinamento de resistência. 4. Envelhecimento. I. Título.

Sistema de Geração de Ficha Catalográfica da UFCSPA com os dados fornecidos pelo(a) autor(a).

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Porto Alegre
2018

AGRADECIMENTOS

Agradeço ao meu orientador, prof. Bruno Manfredini Baroni, que confiou em mim para realizar este projeto. Muito obrigada pela incrível oportunidade que me proporcionastes, por abrir as portas de outros laboratórios e grupos de pesquisa para que eu pudesse desenvolver o projeto e crescer profissionalmente e pessoalmente. Agradeço também por toda a orientação, dedicação, compreensão e paciência que tivestes comigo e com o trabalho ao longo destes dois anos e por todo o conhecimento técnico-científico compartilhado.

Aos professores Eduardo Lusa Cadore, Marco Aurélio Vaz e Ronei Silveira Pinto, que possibilitaram as coletas de dados junto aos seus grupos de pesquisa, sendo sempre muito atenciosos e solícitos para a resolução dos problemas que surgiram ao longo do caminho.

Ao meu colega e grande amigo, Maurício Dornelles, que se dispôs a me auxiliar em todas as etapas deste projeto e a me dar todo o suporte necessário ao longo deste período.

À Juliana Teodoro e à Larissa Xavier Neves da Silva, que me acolheram nos seus grupos de pesquisa e trabalho e estiveram sempre otimistas e animadas me dando todo o suporte necessário.

À diretoria e à secretaria do Lapex, que permitiram o desenvolvimento do projeto em seus laboratórios e auxiliaram na organização das avaliações.

Aos colegas Bernardo Linck, Emmanuel Rocha, Felipe Xavier, Francesca Sonda, Rodrigo Rodrigues e Natália Trevisol que me auxiliaram nas etapas de treinamento e agendamento do laboratório.

Aos colegas do Grupo de Ciência do Esporte e Exercício, pelas discussões e pelos aprendizados compartilhados.

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes), pela bolsa de estudos.

Aos voluntários, por se dedicarem imensamente ao projeto, sempre bem-humorados, prestativos e solícitos nas sessões de treinamento.

Aos meus pais e ao meu irmão, que me deram todo o suporte para alcançar, iniciar, desenvolver e finalizar esta etapa.

Ao meu parceiro, Anderson Fetter, por todo apoio, auxílio, paciência e dedicação ao longo destes anos.

A todos que de alguma forma contribuíram para que este projeto fosse desenvolvido.

RESUMO

Introdução: A terapia de fotobiomodulação tem demonstrado capacidade de aumentar o desempenho físico e otimizar a recuperação pós exercício. Além disto, quando associada ao treinamento de força, tem demonstrado melhoras nos ganhos induzidos pelo exercício na população jovem. Entretanto, este efeito na população idosa permanece incerto. Objetivo: O objetivo do presente estudo foi de investigar o efeito da associação ao treinamento de força em idosos saudáveis na força e na massa muscular dos extensores de joelho e na capacidade funcional de homens idosos. Metodologia: Foi realizado um ensaio clínico randomizado duplo-cego placebo-controlado. Homens idosos saudáveis (idade 60-80 anos) realizaram 12 semanas de treinamento de força (2x/semana) com aplicação de fotobiomodulação placebo (n = 13) ou ativa (n = 11) no quadríceps (850nm, 30J por ponto, 8 pontos por membro) antes de cada sessão. Os seguintes testes foram realizados antes e depois da intervenção: teste de uma repetição máxima (1 RM) dos exercícios “leg press” e extensão de joelhos, pico de torque concêntrico e isométrico, espessura muscular dos músculos reto femoral (RF) e vasto lateral (VL), teste “timed up-and-go” (TUG) e teste de sentar e levantar da cadeira (TSL). Resultados: Houve melhoras significativas em todas as variáveis para ambos os grupos após a intervenção ($p < 0,05$), com exceção da espessura muscular do RF para o grupo placebo ($p = 0,09$). Tamanhos de efeito grandes (ES > 0,8) foram encontrados para 1 RM de “leg press” e extensão de joelhos e TSL para ambos os grupos, assim como para o teste TUG para o grupo fotobiomodulação ativa. Pico de torque isocinético para ambos os grupos e o teste TUG para o grupo placebo apresentaram tamanhos de efeito moderados (ES > 0,5). Pico de torque isométrico e espessuras musculares obtiveram pequenos tamanhos de efeito (ES > 0,2). A análise de inferência baseada em magnitude não demonstrou nenhuma vantagem da terapia ativa em relação à placebo. Conclusão: A aplicação de fotobiomodulação com os parâmetros utilizados no presente estudo não proporciona efeitos adicionais aos ganhos de força, massa muscular e capacidade funcional gerados pelo treinamento de força em idosos saudáveis.

Palavras-chave: fototerapia; laser de baixa potência; treinamento de resistência; envelhecimento.

ABSTRACT

Introduction: Photobiomodulation therapy (PBMT) has demonstrated capacity to enhance exercise performance and post-exercise recovery. Moreover, when associated to resistance training, it has shown a capacity to optimize training induced gains in the young population. However, its effect in the elderly remains unclear. Objective: The purpose of this study was to investigate the effects of PBMT combined to resistance training on knee extensor muscle mass, strength and physical function in elderly men. Methodology: A randomized double-blinded placebo-controlled trial was developed. Healthy elderly men (age 60-80 years) completed 12 weeks of resistance training (2x/week) with application of placebo (n = 13) or active PBMT (n = 11) on quadriceps muscles (850 nm, 30 J per point, 8 points per limb) before each training session. Leg press and leg extension one-repetition maximum (1 RM) tests, isometric and concentric peak torques, rectus femoris (RF) and vastus lateralis (VL) muscle thickness, timed-up-and-go (TUG) and chair rise to standing (CRS) tests were performed before and after the intervention period. Results: There were significant improvements in all outcomes for both groups ($p < 0.05$), except for RF muscle thickness for the placebo group ($p = 0.09$). Large effect sizes (ES > 0.8) were observed for leg press and leg extension 1 RM and CRS tests for both groups, as well as for TUG test for PBMT group. Isokinetic peak torque for both groups and TUG for placebo group had moderate increases (ES > 0.5). Muscle thicknesses and isometric peak torque had small increases (ES > 0.2) in both groups. Magnitude-based inference analysis does not support any advantages for using PBMT compared to placebo. Conclusion: In conclusion, PBMT with the parameters used in this study did not provide any additional benefits in comparison to placebo application on muscle mass, strength and physical function of healthy elderly men engaged in a resistance-training program.

Keywords: phototherapy; low-level laser therapy; strength training; older.

LISTA DE FIGURAS

Artigo

Figure 1 – Flowchart of the study………………………………………….……….………..50

Figure 2 – Photobiomodulation therapy (PBMT) parameters……………….………...51

Figure 3 – Leg press and leg extension mean training load relative to 1RM test on each mesocycle……………………………………...…………………….…………………...52

Figure 4 – Magnitude-based inferences for between-group analyses….……………...53

LISTA DE TABELAS

Revisão da Literatura:

Tabela 1 – Descrição dos estudos avaliando a associação da fotobiomodulação ao treinamento de força...17

Artigo:

Table 1 – Within-group analysis: muscle structure, muscle strength, and functional tests of Placebo and Photobiomodulation therapy (PBMT) groups at pre- and post-training evaluations (mean ± SD)…..……………………………………………………...54

LISTA DE ABREVIATURAS E SIGLAS

Revisão da Literatura

ATP	Adenosina Trifosfato
CK	Creatina Quinase

Artigo

1-RM	One-repetition maximum
ATP	Adenosine triphosphate
CRS	Chair rise to standing
ICC	Intraclass correlation coefficient
J	Joules
PBMT	Photobiomodulation therapy
RF	Rectus femoris
TUG	Timed up-and-go
VL	Vastus lateralis

SUMÁRIO

1 INTRODUÇÃO 9
2 REVISÃO DE LITERATURA 11
2.1 ENVELHECIMENTO 11
2.2 TREINAMENTO DE FORÇA 12
2.3 TERAPIA DE FOTOBIOMODULAÇÃO 14
3 REFERÊNCIAS DA REVISÃO 20
4 ARTIGO 29
INTRODUCTION 31
METHODS 32
RESULTS 38
DISCUSSION 39
CONCLUSIONS 42
REFERENCES 44
5 CONCLUSÃO GERAL 51
ANEXOS 52
ANEXO A – Normas de formatação do periódico European Journal of Applied Physiology 52
ANEXO B – Parecer do CEP 69
ANEXO C – Termo de Consentimento Livre e Esclarecido 72

1 INTRODUÇÃO

Já está bem estabelecido na literatura que a população idosa apresenta declínios nas funções fisiológicas de todos os sistemas corporais, incluindo o sistema musculoesquelético (ALI; GARCIA, 2014). O processo de envelhecimento diminui a massa e a qualidade muscular assim como altera a ativação neuromuscular (BARONI et al., 2013; BROCCA et al., 2017; STEVENS et al., 2003). Esta redução de massa muscular foi classificada inicialmente como “sarcopenia” (MITCHELL et al., 2012). Entretanto, o termo também passou a ser utilizado para nomear a perda de força muscular associada à perda de massa (MITCHELL et al., 2012). Atualmente, existem diferentes definições para o termo e não há um consenso mundial acerca de sua utilização ideal (MITCHELL et al., 2012). Segundo o Grupo de Estudos Europeu sobre Sarcopenia, esta é definida como uma síndrome caracterizada por perdas progressivas e generalizadas na massa e na força muscular que podem levar a efeitos adversos como incapacidade física, baixa qualidade de vida e morte (CRUZ-JENTOFT et al., 2010). A sarcopenia é considerada um componente-chave para o desenvolvimento da síndrome da fragilidade (CLEGG et al., 2013) e possui uma prevalência mundial de até 33% em adultos com mais de 50 anos (CRUZ-JENTOFT et al., 2014). Devido à relação entre massa e força muscular com a longevidade (EVANS; CAMPBELL, 1993; SRIKANTHAN; KARLAMANGLA, 2014), a manutenção e/ou o aumento da massa e da força muscular de idosos se tornou uma grande preocupação da área da saúde mundialmente (CRUZ-JENTOFT et al., 2014; EVANS; CAMPBELL, 1993).

O treinamento de força tem a capacidade de retardar parte do efeito do envelhecimento sobre o organismo humano (CSAPO; ALEGRE, 2016), levando a melhoras importantes na força muscular e na funcionalidade tanto em idosos saudáveis quanto em idosos sarcopênicos e frágeis (CSAPO; ALEGRE, 2016; LOPEZ et al., 2017; VAN ROIE et al., 2013; YOSHIMURA et al., 2017). O treinamento de força também gera aumentos na espessura e na área de secção transversa muscular (CORREA et al., 2013; CSAPO; ALEGRE, 2016), sendo que estes ganhos variam de 1,5% a 15.6% (CSAPO; ALEGRE, 2016; STEWART; SAUNDERS; GREIG, 2014). Além disto, diferentes estratégias ergogênicas vem sendo estudadas com o objetivo de maximizar os ganhos de força muscular e, principalmente, massa muscular induzidas pelo treinamento, como suplementação nutricional (MALAFARINA et al., 2013), reposição hormonal (HILDRETH et al., 2013), entre outros.

A terapia de fotobiomodulação vem sendo estudada como um recurso ergogênico inovador, não-invasivo e não-farmacológico (VANIN et al., 2018). O seu efeito se dá através da absorção da luz por cromóforos específicos da mitocôndria, o que gera uma série de reações intracelulares culminando em aumento da produção de ATP e do metabolismo celular, dentre outros (FERRARESI et al., 2015a; KARU, 2010). Consequentemente, as evidências apontam a fotobiomodulação como uma terapia eficaz para a melhora do desempenho físico e da recuperação pós-exercício (FERRARESI; HUANG; HAMBLIN, 2016; VANIN et al., 2018). Além disto, estudos que associaram a fotobiomodulação ao treinamento de força encontraram um maior ganho de força e massa muscular em comparação ao treinamento associado ao placebo (BARONI et al., 2015; FERRARESI et al., 2011, 2016; VANIN et al., 2016). Entretanto, grande parte da literatura acerca dos efeitos da fotobiomodulação no desempenho foram encontrados em jovens e/ou atletas (BARONI et al., 2015; FERRARESI et al., 2011, 2016; FERRARESI; HUANG; HAMBLIN, 2016; VANIN et al., 2016, 2018) e há poucos estudos com a população idosa, sendo que eles apresentam resultados contraditórios (TOMA et al., 2013, 2016; VASSÃO et al., 2016). Ao meu conhecimento, há apenas um estudo avaliando o efeito crônico da aplicação da fotobiomodulação associada ao treinamento de força em idosos e este não encontrou efeitos adicionais da terapia (TOMA et al., 2016).Contudo, o estudo não utiliza parâmetros apropriados, segundo a revisão sistemática mais recente (VANIN et al., 2018). Sendo assim, o real efeito da fotobiomodulação sobre as adaptações ao treinamento de força em idosos permanece incerto.

Devido à grande importância da força e da massa muscular para idosos (EVANS; CAMPBELL, 1993; SRIKANTHAN; KARLAMANGLA, 2014), tratamentos com potencial de aumentá-las são extremamente relevantes e devem ser investigados. Já que a fotobiomodulação se mostrou eficaz na maximização das adaptações induzidas pelo treinamento de força em jovens (BARONI et al., 2015; FERRARESI et al., 2011; VANIN et al., 2016), ela pode ser muito útil para idosos. Portanto, o objetivo do presente estudo foi verificar o efeito da associação da fotobiomodulação ao treinamento de força na força e na massa muscular dos extensores de joelho e na funcionalidade de idosos saudáveis.

2 REVISÃO DE LITERATURA

2.1 ENVELHECIMENTO

A proporção de pessoas com 60 anos ou mais está crescendo mundialmente (WHO, 2015). Estima-se que países em desenvolvimento, como Brasil, China e Índia, vão apresentar um aumento de 100% na sua população idosa em um pouco mais de 20 anos e calcula-se que os idosos passem a representar mais de 30% da população de países desenvolvidos no ano de 2050 (WHO, 2015). Segundo o Censo Brasileiro de 2015, houve um aumento de aproximadamente 46% no número de pessoas com 65 anos ou mais entre os anos 2005 e 2015 no Brasil (IBGE, 2016), o que reflete a importância de intervenções de saúde para esta população tanto a nível nacional quanto internacional.

O envelhecimento está associado a diversas modificações nos sistemas corporais, incluindo o sistema musculoesquelético (ALI; GARCIA, 2014; BROCCA et al., 2017; CARTER; CHEN; HOOD, 2015). Evidências sugerem uma diminuição significativa em massa, força e qualidade muscular (força por área muscular) a partir da quinta década de vida, principalmente em membros inferiores (JANSSEN et al., 2000; LYNCH et al., 1999). Estudos mostram que, a partir dos 70 anos, há diminuição em torno de 1% ao ano na massa muscular, enquanto a diminuição na força muscular pode chegar a até 5% ao ano (ALI; GARCIA, 2014; DELMONICO et al., 2009). Estas alterações ocorrem independentemente do nível de atividade física e da presença de doenças (BROCCA et al., 2017) e estão associadas a diversas alterações locais (BARONI et al., 2013; BROCCA et al., 2017; CRUZ-JENTOFT et al., 2010; MARZETTI et al., 2013) e sistêmicas (CRUZ-JENTOFT et al., 2010; DALLE; ROSSMEISLOVA; KOPPO, 2017; MARZETTI et al., 2013). Dentre as alterações locais estão a diminuição da área de secção transversa tanto da fibra muscular quanto de todo o grupo muscular, a redução no comprimento do fascículo e o aumento de tecidos gordurosos e não contráteis intramusculares, além de alterações mitocondriais (BARONI et al., 2013; BROCCA et al., 2017; CRUZ-JENTOFT et al., 2010; JANSSEN et al., 2000; LYNCH et al., 1999; NARICI et al., 2003; YOSHIMURA et al., 2017). Já as alterações sistêmicas incluem mudanças nos níveis hormonais e no mecanismo de ativação muscular, presença de estado pró-inflamatório e de nutrição inadequada/má absorção (CRUZ-JENTOFT et al., 2010; DALLE; ROSSMEISLOVA; KOPPO, 2017; STEVENS et al., 2003).

A redução de massa muscular foi classificada inicialmente como "sarcopenia" (MITCHELL et al., 2012). Entretanto, o termo também passou a ser utilizado para nomear a perda de força muscular associada à perda de massa (MITCHELL et al., 2012). Atualmente, existem diferentes definições para o termo e não há um consenso mundial acerca de sua utilização ideal. Há classificações que também consideram a redução de funcionalidade consequente às diminuições de massa e força muscular, que são reconhecidas pelo Instituto de Saúde Nacional Americano (MITCHELL et al., 2012).

Neste documento, a classificação do Grupo de Estudos Europeu sobre Sarcopenia será utilizada, o qual define sarcopenia como uma síndrome caracterizada por perdas progressivas e generalizadas na massa e na força muscular que podem levar a efeitos adversos como incapacidade física, baixa qualidade de vida e morte (CRUZ-JENTOFT et al., 2010). Revisões sistemáticas recentes encontraram prevalências de até 17% e 33% de sarcopenia na população idosa do Brasil e de países desenvolvidos, respectivamente (CRUZ-JENTOFT et al., 2014; DIZ et al., 2017), dependendo da amostra estudada. Estas prevalências expressivas de sarcopenia associadas à relação direta entre perda de massa e força muscular com diminuição da funcionalidade e da longevidade (CRUZ-JENTOFT et al., 2010; EVANS; CAMPBELL, 1993; SRIKANTHAN; KARLAMANGLA, 2014), tornam intervenções que objetivem o aumento/a manutenção do sistema muscular de idosos ainda mais importantes (CRUZ-JENTOFT et al., 2014; EVANS; CAMPBELL, 1993).

2.2 TREINAMENTO DE FORÇA

O treinamento de força é uma modalidade de exercício que se popularizou nas últimas décadas devido à sua capacidade de aumento no desempenho físico (KRAEMER; RATAMESS, 2004). Esta melhora ocorre através do aumento de força, potência e massa muscular, assim como do desempenho muscular local, do controle motor, do equilíbrio e da coordenação (KRAEMER; RATAMESS, 2004). Inicialmente, o treinamento de força era realizado somente por pessoas que buscavam ganho de força e massa muscular, como fisiculturistas (KRAEMER; RATAMESS, 2004). Entretanto, a partir de década de 1990, após uma melhor compreensão dos seus benefícios para a saúde, houve sua popularização e recomendação para a maioria das populações, incluindo a idosa (FIATARONE et al., 1994; KRAEMER; RATAMESS, 2004).

Apesar de não impedir o envelhecimento, o treinamento de força possui um grande potencial de minimizar os seus efeitos sobre o organismo humano (BORDE; HORTOBAGYI; GRANACHER, 2015). Diferentes revisões sistemáticas já foram realizadas e evidenciaram aumentos de força muscular em idosos saudáveis (BORDE; HORTOBAGYI; GRANACHER, 2015; CSAPO; ALEGRE, 2016), sarcopênicos (YOSHIMURA et al., 2017) e frágeis (LOPEZ et al., 2017). Os resultados reportados na literatura diferem muito em relação aos ganhos de força máxima em idosos saudáveis, variando entre 20-60% em estudos com diferentes amostras e metodologias (CADORE et al., 2010, 2012, 2013; CORREA et al., 2013; CSAPO; ALEGRE, 2016; FERRARI et al., 2013; LIXANDRÃO et al., 2016; TIGGEMANN et al., 2016; VAN ROIE et al., 2013). O fortalecimento se deve, em parte, às adaptações de ordem neuromuscular, em especial à capacidade de ativação muscular (HÄKKINEN et al., 2000). Já do ponto de vista das adaptações estruturais, o treinamento de força gera aumento na área de secção transversa e na espessura muscular, os quais variam em torno de 1,5% a 15% (BORDE; HORTOBAGYI; GRANACHER, 2015; CSAPO; ALEGRE, 2016; STEWART; SAUNDERS; GREIG, 2014).

O treinamento de força também incrementa a funcionalidade da população idosa (TIGGEMANN et al., 2016; VAN ROIE et al., 2013). Apesar de o treinamento de força não envolver atividades funcionais, ele tem gerado melhoras em torno de 5-20% em testes funcionais como o “Timed up-and-go” e o “Teste de Sentar e Levantar” (TIGGEMANN et al., 2016; VAN ROIE et al., 2013). Estas melhoras em tarefas motoras consideradas mais próximas das demandas diárias do indivíduo representam a transferência dos ganhos obtidos com o treinamento (ISSURIN, 2013). Ou seja, o treinamento de força consegue melhorar a capacidade funcional de idosos sem exercitar estas atividades na rotina de treinos. Entretanto, é importante salientar que a periodização do treinamento (frequência, duração, volume, etc.) e as características individuais (idade, sexo, nível de atividade física) interferem diretamente na magnitude de todas as adaptações ao treinamento de força (BORDE; HORTOBAGYI; GRANACHER, 2015; BROCCA et al., 2017).

Devido à relação da força e da massa muscular com a longevidade de idosos (EVANS; CAMPBELL, 1993; SRIKANTHAN; KARLAMANGLA, 2014) , diferentes estratégias vem sendo investigadas de modo associado ao treinamento a fim de maximizar estas melhoras (MALAFARINA et al., 2013; TOMA et al., 2016). Contudo, estudos investigando os efeitos de suplementos alimentares (CHALÉ et al., 2013; MALAFARINA et al., 2013; TIELAND et al., 2012) e reposições hormonais (HILDRETH et al., 2013; KENNY et al., 2010) associados a diferentes modalidades de exercícios em idosos tem encontrado efeitos contraditórios. Desta forma, faz-se necessária a investigação de diferentes modalidades terapêuticas para a otimização das adaptações neuromusculares associadas ao treinamento em idosos.

2.3 TERAPIA DE FOTOBIOMODULAÇÃO

“Terapia de fotobiomodulação” é o termo mais atual e abrangente para descrever a terapia até então conhecida como “fototerapia”, a qual envolve as intervenções com energia proveniente de fontes luminosas com objetivos terapêuticos (ANDERS; LANZAFAME; ARANY, 2015). As formas mais comuns de fotobiomodulação são as que utilizam LASER (Light Amplification by Stimulated Emission of Radiation) e LED (Light Emitting Diode) como fontes luminosas (ANDERS; LANZAFAME; ARANY, 2015). A ação da fotobiomodulação ocorre através da absorção da energia luminosa por cromóforos específicos na mitocôndria gerando uma série de reações que levam a aumentos da produção do ATP, do consumo de oxigênio, de síntese proteica e do metabolismo celular (FERRARESI et al., 2015a; HUANG et al., 2011; KARU, 2010). Ao longo dos anos, inúmeros trabalhos têm relatado o efeito da fotobiomodulação na cicatrização de feridas cutâneas (AL-WATBAN; ZHANG; ANDRES, 2007; MINATEL et al., 2009), na regeneração de tecidos tendinosos (ENWEMEKA; REDDY, [s.d.]; OLIVEIRA et al., 2009), musculares (CRESSONI et al., 2008) e nervosos (ROCHKIND, 2009); além de sua ação analgésica (BJORDAL et al., 2007; CHOW et al., 2009) e anti-inflamatória (LOPES-MARTINS et al., 2005; YAMAURA et al., 2009). Mais recentemente, uma inovadora área de atuação desta terapia vem recebendo atenção da comunidade científica: a relação da fotobiomodulação com o processo de contração muscular.

Lopes-Martins et al. (2006) foram os primeiros a demonstrar que a aplicação da fotobiomodulação em músculos isolados de ratos previamente a um protocolo de repetidas contrações musculares estimuladas eletricamente era capaz de amenizar o processo de fadiga e incrementar o desempenho do músculo ao longo do protocolo (LOPES-MARTINS et al., 2006). Estes achados foram sustentados por estudos posteriores em modelo animal com diferentes protocolos (FERRARESI et al., 2015b, 2015c; LEAL JUNIOR et al., 2010a). Já em seres humanos, Leal Junior et al. (2008) foram os primeiros a demonstrar a melhora do desempenho físico por meio da fotobiomodulação. Atletas de voleibol conseguiram realizar um maior número de repetições quando tiveram seus músculos flexores de cotovelo irradiados com terapia ativa em comparação à placebo previamente a um protocolo de exercício até a exaustão (LEAL JUNIOR et al., 2008). Resultados positivos também foram verificados em estudos subsequentes com este mesmo modelo experimental (LEAL JUNIOR et al., 2009a, 2009b, 2010b), assim como em estudos envolvendo exercício isométrico (DE ALMEIDA et al., 2012), exercício isocinético (BARONI et al., 2010a), exercício em esteira (DE MARCHI et al., 2012) e em testes de ciclismo (LANFERDINI et al., 2017, 2018).

Somados aos efeitos na performance e na fadiga muscular, estudos demonstraram a atenuação de marcadores de dano muscular induzido por exercício, como dor muscular tardia, queda da capacidade de produção de força e níveis de CK, redução do processo inflamatório e do processo de fadiga com a aplicação da fotobiomodulação (ANTONIALLI et al., 2014; BARONI et al., 2010b; FRITSCH et al., 2016). Este corpo de evidências levou ao desenvolvimento de revisões sobre o tema (BORSA; LARKIN; TRUE, 2013; FERRARESI; HUANG; HAMBLIN, 2016; LEAL-JUNIOR et al., 2015; VANIN et al., 2018), incluindo duas meta-análises (LEAL-JUNIOR et al., 2015; VANIN et al., 2018), as quais concluíram que a fotobiomodulação apresenta evidências promissoras como um agente não-farmacológico capaz de potencializar o desempenho de seres humanos na execução de exercício físico e otimizar o processo de regeneração muscular pós-exercício.

Além dos efeitos agudos da terapia sobre o desempenho físico, redução do processo da fadiga e otimização do processo de recuperação muscular (FERRARESI; HUANG; HAMBLIN, 2016; VANIN et al., 2018), a aplicação crônica da fotobiomodulação associada ao treinamento de força também tem se mostrado eficaz para maximização dos ganhos induzidos pelo treinamento (BARONI et al., 2015; FERRARESI et al., 2011; VANIN et al., 2016). Foi evidenciado que quando aplicada antes (BARONI et al., 2015; VANIN et al., 2016) ou depois (FERRARESI et al., 2011) do treinamento, a fotobiomodulação é capaz de aumentar os ganhos de força (BARONI et al., 2015; FERRARESI et al., 2011; VANIN et al., 2016) e de espessura muscular proporcionados pelo treinamento de força (BARONI et al., 2015; VANIN et al., 2016), conforme Tabela 1. Tal resultado é explicado pelos efeitos terapêuticos já mencionados, como aumento do desempenho muscular, redução da fadiga e aceleração da recuperação pós-exercício (BARONI et al., 2015; FERRARESI et al., 2011; MIRANDA et al., 2016). Entretanto, estes estudos foram realizados com adultos jovens, sendo que o seu efeito em outras populações ainda permanece incerto.

Em vista dos efeitos positivos da fotobiomodulação em adultos jovens (FERRARESI; HUANG; HAMBLIN, 2016; VANIN et al., 2018) e dos efeitos do envelhecimento no sistema musculoesquelético (MITCHELL et al., 2012; NARICI et al., 2003), seria de enorme importância encontrar parâmetros ideais para a aplicação desta terapia em idosos. Contudo, poucos estudos foram realizados com esta população e os efeitos encontrados foram contraditórios (TOMA et al., 2013, 2016; VASSÃO et al., 2016). A aplicação de fotobiomodulação antes de protocolos de fadiga de extensão de joelhos com pesos livres gerou aumento no número de repetições (TOMA et al., 2013), enquanto a sua aplicação prévia a um protocolo de extensão de joelho no dinamômetro isocinético não aumentou o desempenho durante o exercício (VASSÃO et al., 2016). Além disto, o único estudo investigando o efeito da aplicação crônica da terapia em associação ao treinamento de força em idosos não encontrou diferenças em relação ao grupo placebo após o período de treinamento (TOMA et al., 2016). Entretanto, este estudo utilizou um probe simples (“probe caneta”) para a aplicação da terapia em um músculo grande como o quadríceps totalizando uma dose de energia de 56 J (TOMA et al., 2016). Estes parâmetros não estão de acordo com as recomendações da revisão sistemática mais recente para melhores efeitos no desempenho de grandes grupos musculares (VANIN et al., 2018), o que pode ter limitado os resultados do estudo de Toma *et al*. (2016) e ressalta a necessidade de maiores investigações acerca do efeito de parâmetros ideais de fotobiomodulação em idosos.

TABELAS

Tabela 1. Descrição dos estudos avaliando a associação da fotobiomodulação ao treinamento de força

Autores (ano)	Amostra	Protocolo de treinamento	Protocolo de fotobiomodulação	Variáveis analisadas	Resultados
Baroni et al. (2015)	Homens jovens saudáveis (idade 20-35 anos) GC (n = 10) GPT (n = 10) GFT (n = 10)	Treinamento excêntrico isocinético de extensores de joelho, 2x/sem, 8 semanas 1ª-5ª sem: 3 x 10 repetições contrações excêntricas máximas 5ª-8ª sem: 4 x 10 repetições contrações excêntricas máximas	Antes do treinamento Cluster com 5 diodos de laser; Comprimento de onda 810nm; Potência 200mW; Dose por diodo 6 J; Dose por ponto 30 J; 8 pontos de aplicação no quadríceps; Dose total por membro 240 J; Tempo total de aplicação por membro 4 min	Espessura muscular do VL, RF, VM e do quadríceps total (ecografia), PTiso, PTcon e PTexc de extensores de joelhos (dinamometria isocinética)	GFT obteve melhores resultados na hipertrofia total do quadríceps, no PTisom e no PTexc ($p < 0,05$)
Ferraresi et al. (2011)	Homens jovens saudáveis fisicamente ativos (idade 18-28 anos) GC (n = 10) GT (n = 10) GFT (n = 10)	Exercícios de “leg press” e extensão de joelhos,2x/sem, 12 semanas 5 x 10 repetições ou até a falha concêntrica a 80% 1 RM	Após o treinamento Feixe com 6 diodos de laser; Comprimento de onda 808nm; Potência 60mW; Dose por diodo 0,6 J; 7 pontos de aplicação no quadríceps; Dose total por membro 25,2 J Tempo total de aplicação por membro 70 s	Perimetria da coxa, 1 RM “leg press”, 1 RM extensão de joelhos, CVM e PT médio de extensores de joelho do membro dominante (dinamometria isocinética)	GTF obteve maiores ganhos percentuais apenas no 1 RM “leg press” ($p < 0,05$)
Toma et al. (2016)	Mulheres idosas ativas/insuficientemente ativas (idade 60-70 anos) GC (n = 11) GTP (n = 13) GTF (n = 14)	Exercício de extensão de joelhos 2x/sem, 8 semanas 3 x 12 repetições a 60-80% 1RM	Depois do treinamento Sonda com 1 diodo de laser; Comprimento de onda 808nm; Potência 100mW; Dose por diodo 7 J; Dose por ponto 7 J; 8 pontos de aplicação no quadríceps; Dose total por membro 56 J; Tempo total de aplicação por membro ~9,5 min	TC6, trabalho total, PTcon, potência e índice de fadiga de extensores de joelho do membro dominante (dinamometria isocinética), nível de lactato 0, 3, 6 e 30 min depois da avaliação isocinética, IFE (eletromiografia de superfície), 1RM extensão de joelhos	GC, GT e GTF não apresentaram diferenças para o TC6, índice de fadiga e IFE. GTF apresentou melhores resultados que GC mas não que GT para trabalho total, PTcon, potência, nível de lactato em 3 min e 1RM extensão de joelhos.
Vanin et al. (2016)	Homens jovens saudáveis (idade 18-35 anos)	Exerecícios de “leg press” e extensão de joelhos, 2x/sem, 12	Antes e/ou depois do treinamento; Cluster com 12 diodos (4 de laser	1RM “leg press”, 1RM extensão de joelhos, CVM	GFTP aprentou melhores

GFTF (n=12) GFTP (n = 12) GPTF (n = 12) GPTP (n = 12)	semanas 5 x 10 repetições ou até a falha concêntrica a 80% 1RM unilateralmente, para ambos os membros	super-pulsado, 4 de LED vermelho, 4 de LED infravermelho); Comprimentos de ondas de 905nm (laser super-pulsado), 640nm (4 LEDs vermelhos) e 875nm (4 LEDs infravermelhos); Potência 1,25mW, 60mW, 70mW, respectivamente; Dose por diodos 0,07 J, 3,42 J e 3,99 J, respectivamente; Dose por ponto 30 J; 6 pontos de aplicação no quadríceps; Dose total por membro 180 J; Tempo total de aplicação 228 s (todos pontos tratados simultaneamente)	(dinamometria isocinética) e perimetria de extensores de joelho bilateralmente	incrementos que os demais grupos para 1RM “leg press”, 1RM extensão de joelhos e CVM para ambos os membros ($p < 0$,0FT. O GPTP apresentou pior incremento de 1RM “leg press” do membro esquerdo que os demais grupos ($p < 0,05$). Não houveram diferenças entre grupos para perimetria ($p > 0,05$).

Legenda: 1RM: 1 Repetição Máxima; CVM: Contração Voluntária Máxima; GC: Grupo Controle; GFT: Grupo Fotobiomodulação + Treinamento; GPT: Grupo Placebo + Fotobiomodulação; GT: Grupo Treinamento; GTF: Grupo Treinamento + Fotobiomodulação; GTP: Grupo Treinamento + Placebo; GFTF: Grupo Fotobiomodulação + Treinamento + Fotobiomodulação; GFTP: Grupo Fotobiomodulação + Treinamento + Placebo; GPTF: Grupo Placebo + Treinamento + Fotobiomodulação; GPTP: Grupo Placebo + Treinamento + Placebo; J: Joules; IFE: Índice de Fadiga por Eletromiografia; PT: Pico de Torque; PTcon: Pico de Torque concêntrico; PTexc: Pico de Torque excêntrico; PTiso: Pico de Torque isométrico

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4 ARTIGO

EFFECTS OF PHOTOBIOMODULATION THERAPY ASSOCIATED TO RESISTANCE TRAINING IN ELDERLY MEN: A RANDOMIZED DOUBLE-BLINDED PLACEBO-CONTROLLED TRIAL

(A ser submetido ao periódico European Journal of Applied Physiology)

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AKNOWLEDGEMENTS

The authors want to thank CAPES and CNPq for the scholarships provided.

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The authors declare that no funding was received for the development of the study.

ABSTRACT

Purpose: The purpose of this study was to investigate the effects of photobiomodulation therapy (PBMT) combined to resistance training on knee extensor muscle mass, strength and functional capacity in elderly men. Methods: In this randomized double-blinded placebo-controlled trial, healthy elderly men (age 60-80 years) completed 12 weeks of resistance training (2x/week) with application of placebo (n = 13) or active PBMT (n = 11) on quadriceps muscles (850 nm, 30 J per point, 8 points per limb) before each training session. Leg press and knee extension one-repetition maximum (1RM) tests, isometric and concentric peak torques, rectus femoris (RF) and vastus lateralis (VL) muscle thickness, timed-up-and-go (TUG) and chair rise to standing (CRS) tests were performed before and after the intervention period. Results: There were significant improvements in all outcomes for both groups ($p < 0.05$), except for RF muscle thickness for the placebo group ($p = 0.09$). Large effect sizes (ES > 0.8) were observed for leg press and leg extension 1RM and CRS tests for both groups, as well as for TUG test for PBMT group. Isokinetic peak torque for both groups and TUG for placebo group had moderate increases (ES > 0.5). Muscle thicknesses and isometric peak torque had small increases (ES > 0.2) in both groups. Magnitude-based inference analysis did not support any advantages for using PBMT compared to placebo. Conclusion: Differently than previously evidenced in young subjects, PBMT with the parameters used in this study did not provide any additional benefits in comparison to placebo application on muscle mass, strength and functional capacity of healthy elderly men engaged in a resistance-training program.

Keywords: phototherapy, low-level laser therapy, strength training, older.

List of abbreviations:

1-RM	One-repetition maximum
ATP	Adenosine triphosphate
CRS	Chair rise to standing
ICC	Intraclass correlation coefficient
J	Joules
PBMT	Photobiomodulation therapy
RF	Rectus femoris
TUG	Timed up-and-go
VL	Vastus lateralis

INTRODUCTION

It is well known that elderly individuals present multifactorial declines in physiological functions of all body systems, including the musculoskeletal system (ALI; GARCIA, 2014). The ageing process is associated with decreases in the muscle quantity and quality, as well as in the neural factors related to muscle strength and power output; consequently, older people present reduced muscle strength and limited functional capacity (MITCHELL et al., 2012). Sarcopenia (i.e., the age-related phenomenon characterised by progressive loss of muscle mass and strength) has been found in up to 33% of adults with 50 years old or older living in the community (CRUZ-JENTOFT et al., 2014), and is considered a key component of frailty syndrome (i.e., a state of dramatic response to a stimulus, leading to change in health status) (CLEGG et al., 2013). Because of the relationship between muscle mass and strength with elderly longevity (MITCHELL et al., 2012), maintaining and/or improving muscle mass and strength of older people has become a major health concern in the last decades (CRUZ-JENTOFT et al., 2014; MITCHELL et al., 2012).

Resistance training has been proved to counteract at least part of the ageing process (CSAPO; ALEGRE, 2016). Conditioning status of knee extensors is considered a factor for physical function of older subjects (MITCHELL et al., 2012), and resistance training programs in that population have been proven effective for increasing thickness and maximal strength by around 40% and 10%, respectively (CSAPO; ALEGRE, 2016). That localized changes on muscle structure and strength lead to significant improvements on the elderly’s systemic functional capacity, such those measured through tests involving functional motor tasks (i.e.,stair climb test, chair rise to standing test, 6 Minute Walk Test) (RAYMOND et al., 2013). Therefore, increasing attention has been devoted to strategies that are potentially capable of maximizing the adaptations promoted by resistance training in the elderly (MALAFARINA et al., 2013; MITCHELL et al., 2012), such as nutritional supplementation (MALAFARINA et al., 2013) and hormonal reposition (HILDRETH et al., 2013). However, there is no consensus about safety and effectiveness of these approaches to enhance the muscular response to resistance training in elderly (MITCHELL et al., 2012).

Photobiomodulation therapy (PBMT) is an innovative, non-invasive and non-pharmacological ergogenic approach (for a review, see Vanin et al. 2018). The absorption of light energy by specific chromophores at mitochondria lead to a series on intracellular reactions that increase the ATP production and cellular metabolism, among other responses (KARU, 2010). Evidences have supported that PBMT application leads to greater energy availability in high intensity exercise, which may also be related to the integration between aerobic and anaerobic

ATP production (GOREHAM et al., 1999). Consequently, these effects are believed to be related to the increase in exercise performance and the improve post-exercise recovery (FERRARESI et al., 2011; VANIN et al., 2018). In addition, studies that associated PBMT to resistance training programs have found greater muscle hypertrophy and strengthening compared to resistance training alone or combined to placebo treatment (BARONI et al., 2015; FERRARESI et al., 2011; MIRANDA et al., 2016). However, the positive effects of PBMT have been tested almost only in young and athletic populations. When applied in the older population, contradictory results have been found regarding its acute effects (TOMA et al., 2013; VASSÃO et al., 2016), and the single study that investigated the chronic effect of PBMT associated to resistance training in elderly found no advantages compared to resistance training alone (TOMA et al., 2016). Nevertheless, TOMA *et al.*,(2016) used a single probe instead a cluster probe to treat the whole quadriceps muscle, and their total energy dose of 56 J is below the suggestions of the most recent systematic review for treating large musclular groups (i.e., 60-300 J) (VANIN et al., 2018). PBMT has a typical biphasic dose-response effect, and optimal treatment parameters are specific to the therapy's aim, the target tissue, and the subject/tissue status (HUANG et al., 2011). Thus, further investigations are needed to elucidate whether PBMT may maximize resistance training adaptations in elderly.

The objective of the present study was to investigate the effect of PBMT combined to resistance training on knee extensor muscle mass, strength and functional capacity of healthy elderly men. Our hypothesis was that applying PBMT before each resistance training session with proven effective parameters (BARONI et al., 2015) volunteers would have a greater exercise performance during the training session and an optimized post-exercise recovery (Vanin et al. 2018), leading to faster increments in training load and to greater mechanical work in comparison to volunteers treated with placebo, what could maximize training-induced adaptations (CSAPO; ALEGRE, 2016; RAYMOND et al., 2013).

METHODS

Study design

This study was a randomized double-blinded placebo-controlled trial. Volunteers were engaged in a 12-week resistance training program. Placebo or PBMT treatments were applied to their quadriceps muscles before each training session, according to the groups' allocation. Knee extensors ultrasonography, isokinetic dynamometry, one-repetition maximum (1RM) tests, and functional capacity tests were performed before and after the resistance training program. This study was approved by the Ethics Committee of the Federal University of

Health Sciences of Porto Alegre (Porto Alegre, Brazil), prospectively registered at ClinicalTrials.gov (NCT03287284) and conducted according with the 1964 Helsinki declaration and its later amendments. All subjects were informed on the procedures, benefits and risks prior to signing an informed consent document to participate in the study. There were no changes in the methods after trial commencement.

Volunteers

Individuals were recruited to participate in the study through newspaper and social media advertisement. During the first visit, all volunteers were informed about the study procedures and performed a health screening. To be included in the study participants had to be 60 to 80 years old, have no cardiovascular, neurological or musculoskeletal restrictions to resistance training; and, be at least three months without performing any systematic, regular resistance training. Participants had also to present a recent exercise electrocardiogram test reviewed by a cardiologist evidencing their capacity to perform physical exercises. If they did not present one, they were indicated to consult with the cardiologist of the university. Participants were excluded if they presented difficulties in understanding or performing tests and training exercises.

Sample size calculation

Sample size was calculated using the G*Power software (version 3.1.9.2) based on previous trials (CADORE et al., 2013; VAN ROIE et al., 2013) that determined that a sample of n = 9 participants would provide a statistical power over 0.90. The outcomes used to calculate the sample size were leg press and leg extension 1RM, as well as rectus femoris muscle thickness.

Randomization and blinding

As shown in Figure 1, 40 men volunteered for the study. Thirty-one volunteers met the inclusion/exclusion criteria and were allocated into the two experimental groups through an on-line computer randomization program: Placebo Group (n=16) and PBMT Group (n=15). There were 7 drop outs during the training period, as shown in Figure 1. Therefore, 24 volunteers completed the study schedule and were included in the final analyses: Placebo group (n = 13), and PBMT group (n = 11).

Concealment was guaranteed as the researcher who applied the therapy was the only one aware of the randomization, while the researchers who were involved in the training sessions and assessments remained blinded. Because PBMT provoked no thermic or other perceptive effects and PBMT and placebo treatments followed the same application procedures, volunteers were also blinded to their allocation into PBMT or placebo groups.

<<Insert Figure 1 around here>>

Assessment procedures

All assessments were performed twice within three weeks before the start of the training program. Volunteers responded to the International Physical Activity Questionnaire (BENEDETTI et al., 2007) and were familiarized for each test before evaluation sessions, and the test-retest served to assess the reliability of our measures. In addition, the evaluation protocol was divided in two days with a minimum 48-hour interval period: day 1 – ultrasound and isokinetic dynamometry; day 2 – 1RM and functional tests.

Ultrasonography

Muscle thickness of rectus femoris (RF) and vastus lateralis (VL) muscles were measured with the SSD 4000 ultrasound equipment (Aloka Inc., Japan) with a linear-array probe (60 mm; 7.5 MHz). Before each assessment, subjects were required to rest for 10 minutes in the supine position with knees and hips in neutral position. The measurements were performed at midway between the femur lateral condyle and the articular line of the knee at the anterior side of the thigh for RF and at the lateral side of the thigh for the VL from the right lower limb (BARONI et al., 2015). A single experienced examiner performed all ultrasound scans. To ensure that all measurements were performed at the same position, the probe position as well as anatomical and skin references were drawn in a transparent paper which was used on the following evaluations. Three parallel images were taken from both RF and VL. Images were analysed in Image-J software (National Institutes of Health, USA). The superior and inferior muscle aponeurosis were identified and the distance between them was measured at three points of each image (left border, middle and right border). A mean value was calculated for each image and for the three images for each assessment; the last one being used for analysis (BARONI et al., 2015). The method presented high interclass correlation coefficient (ICC): 0.97 for RF thickness and 0.98 for VL thickness.

Isokinetic dynamometry

Subjects were positioned seated according to the manufacturer's recommendations for knee flexion-extension assessment at the Biodex System 3 Pro equipment (Biodex Medical Systems, EUA). They performed a warm-up of two sets of ten submaximal repetitions with a one-minute rest interval between sets of knee flexion-extension movements at angular velocity of $90°s^{-1}$. Thereafter, individuals performed three 5-sec maximal voluntary isometric contractions of knee extensors at 60° of knee flexion (0° = full knee extension). If there was more than 10% difference between tests, a fourth attempt was performed. Next, subjects performed two sets of three repetitions of isokinetic concentric knee flexion-extension movements at angular velocity of $60°^{-1}$ (range of motion = 90°-10°). A two-minute rest was given between each test to minimize possible fatigue effects (BARONI et al., 2015). The dynamometric tests were performed only with the right lower limb and the highest peak torque values obtained during isometric and isokinetic concentric tests were used for statistical analyses. The tests presented ICC values of 0.92 for isometric peak torque and 0.86 for isokinetic concentric peak torque.

1RM tests

Maximal dynamic strength was assessed by the one-repetition maximum test (1RM) on bilateral leg press and knee extension exercises. Subjects walked for 10 minutes on a treadmill and performed the specific movements as warm up before the tests. Each subject's maximal load was determined with no more than five attempts with a 4-minute recovery between tests. A 10-minute recovery was respected between leg press and knee extension tests. Performance time for each contraction (concentric and eccentric) was two seconds, controlled by the researchers using an electronic metronome (CADORE et al., 2013). The movement range of motion was also controlled, so that volunteers had to reach 90 degrees of knee and hip flexion in the 1RM leg press test as well as the maximal knee extension in the 1RM knee extension test. The tests presented had high test-retest reliability (ICC 0.96 for both leg press and leg extension 1 RM).

Functional tests

The Chair Rise to Standing (CRS) test was performed with the individuals seated in a hard-backed chair with a 43 cm height next to the wall with their arms across their chest. They were requested to rise to a full standing position and return to the initial sitting position as fast as possible for five times (MCCARTHY et al., 2004). They performed three attempts with a two-minute interval between them, being the lower value registered for statistical analysis. The test presented ICC value of 0.85.

The Timed up-and-go (TUG) test was performed with individuals seated in the same hard-backed chair with a 43 cm height next to the wall with their hands on their hips. They were requested to rise and walk as fast as possible without running until a cone positioned three meters away and return to the initial sitting position. Timing started with the command 'go' and ended when subjects touched their back on the back of the chair (PODSIADLO; RICHARDSON, 1991). Each individual performed three attempts with a two-minute interval and the lowest value was recorded for statistical analysis. The ICC of the test was 0.88.

Intervention procedures

Photobiomodulation Therapy (PBMT) / Placebo

Before each training session, PBMT/placebo were applied on both lower limbs. Treatments were delivered with a cluster probe composed by five 850 nm laser diodes, each one with a 100mW power output (Chattanooga Corp., Chattanooga, USA). Eight sites of the quadriceps muscle were defined by palpation and treated: two at vastus lateralis, three at vastus medialis, and three at rectus femoris (Figure 2). Each site was treated for 60s, leading to a dose of 6 J per diode, 30 J per site, and 240 J per leg (BARONI et al., 2015). The probe was held stationary in skin contact at 90° angle with light skin pressure. Placebo was applied on the same way, but with the device turned off. Subjects were in the supine position, blindfolded and with headphones listening to music of their own choice to prevent clues about the active or placebo application. As soon as the application was finished, they were instructed to start their training session.

<< Insert Figure 2 around here >>

Resistance Training

After the 10-minutes warm up on a treadmill, individuals started the resistance exercises. We standardized leg press and knee extension exercises as the first and the second exercises, respectively, for all volunteers in every training session to ensure a similar interval between the end of the PBMT/placebo application and the beginning of the goal exercises. After that, individuals performed other five exercises (seated supine, seated row, leg curl, abdominal curl and back extension exercises) so that they had a complete resistance training program. The periodization was performed as previously described (CADORE et al., 2013). Subjects performed two sets of 18–20 repetitions maximum (RM) during weeks 1 and 2, progressing to two sets of 15–17 RM at weeks 3 and 4, two sets of 12-14 RM in weeks 5-7, three sets of 8-10 RM in weeks 8-10 and finalizing with three sets of 6-8 RM in weeks 11 and 12. The recovery time between sets was of 90-120 seconds (CADORE et al., 2013). All sets were performed until failure and the workload was constantly adjusted to keep the number of repetitions within the established interval. The load and number of repetitions performed in each exercise were recorded so that instructors could control the training of each participant and their workload. These data were used to calculate mean workload applied in each mesocycle (Figure 3). The intervention was realized twice weekly for 12 weeks, leading to a total of 24 training sessions. The sessions were always performed on Mondays and Wednesdays afternoon with the supervision of one experienced instructor for each volunteer to ensure that exercises were performed correctly, within the interval of repetitions desired and until failure. It was established that if a volunteer missed one session, he could recover it on the following Friday. So, all the individuals completed all the training sessions.

Statistical analyses

Within-group analysis to verify training effects were performed with the following calculations: percent change (Δ% = post-training/pre-training-1); paired sample t-test, with a significance level set as 5% (α <0,05); effect size (ES) through the Cohen's d [ES = $(M_{post} - M_{pre})/SD_{pooled}$, where M_{post} is the mean post-training measure, M_{pre} is the mean pre-training measure, and SD_{pooled} is the pooled standard deviation of the pre- and post-measurement], and training effects were considered as "trivial" (ES<0.2), "small" (ES>0.2), "moderate" (ES>0.5) or "large" (ES>0.8) (COHEN, 1977).

Longitudinal percent changes (pre- to post-training) were used for between-group analysis. Data were analysed for practical significance using magnitude-based inferences because traditional statistical approaches often do not indicate the magnitude of an effect, which is typically more relevant to sports medicine than statistical significance (HOPKINS et al., 2009). The chances of a possible substantial effect favourable to Placebo or PBMT groups were calculated [i.e., greater that the smallest worthwhile change (0.2 multiplied by the between-subject standard deviation)]. Quantitative chances of trivial effects and substantial effects for each group were assessed qualitatively as follows: <1%, almost certainly not; 1-5%, very unlikely; 5-25%, unlikely; 25-75% = possibly; 75-95% = likely; 95-99% = very likely; >99% = almost certain (BATTERHAM; HOPKINS, 2006). When the Placebo and PBMT values were both >5 %, the inference was classified as unclear (BATTERHAM; HOPKINS, 2006).

RESULTS

There were no differences ($p > 0.05$) between groups for age (Placebo 66.67±5.84; PBMT 68.93±7.47); height (Placebo 1.71±0.05; PBMT 1.74±0.06); weight (Placebo 76.64±8.82; PBMT 80.81±12.24) and body mass index (Placebo 26.25±2.82; PBMT 26.78±4.13). Moreover, the physical activity level of the individuals was also similar between groups: 75.0% from the Placebo and 66.7% from the PBMT were active, 12.5% from Placebo and 20.0% of the PBMT were sedentary and 12.5% from the Placebo and 13.3% from the PBMT were irregularly active.

There were no differences between the relative training load between groups across the training period and both groups showed similar pattern of mean load increases ($p > 0.05$) (Figure 3).

<< Insert Figure 3 around here >>

Table 1 shows the within-group analysis. The training programs increased VL muscle thickness in both groups with a small effect size, while RF muscle thickness achieved only trivial effect sizes. Both groups presented small and moderate effect sizes for isometric and concentric peak torques, respectively. Leg press 1RM, knee extension 1RM and the CRS had large effect sizes. TUG improved with a small effect size in Placebo group and a moderate effect size in PBMT group.

<< Insert Table 1 around here >>

Figure 4 presents the between-group analysis. Unclear nuclear differences were found for all outcomes, which support similar adaptations to resistance training in Placebo and PBMT groups for knee extensor muscle thickness, strength and functional capacity.

<< Insert Figure 4 around here >>

DISCUSSION

As expected, independently of PBMT or placebo therapy, resistance training increased knee extensor thickness, maximal strength and functional capacity of elderly men. The main finding of the current study is that the addition of PBMT prior to resistance training sessions did not add any benefit to resistance training plus placebo therapy in older men, since both training groups showed similar enhancements in all investigated outcomes. This finding means that practitioners should not apply PBMT before resistance training or rehabilitation session in elderly individuals, at least with the parameters utilized in the current study, as it does not provide additional effects on muscle mass, strength and physical function.

Resistance training programs are known to increase muscle strength and mass, as well as physical function in older adults (BORDE; HORTOBAGYI; GRANACHER, 2015; CSAPO; ALEGRE, 2016; RAYMOND et al., 2013). However, the training periodization (frequency, duration, volume of training, etc.) and subjects' characteristics (age, sex, physical activity level) interfere directly on the magnitude of the muscular adaptations (BORDE; HORTOBAGYI; GRANACHER, 2015; BROCCA et al., 2017). Comparison between studies should be made with caution and should always concern trials with similar study population and periodization (BORDE; HORTOBAGYI; GRANACHER, 2015; BROCCA et al., 2017). It means that the adaptations magnitude of the current study should not be directly compared to previous studies which associated resistance training and PBMT in young men (BARONI et al., 2015; FERRARESI et al., 2011, 2016; VANIN et al., 2016) and elderly women (TOMA et al., 2016) due to different training periodization, age and/or sex of the participants.

Although only small effect sizes have been observed on VL muscle thickness of both groups in our study, the percent increases (6-7%) are similar to the ones previously reported with the elderly population (CSAPO; ALEGRE, 2016; LIXANDRÃO et al., 2016). A recent systematic review found very modest training-associated gains in muscle thickness and cross sectional area in this population (CSAPO; ALEGRE, 2016). It was argued that the hypertrophic capacity of the elderly may be impaired due to age-related motor unit loss and concomitant accumulation of intramuscular non-contractile tissues (CSAPO; ALEGRE, 2016). However, the limited hypertrophic response seen in elderly in relation to young is controversial, since studies have shown similar increases in muscle mass and strength in response to resistance training in both groups (HÄKKINEN et al., 2000; MAYHEW et al., 2009). Both groups present increments of approximately 10% and a high variability is seen between individuals (KRAEMER et al., 1999), what may limit the effect sizes observed in hypertrophic response.

The current study did not assess neuromuscular adaptations provided by resistance training program, but this is a typical response to resistance training and explains the larger relative increases found in 1 RM tests compared to those observed in muscle thickness (HÄKKINEN et al., 2000). The improvements found in leg press and knee extension 1RM (40% and 23-24%, respectively) are similar to the increases reported by studies which used the same periodization in concurrent trainings in elderly men (CADORE et al., 2012, 2013). Moreover, the increments found in isometric and isokinetic peak torques (6% and 7-10%, respectively) are in agreement with previous studies which also reported increments in isometric (CADORE et al., 2013; VAN ROIE et al., 2013) and isokinetic peak torques (VAN ROIE et al., 2013) in similar population. The smaller gains assessed by isokinetic dynamometry may be due to training specificity; isokinetic exercises were not performed along training program and there is no full transference of training-induced strength gains to that tests (ISSURIN, 2013).

The increments in the CRS and TUG tests (9% and 4-6%, respectively) are in agreement with previous trials analysing the effect of resistance training in functional capacity of elderly (DIAS et al., 2015; TIGGEMANN et al., 2016; VAN ROIE et al., 2013). They represent the training transfer, since the leg press and knee extension exercises led to an improvement in untrained tasks (ISSURIN, 2013). Although the within-group analyses showed different effect sizes for PBMT and placebo groups, suggesting an advantage for the PBMT group, the magnitude-based inference analyses supported the similar adaptations between groups, as well as for all other outcomes. Therefore, the current results further support findings of (TOMA et al., 2016) that there is no evidence of additional effect of adding PBMT to resistance training programs on the functional capacity of elderly.

Studies with young men have demonstrated that PBMT maximizes the strength gain and the hypertrophic response to resistance training (BARONI et al., 2015; FERRARESI et al., 2011; VANIN et al., 2016). Authors have justified the positive effects of PBMT mainly through the acute effects of PBMT, such as reduced muscle fatigue, enhanced exercise performance and optimized post-exercise recovery (BARONI et al., 2015; FERRARESI et al., 2011; VANIN et al., 2016). That resistance training studies and other previous investigations (see Vanin et al. 2018) have supported our initial hypothesis that PBMT group would have enhanced exercise performance during training sessions, leading to higher mechanical work supported by the muscle; as well as better recovery between training sessions, also contributing to a higher performance in the following training day compared to placebo group. Consequently, we expected that PBMT group would have faster increments in training load than placebo group. However, training load progression was similar between PBMT and placebo groups (see Figure 3). These findings refuted our initial hypothesis about how PBMT would act as an ergogenic factor for elderly subjects engaged in a resistance training program.

It is important to note that almost all evidences supporting the ergogenic action of PBMT on human performance were provided by studies with young adults (VANIN et al., 2018). Interestingly, trials involving older subjects have presented inconsistent results. While Toma *et al.* (2013) found an increase in the number of repetitions of knee extension exercise after PBMT application, Vassão *et al.* (2016) found no effect of its prior application on isokinetic exercise performance. At the same time, the only study so far with resistance training associated to PBMT in elderly found no additional benefits of this therapy compared to placebo application (TOMA et al., 2016), which is further supported by our findings. Even though the exercise protocols and the PBMT parameters differed among the trials, it is not clear why PBMT seems to work for young but not for elderly individuals.

It is well known that PBMT acts on mitochondria improving the cytochrome c oxidase activity, the respiratory chain reactions, the ATP production and the cellular metabolism (KARU, 2010). It is also known that elderly people present muscle atrophy independently from being physically active or having a disease (BROCCA et al., 2017). Furthermore, mitochondrial function presents deficits with age and it has been considered as a potential mediator of sarcopenia (CARTER; CHEN; HOOD, 2015). Aged muscles present mitochondria with less organelle content, reduced layer thickness, enzymes (being cytochrome oxidase one of them) and function, including protein synthesis, respiration and ATP production (CARTER; CHEN; HOOD, 2015). Therefore, if there are less enzymes to absorb the light photons, its energy may be lost leading to no clinical effect. Interestingly, PBMT seems to not affect the exercise performance of patients with cardiovascular diseases (BUBLITZ et al., 2016; STEIN et al., 2018), a population that also presents reduced mitochondrial activity and sarcopenia (MARZETTI et al., 2013). However, as the present study did not investigate the mechanism of action of PBMT in the elderly, we do not have data to confirm or refute this hypothesis. We recommend that future studies should investigate the effects of PBMT in young in comparison to elderly to similar exercise protocol and/or training program to elucidate specific responses of each age group to PBMT.

PBMT presents a typical biphasic dose-response effect (HUANG et al., 2011) and there is still no consensus about the ideal parameters to optimize adaptations to resistance training in any population. Therefore, although the parameters used in our study have been proven effective in young people (BARONI et al., 2015), we cannot exclude the possibility that a different dosage may be needed to optimize training responses in older people. In fact, a few studies analysed the dose-response effect of PBMT in young people and found contradictory results (AVER VANIN et al., 2016; DELLAGRANA et al., 2018; LANFERDINI et al., 2018). The application of dosages of 270 J and 300 J were the most effective ones for increasing performance outcomes of recreational runners during running tests (DELLAGRANA et al., 2018) and soccer players during isokinetic tests (AVER VANIN et al., 2016), respectively. However, only the application of 135 J, and not 270 J or 405 J, improved the exercise performance of cycling athletes in incremental cycling tests until exhaustion (LANFERDINI et al., 2018). It remains unclear if the exercise protocol, the sample characteristics and/or the other parameters of the PBMT were responsible for that specifics dose-response effects. Different dosages with different parameters of PBMT need to be tested to provide the best parameters to each population and exercise protocol before conclusions can be drawn.

A limitation of the current study is the lack of investigation on biochemical parameters, what limits the discussion about the mechanisms responsible for the absence of PBMT effect on this population. Moreover, the addition of experimental groups with different parameters of PBMT would have allowed us a broader view on the effects of this treatment in training responses of older men. To the best of our knowledge, there are only a few previous studies that investigated the effects of PBMT in muscular performance of the elderly population (TOMA et al., 2013, 2016; VASSÃO et al., 2016) and only one of them investigated the chronic effects of the therapy (Toma et al. 2016). One positive aspect of the current study is that its design was developed to be similar to the clinical practice and to provide results that could be easily replicated. Moreover, it provided reliable results on muscle strength, mass and physical function. The potential benefit of PBMT to counteract the age-related impairments in the musculoskeletal system and in functional capacity highlights the need for more studies to find how the older can also benefit from the therapy, what has been already shown for the young.

CONCLUSIONS

The current study did not find any additional effect of PBMT with the tested parameters compared to placebo treatment combined to resistance training on knee extensor muscle mass, strength and functional performance of elderly men. Given the potential benefits of PBMT on the fight against sarcopenia and its deleterious effects, as well as the characteristic dose-response effect of PBMT, scientists are encouraged to perform further investigations on that issue.

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Authors' contributions

BB, EC, RP, MV conceived and designed research. CF, MD, JT and LS conducted experiments. CF and BB analyzed data. CF and BB wrote the manuscript. All authors read the manuscript, contributed to its improvement and approved its final version.

Authors declare that there is no professional relationships with companies or manufacturers who will benefit from the results of the present study.

Figure 1. Flowchart of the study

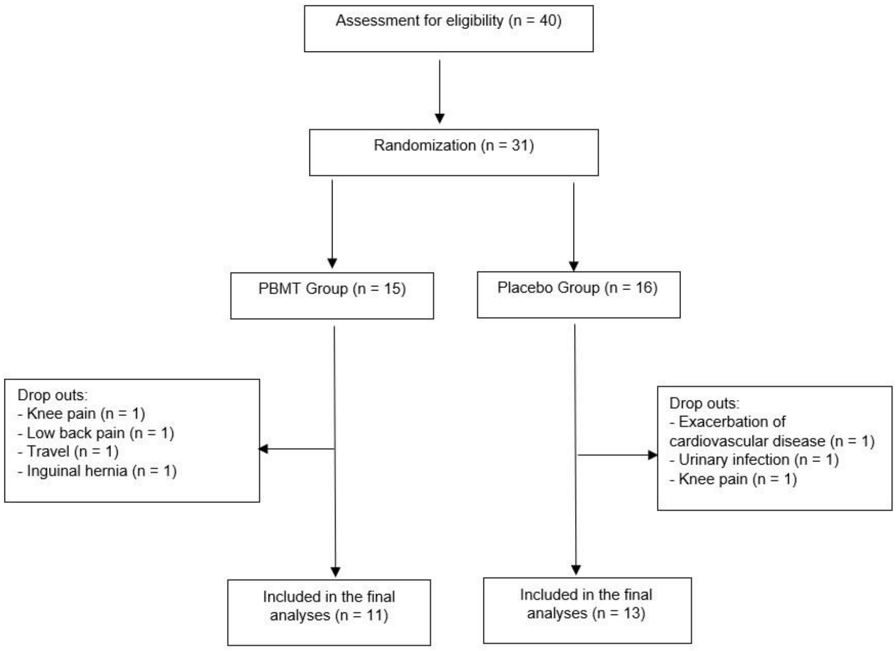


Figure 2. Photobiomodulation therapy (PBMT) parameters

PBMT PARAMETERS	
Number of points (per leg)	8 points
Treatment time (per point)	60 s
Number of diodes used (cluster probe)	5 diodes
Wavelength	850 nm
Frequency	Continuous
Spot size (per diode)	0.029 cm²
Peak power (per diode)	100 mW
Power density (per diode)	3.4 W/cm²
Energy density (per diode)	206.9 J/cm²
Energy (per diode)	6 J
Energy (per point)	30 J
Energy (per leg)	240 J

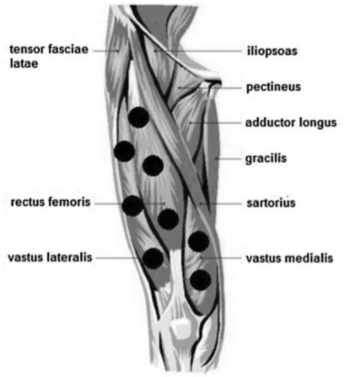
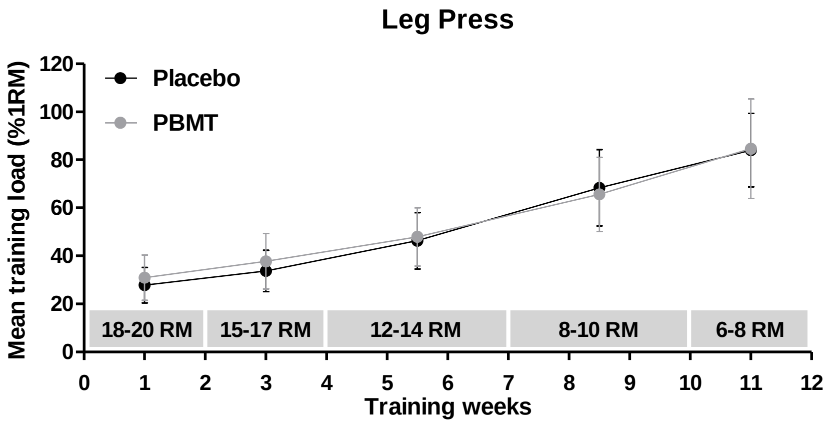


Figure 3. Leg press and leg extension mean training load relative to 1RM test on each mesocycle



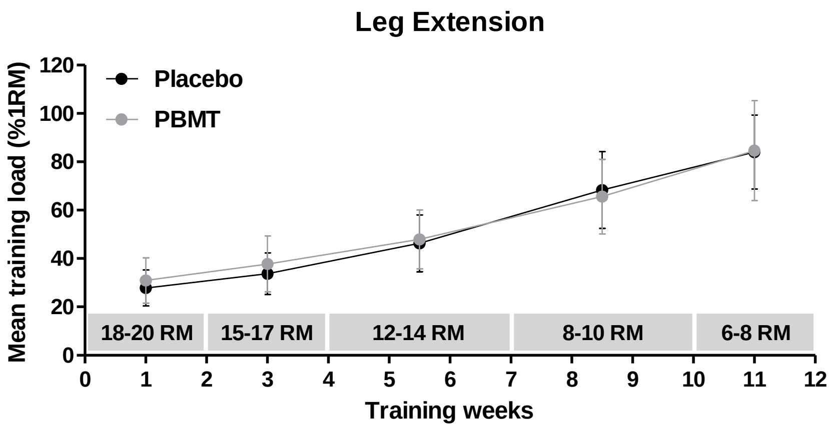


Figure 4. Magnitude-based inferences for between-group analyses

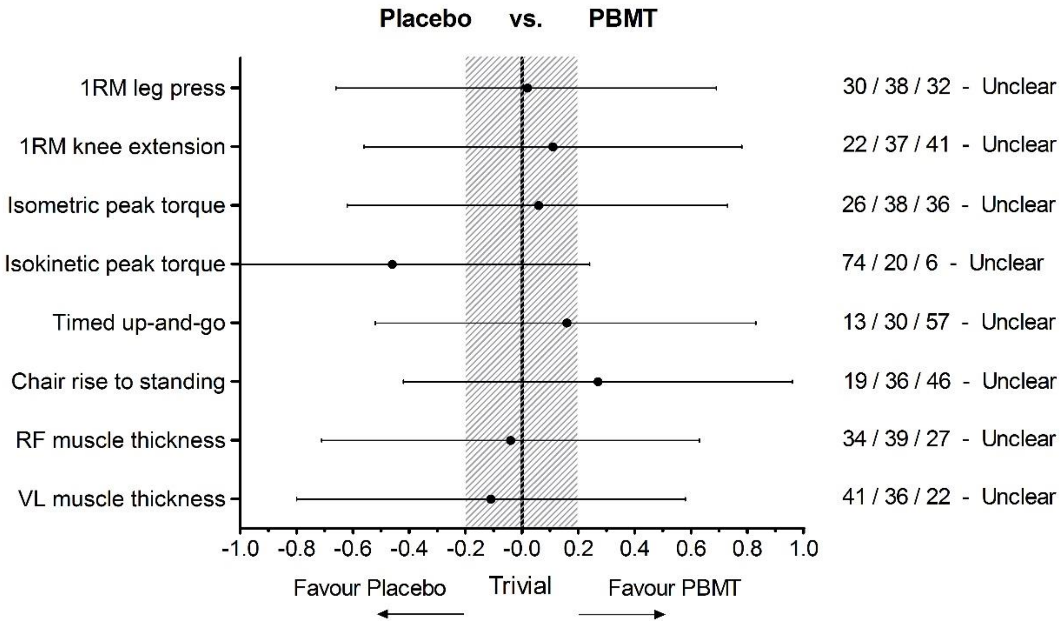


Table 1. Within-group analysis: muscle structure, muscle strength, and functional tests of Placebo and Photobiomodulation therapy (PBMT) groups at pre- and post-training evaluations (mean ± SD).

	Placebo group (n=13)					PBMT group (n=11)				
	Pre	Post	Δ%	p-value	ES	Pre	Post	Δ%	p-value	ES
Muscle structure										
RF muscle thickness (cm)	01.53±00.27	01.58±00.28	02.83±05.35	0.091	0.19	01.54±00.40	01.58±00.43	02.64±03.64	0.030*	0.10
VL muscle thickness (cm)	01.96±00.34	02.10±00.36	07.55±05.91	0.001*	0.41#	02.02±00.28	02.15±00.27	06.74±08.12	0.015*	0.50#
Muscle strength										
Isometric PT (Nm)	191.17±36.66	201.91±37.64	06.22±08.64	0.033*	0.27#	201.43±27.70	214.40±26.87	06.70±05.03	0.011*	0.48#
Concentric PT (Nm)	154.95±27.81	170.45±28.98	10.34±05.19	0.000*	0.57&	168.30±21.62	179.69±19.97	07.14±06.22	0.014*	0.55&
Leg-press 1RM (kg)	241.38±56.43	332.54±55.18	40.00±14.75	0.000*	1.63†	234.18±27.14	326.68±38.69	40.23±12.54	0.000*	2.81†
Knee extension 1RM (kg)	88.69±17.26	108.77±19.50	23.43±12.74	0.000*	1.09†	93.91±18.08	116.82±23.83	24.75±12.54	0.000*	1.11†
Functional tests										
Timed up-and-go (s)	06.38±00.86	05.96±00.88	06.59±05.98	0.001*	0.48#	06.38±00.54	06.04±00.32	04.59±06.39	0.071	0.79&
Chair rise to standing (s)	09.23±01.26	08.29±00.94	09.73±07.50	0.001*	0.85†	09.78±00.60	08.94±00.67	08.57±05.68	0.002*	1.33†

Δ% = mean percent change; ES = effect size; RF = *rectus femoris*; VL = *vastus lateralis*; PT = peak torque; 1RM = one-repetition maximum.
* significant difference ($p<0.05$); # small effect size; & moderate effect size; † large effect size.

5 CONCLUSÃO GERAL

A terapia de fotobiomodulação com os parâmetros estudados neste trabalho não apresenta efeitos adicionais em relação à terapia placebo quando associada ao treinamento de força para ganhos de força e massa muscular de extensores de joelhos e capacidade funcional de idosos. Devido ao potencial desta terapia de combater a sarcopenia e à sua característica bifásica de dose e resposta, a comunidade científica deve ser encorajada a continuar investigando o efeito de diferentes parâmetros de fotobiomodulação sobre a otimização dos ganhos do treinamento de força nesta população.

ANEXOS

ANEXO A – Normas de formatação do periódico European Journal of Applied Physiology

Types of papers

The journal publishes Original Articles, Editorials, Invited Reviews, Letters to the Editor, and Replies.

- **Instructions for Invited Reviews**

The European Journal of Applied Physiology (EJAP) now publishes Invited Reviews only. The journal welcomes topics from physiological mechanics, biochemistry, endocrinology, ergonomics, immunology, motor control, neuroscience and nutrition.

Invitations are issued by the Reviews Editor Michael Lindinger (mi.lindinger@gmail.com) on behalf of EJAP.

Authors wishing to submit proposals for consideration are welcome to contact the Reviews Editor, providing a brief description of the review topic (i.e. title and one-paragraph summary). If a proposal is deemed to be relevant and appropriate after an initial evaluation, authors will receive a formal invitation to write the Review.

- Maximum manuscript size is 15 printed pages (4500-5000 characters/page)

- Colored illustrations highlighting critical concepts are strongly encouraged

- no limitation to number of references

- Abstracts should aim for 150-250 words

- Abstracts should contain the need for the review, primary objectives and logical conclusions

- Abstracts must not contain undefined abbreviations or references

- **Instructions for Letters to the Editor**

In addition to manuscripts, letters or comments discussing an article published in the past six months in EJAP are welcome and may appear in print in one of the following issues. Each comment will be sent to the corresponding author of the discussed article together with an invitation to respond. The comment and the reply may be sent to an independent referee. However, the editor-in-chief will make the final decision whether the correspondence will be published. EJAP allows the original author a deadline of two weeks to reply. If no answer is received within this timeframe, the editor-in-chief will decide if the letter or comment will be published without response. Letters and comments may be edited and shortened for reasons of clarity and space. In order to avoid long disputes, only the original comment together with the author's response will be published. Any additional comments or remarks should be sent to the authors directly and will not further be handled by EJAP.

- Maximum manuscript size is 1000 words

- maximum number of references is 5

- Figures can be added to clarify the written content

- Please include a separate page with a short title, the writer's name, affiliations and the exact citation of the article commented on

Article Requirements

To facilitate rapid publication manuscripts should be prepared carefully in accordance with the following requirements.

The Conflict of interest is mandatory for all articles types.

Special Issues

• Contributions that are part of a Special Issue must include the following footnote on the title page:

"This article is published as part of the Special Issue on [title of the Special Issue]"

Manuscript Submission

Submission of a manuscript implies: that the work described has not been published before; that it is not under consideration for publication anywhere else; that its publication has been approved by all co-authors, if any, as well as by the responsible authorities – tacitly or explicitly – at the institute where the work has been carried out. The publisher will not be held legally responsible should there be any claims for compensation.

Permissions

Authors wishing to include figures, tables, or text passages that have already been published elsewhere are required to obtain permission from the copyright owner(s) for both the print and online format and to include evidence that such permission has been granted when submitting their papers. Any material received without such evidence will be assumed to originate from the authors.

Online Submission

Please follow the hyperlink “Submit online” on the right and upload all of your manuscript files following the instructions given on the screen.

Author Contribution Statement

Authors must provide a short description of the contributions made by each listed author (please use initials). This will be published in a separate section in front of the Acknowledgments.

For example: AM and DB conceived and designed research. AM and BB conducted experiments. GR contributed new reagents or analytical tools. AM and GR analyzed data. AM wrote the manuscript. All authors read and approved the manuscript.

Title Page

The title page should include:

- The name(s) of the author(s)
- A concise and informative title
- The affiliation(s) and address(es) of the author(s)
- The e-mail address, and telephone number(s) of the corresponding author
- If available, the 16-digit ORCID of the author(s)

Abstract

Please provide a structured abstract of 150 to 250 words which should be divided into the following sections:

- Purpose (stating the main purposes and research question)
- Methods
- Results

- Conclusions

Keywords

Please provide 4 to 6 keywords which can be used for indexing purposes.

Abbreviations

Authors are allowed to use abbreviations when appropriate, but these should be used sparingly. Abbreviations should be defined at first mention in the text and supplied as a list, in alphabetical order, to be included after the keywords, e.g.

ANOVA	**Analysis of variance**
EMG	Electromyography
MVC	Maximal voluntary contraction

If there are no abbreviations, state "None" in the Abbreviation list.

Specific remarks on Abstract

The sections should describe briefly and concisely the background and aim/hypothesis of the investigation, the most important methods, the major results and the conclusions drawn. Major results should be presented quantitatively where appropriate, and changes reported must be expected to be statistically significant (e.g. write "endurance time increased from a ± b to c ± d min" and not "endurance time increased (P ‹ 0.01)"). The conclusion should highlight the physiological significance of the study and not be a repetition of the results. The abstract should not contain any undefined abbreviations and references may not be cited.

Text Formatting

Manuscripts should be submitted in Word.

Use a normal, plain font (e.g., 10-point Times Roman) for text.

Use italics for emphasis.

Use the automatic page numbering function to number the pages.

Do not use field functions.

Use tab stops or other commands for indents, not the space bar.

Use the table function, not spreadsheets, to make tables.

Use the equation editor or MathType for equations.

Save your file in docx format (Word 2007 or higher) or doc format (older Word versions).

Manuscripts with mathematical content can also be submitted in LaTeX.

- LaTeX macro package

Headings

Please use no more than three levels of displayed headings.

Result section

The results should describe the experimental findings in a way that it is easy to read. The text should be comprehensible to scientifically interested persons, who are not necessarily specialists in the particular field of the investigation. Thus, the text in the results section should be presented with focus on physiology and the outcome of statistical analyses should generally be limited to those used to test specified hypotheses. We encourage inclusion of complete statistical analyses and full data sets at the individual level, but these should be presented in tables or as Electronic Supplementary Material (ESM).

Figures should, if possible, include original records obtained during the actual experiments, and not simply group-mean responses. For instance, representative original records provide a good indication of the signal-to-noise relation and they can be used to show how measurements were performed. Moreover, the inclusion of original records is an excellent way of illustrating complex differences between groups.

Conclusions section

Authors should provide concise conclusions to their work and are encouraged to put their results into a wider physiological context. The conclusions must not just be a repetition of the results.

Acknowledgments

Acknowledgments of people, grants, funds, etc. should be placed in a separate section on the title page. The names of funding organizations should be written in full.

Scientific style

Please always use internationally accepted signs and symbols for units (SI units).

References

Citation

Cite references in the text by name and year in parentheses. Some examples:

- Negotiation research spans many disciplines (Thompson 1990).
- This result was later contradicted by Becker and Seligman (1996).
- This effect has been widely studied (Abbott 1991; Barakat et al. 1995a, b; Kelso and Smith 1998; Medvec et al. 1999, 2000).

Reference list

The list of references should only include works that are cited in the text and that have been published or accepted for publication. Personal communications and unpublished works should only be mentioned in the text. Do not use footnotes or endnotes as a substitute for a reference list.

Reference list entries should be alphabetized by the last names of the first author of each work. Order multi-author publications of the same first author alphabetically with respect to second, third, etc. author. Publications of exactly the same author(s) must be ordered chronologically.

- Journal article

  Gamelin FX, Baquet G, Berthoin S, Thevenet D, Nourry C, Nottin S, Bosquet L (2009) Effect of high intensity intermittent training on heart rate variability in prepubescent children. Eur J Appl Physiol 105:731-738. https://doi.org/10.1007/s00421-008-0955-8

  Ideally, the names of all authors should be provided, but the usage of “et al” in long author lists will also be accepted:

  Smith J, Jones M Jr, Houghton L et al (1999) Future of health insurance. N Engl J Med 965:325–329

- Article by DOI

  Slifka MK, Whitton JL (2000) Clinical implications of dysregulated cytokine production. J Mol Med. https://doi.org/10.1007/s001090000086
- Book

  South J, Blass B (2001) The future of modern genomics. Blackwell, London
- Book chapter

  Brown B, Aaron M (2001) The politics of nature. In: Smith J (ed) The rise of modern genomics, 3rd edn. Wiley, New York, pp 230-257
- Online document

  Cartwright J (2007) Big stars have weather too. IOP Publishing PhysicsWeb. http://physicsweb.org/articles/news/11/6/16/1. Accessed 26 June 2007
- Dissertation

  Trent JW (1975) Experimental acute renal failure. Dissertation, University of California

Always use the standard abbreviation of a journal's name according to the ISSN List of Title Word Abbreviations, see

- ISSN LTWA

If you are unsure, please use the full journal title.

For authors using EndNote, Springer provides an output style that supports the formatting of in-text citations and reference list.

- EndNote style (zip, 2 kB)

Please note:

The Editors-in-Chief higly disapprove of using dissertations as primary sources.

Tables

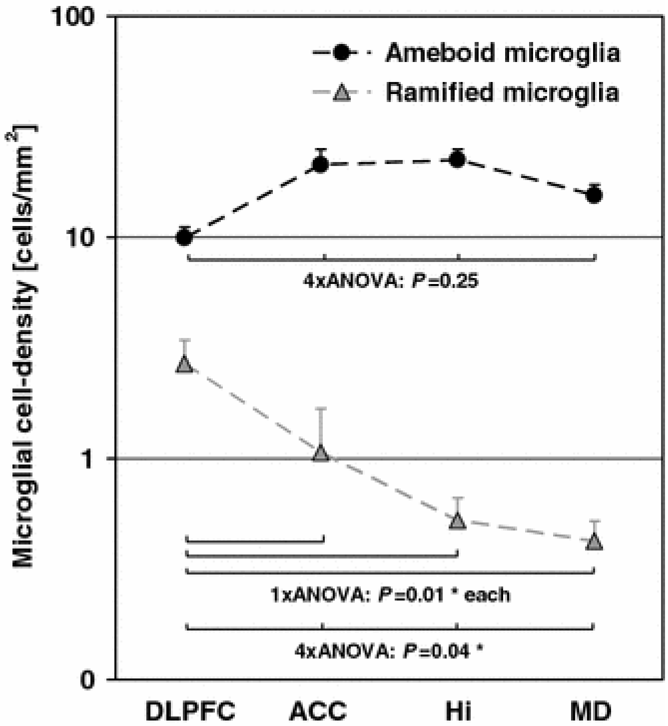
- All tables are to be numbered using Arabic numerals.
- Tables should always be cited in text in consecutive numerical order.
- For each table, please supply a table caption (title) explaining the components of the table.
- Identify any previously published material by giving the original source in the form of a reference at the end of the table caption.
- Footnotes to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data) and included beneath the table body.

Artwork and Illustrations Guidelines

Electronic Figure Submission

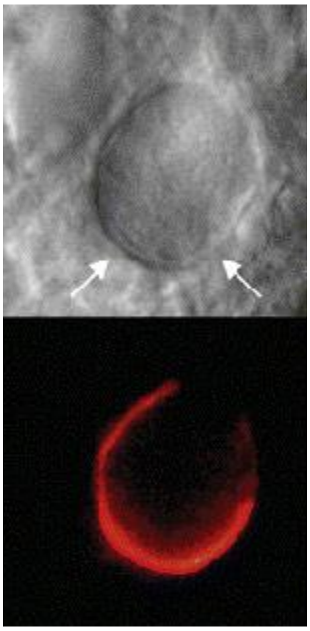
- Supply all figures electronically.
- Indicate what graphics program was used to create the artwork.
- For vector graphics, the preferred format is EPS; for halftones, please use TIFF format. MSOffice files are also acceptable.
- Vector graphics containing fonts must have the fonts embedded in the files.
- Name your figure files with "Fig" and the figure number, e.g., Fig1.eps.

Line Art



- Definition: Black and white graphic with no shading.
- Do not use faint lines and/or lettering and check that all lines and lettering within the figures are legible at final size.
- All lines should be at least 0.1 mm (0.3 pt) wide.
- Scanned line drawings and line drawings in bitmap format should have a minimum resolution of 1200 dpi.
- Vector graphics containing fonts must have the fonts embedded in the files.

Halftone Art

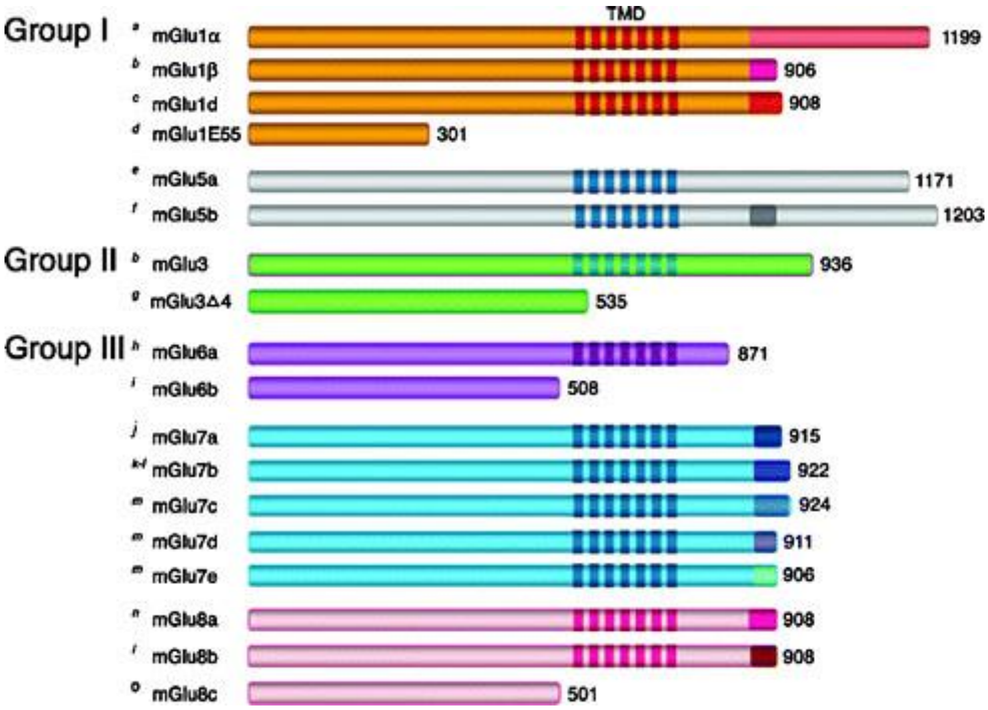


- Definition: Photographs, drawings, or paintings with fine shading, etc.

- If any magnification is used in the photographs, indicate this by using scale bars within the figures themselves.

- Halftones should have a minimum resolution of 300 dpi.

Combination Art



- Definition: a combination of halftone and line art, e.g., halftones containing line drawing, extensive lettering, color diagrams, etc.

- Combination artwork should have a minimum resolution of 600 dpi.

Color Art

- Color art is free of charge for online publication.

- If black and white will be shown in the print version, make sure that the main information will still be visible. Many colors are not distinguishable from one another when converted to black and white. A simple way to check this is to make a xerographic copy to see if the necessary distinctions between the different colors are still apparent.

- If the figures will be printed in black and white, do not refer to color in the captions.

- Color illustrations should be submitted as RGB (8 bits per channel).

Figure Lettering

- To add lettering, it is best to use Helvetica or Arial (sans serif fonts).
- Keep lettering consistently sized throughout your final-sized artwork, usually about 2–3 mm (8–12 pt).
- Variance of type size within an illustration should be minimal, e.g., do not use 8-pt type on an axis and 20-pt type for the axis label.
- Avoid effects such as shading, outline letters, etc.
- Do not include titles or captions within your illustrations.

Figure Numbering

- All figures are to be numbered using Arabic numerals.
- Figures should always be cited in text in consecutive numerical order.
- Figure parts should be denoted by lowercase letters (a, b, c, etc.).
- If an appendix appears in your article and it contains one or more figures, continue the consecutive numbering of the main text. Do not number the appendix figures,

"A1, A2, A3, etc." Figures in online appendices (Electronic Supplementary Material) should, however, be numbered separately.

Figure Captions

- Each figure should have a concise caption describing accurately what the figure depicts. Include the captions in the text file of the manuscript, not in the figure file.
- Figure captions begin with the term Fig. in bold type, followed by the figure number, also in bold type.
- No punctuation is to be included after the number, nor is any punctuation to be placed at the end of the caption.
- Identify all elements found in the figure in the figure caption; and use boxes, circles, etc., as coordinate points in graphs.
- Identify previously published material by giving the original source in the form of a reference citation at the end of the figure caption.

Figure Placement and Size

- Figures should be submitted separately from the text, if possible.
- When preparing your figures, size figures to fit in the column width.
- For most journals the figures should be 39 mm, 84 mm, 129 mm, or 174 mm wide and not higher than 234 mm.
- For books and book-sized journals, the figures should be 80 mm or 122 mm wide and not higher than 198 mm.

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If you include figures that have already been published elsewhere, you must obtain permission from the copyright owner(s) for both the print and online format. Please be aware that some publishers do not grant electronic rights for free and that Springer will not be able to refund any costs that may have occurred to receive these permissions. In such cases, material from other sources should be used.

Accessibility

In order to give people of all abilities and disabilities access to the content of your figures, please make sure that

- All figures have descriptive captions (blind users could then use a text-to-speech software or a text-to-Braille hardware)
- Patterns are used instead of or in addition to colors for conveying information (colorblind users would then be able to distinguish the visual elements)
- Any figure lettering has a contrast ratio of at least 4.5:1

Electronic Supplementary Material

Springer accepts electronic multimedia files (animations, movies, audio, etc.) and other supplementary files to be published online along with an article or a book chapter. This feature can add dimension to the author's article, as certain information cannot be printed or is more convenient in electronic form.

Before submitting research datasets as electronic supplementary material, authors should read the journal's Research data policy. We encourage research data to be archived in data repositories wherever possible.

Submission

- Supply all supplementary material in standard file formats.
- Please include in each file the following information: article title, journal name, author names; affiliation and e-mail address of the corresponding author.
- To accommodate user downloads, please keep in mind that larger-sized files may require very long download times and that some users may experience other problems during downloading.

Audio, Video, and Animations

- Aspect ratio: 16:9 or 4:3
- Maximum file size: 25 GB
- Minimum video duration: 1 sec
- Supported file formats: avi, wmv, mp4, mov, m2p, mp2, mpg, mpeg, flv, mxf, mts, m4v, 3gp

Text and Presentations

- Submit your material in PDF format; .doc or .ppt files are not suitable for long-term viability.
- A collection of figures may also be combined in a PDF file.

Spreadsheets

- Spreadsheets should be submitted as .csv or .xlsx files (MS Excel).

Specialized Formats

- Specialized format such as .pdb (chemical), .wrl (VRML), .nb (Mathematica notebook), and .tex can also be supplied.

Collecting Multiple Files

- It is possible to collect multiple files in a .zip or .gz file.

Numbering

- If supplying any supplementary material, the text must make specific mention of the material as a citation, similar to that of figures and tables.
- Refer to the supplementary files as "Online Resource", e.g., "... as shown in the animation (Online Resource 3)", "... additional data are given in Online Resource 4".
- Name the files consecutively, e.g. "ESM_3.mpg", "ESM_4.pdf".

Captions

- For each supplementary material, please supply a concise caption describing the content of the file.

Processing of supplementary files

- Electronic supplementary material will be published as received from the author without any conversion, editing, or reformatting.

Accessibility

In order to give people of all abilities and disabilities access to the content of your supplementary files, please make sure that

- The manuscript contains a descriptive caption for each supplementary material

- Video files do not contain anything that flashes more than three times per second (so that users prone to seizures caused by such effects are not put at risk)

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This journal is committed to upholding the integrity of the scientific record. As a member of the Committee on Publication Ethics (COPE) the journal will follow the COPE guidelines on how to deal with potential acts of misconduct.

Authors should refrain from misrepresenting research results which could damage the trust in the journal, the professionalism of scientific authorship, and ultimately the entire scientific endeavour. Maintaining integrity of the research and its presentation can be achieved by following the rules of good scientific practice, which include:

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- A single study is not split up into several parts to increase the quantity of submissions and submitted to various journals or to one journal over time (e.g. "salami-publishing").
- No data have been fabricated or manipulated (including images) to support your conclusions
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- Adding and/or deleting authors and/or changing the order of authors **at revision stage** may be justifiably warranted. A letter must accompany the revised manuscript to explain the reason for the change(s) and the contribution role(s) of the added and/or deleted author(s). Further documentation may be required to support your request.

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If there is a suspicion of misconduct, the journal will carry out an investigation following the COPE guidelines. If, after investigation, the allegation seems to raise valid concerns, the accused author will be contacted and given an opportunity to address the issue. If misconduct has been established beyond reasonable doubt, this may result in the Editor-in-Chief's implementation of the following measures, including, but not limited to:

- If the article is still under consideration, it may be rejected and returned to the author.
- If the article has already been published online, depending on the nature and severity of the infraction, either an erratum will be placed with the article or in severe cases complete retraction of the article will occur. The reason must be given in the published erratum or retraction note. Please note that retraction means that the paper is **maintained on the platform**, watermarked "retracted" and explanation for the retraction is provided in a note linked to the watermarked article.
- The author's institution may be informed.

Compliance with Ethical Standards

To ensure objectivity and transparency in research and to ensure that accepted principles of ethical and professional conduct have been followed, authors should include information regarding sources of funding, potential conflicts of interest (financial or non-financial), informed consent if the research involved human participants, and a statement on welfare of animals if the research involved animals.

Authors should include the following statements (if applicable) in a separate section entitled "Compliance with Ethical Standards" when submitting a paper:

- Disclosure of potential conflicts of interest
- Research involving Human Participants and/or Animals
- Informed consent

Please note that standards could vary slightly per journal dependent on their peer review policies (i.e. single or double blind peer review) as well as per journal subject discipline. Before submitting your article check the instructions following this section carefully.

The corresponding author should be prepared to collect documentation of compliance with ethical standards and send if requested during peer review or after publication.

The Editors reserve the right to reject manuscripts that do not comply with the above-mentioned guidelines. The author will be held responsible for false statements or failure to fulfill the above-mentioned guidelines.

Disclosure of potential conflicts of interest

Authors must disclose all relationships or interests that could have direct or potential influence or impart bias on the work. Although an author may not feel there is any conflict, disclosure of relationships and interests provides a more complete and transparent process, leading to an accurate and objective assessment of the work. Awareness of a real or perceived conflicts of interest is a perspective to which the readers are entitled. This is not meant to imply that a financial relationship with an organization that sponsored the research or compensation received for consultancy work is inappropriate. Examples of potential conflicts of interests **that are directly or indirectly related to the research** may include but are not limited to the following:

- Research grants from funding agencies (please give the research funder and the grant number)
- Honoraria for speaking at symposia
- Financial support for attending symposia
- Financial support for educational programs
- Employment or consultation
- Support from a project sponsor
- Position on advisory board or board of directors or other type of management relationships
- Multiple affiliations
- Financial relationships, for example equity ownership or investment interest
- Intellectual property rights (e.g. patents, copyrights and royalties from such rights)
- Holdings of spouse and/or children that may have financial interest in the work

In addition, interests that go beyond financial interests and compensation (non-financial interests) that may be important to readers should be disclosed. These may include but are not limited to personal relationships or competing interests directly or indirectly tied to this research, or professional interests or personal beliefs that may influence your research.
The corresponding author collects the conflict of interest disclosure forms from all authors. In author collaborations where formal agreements for representation allow it, it is sufficient for the corresponding author to sign the disclosure form on behalf of all authors. Examples of forms can be found

- here:

The corresponding author will include a summary statement in the text of the manuscript in a separate section before the reference list, that reflects what is recorded in the potential conflict of interest disclosure form(s).

See below examples of disclosures:

Funding: This study was funded by X (grant number X).

Conflict of Interest: Author A has received research grants from Company A. Author B has received a speaker honorarium from Company X and owns stock in Company Y. Author C is a member of committee Z.

If no conflict exists, the authors should state:

Conflict of Interest: The authors declare that they have no conflict of interest.

Research involving human participants and/or animals

1) Statement of human rights

When reporting studies that involve human participants, authors should include a statement that the studies have been approved by the appropriate institutional and/or national research ethics committee and have been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

If doubt exists whether the research was conducted in accordance with the 1964 Helsinki Declaration or comparable standards, the authors must explain the reasons for their approach, and demonstrate that the independent ethics committee or institutional review board explicitly approved the doubtful aspects of the study.

The following statements should be included in the text before the References section:

Ethical approval: "All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards."

For retrospective studies, please add the following sentence:

"For this type of study formal consent is not required."

2) Statement on the welfare of animals

The welfare of animals used for research must be respected. When reporting experiments on animals, authors should indicate whether the international, national, and/or institutional guidelines for the care and use of animals have been followed, and that the studies have been approved by a research ethics committee at the institution or practice at which the studies were conducted (where such a committee exists).

For studies with animals, the following statement should be included in the text before the References section:

Ethical approval: "All applicable international, national, and/or institutional guidelines for the care and use of animals were followed."

If applicable (where such a committee exists): "All procedures performed in studies involving animals were in accordance with the ethical standards of the institution or practice at which the studies were conducted."

If articles do not contain studies with human participants or animals by any of the authors, please select one of the following statements:

"This article does not contain any studies with human participants performed by any of the authors."

"This article does not contain any studies with animals performed by any of the authors."

"This article does not contain any studies with human participants or animals performed by any of the authors."

Informed consent

All individuals have individual rights that are not to be infringed. Individual participants in studies have, for example, the right to decide what happens to the (identifiable) personal data gathered, to what they have said during a study or an interview, as well as to any photograph that was taken. Hence it is important that all participants gave their informed consent in writing prior to inclusion in the study. Identifying details (names, dates of birth, identity numbers and other information) of the participants that were studied should not be published in written descriptions, photographs, and genetic profiles unless the information is essential for scientific purposes and the participant (or parent or guardian if the participant is incapable) gave written informed consent for publication. Complete anonymity is difficult to achieve in some cases, and informed consent should be obtained if there is any doubt. For example, masking the eye region in photographs of participants is inadequate protection of anonymity. If identifying characteristics are altered to protect anonymity, such as in genetic profiles, authors should provide assurance that alterations do not distort scientific meaning.

The following statement should be included:

Informed consent: "Informed consent was obtained from all individual participants included in the study."

If identifying information about participants is available in the article, the following statement should be included:

"Additional informed consent was obtained from all individual participants for whom identifying information is included in this article."

Research Data Policy

A submission to the journal implies that materials described in the manuscript, including all relevant raw data, will be freely available to any researcher wishing to use them for non-commercial purposes, without breaching participant confidentiality.

The journal strongly encourages that all datasets on which the conclusions of the paper rely should be available to readers. We encourage authors to ensure that their datasets are either deposited in publicly available repositories (where available and appropriate) or presented in the main manuscript or additional supporting files whenever possible. Please see Springer Nature's information on recommended repositories.

- List of Repositories
- Research Data Policy

General repositories - for all types of research data - such as figshare and Dryad may be used where appropriate.

Datasets that are assigned digital object identifiers (DOIs) by a data repository may be cited in the reference list. Data citations should include the minimum information recommended by DataCite: authors, title, publisher (repository name), identifier.

- DataCite

Where a widely established research community expectation for data archiving in public repositories exists, submission to a community-endorsed, public repository is mandatory. Persistent identifiers (such as DOIs and accession numbers) for relevant datasets must be provided in the paper

For the following types of data set, submission to a community-endorsed, public repository is mandatory:

Mandatory deposition	Suitable repositories
Protein sequences	Uniprot
DNA and RNA sequences	Genbank DNA DataBank of Japan (DDBJ) EMBL Nucleotide Sequence Database (ENA)
DNA and RNA sequencing data	NCBI Trace Archive NCBI Sequence Read Archive (SRA)
Genetic polymorphisms	dbSNP dbVar European Variation Archive (EVA)
Linked genotype and phenotype data	dbGAP The European Genome-phenome Archive (EGA)

Macromolecular structure	Worldwide Protein Data Bank (wwPDB) Biological Magnetic Resonance Data Bank (BMRB) Electron Microscopy Data Bank (EMDB)
Microarray data (must be MIAME compliant)	Gene Expression Omnibus (GEO) ArrayExpress
Crystallographic data for small molecules	Cambridge Structural Database

For more information:

- Research Data Policy Frequently Asked Questions

Data availability

The journal encourages authors to provide a statement of Data availability in their article. Data availability statements should include information on where data supporting the results reported in the article can be found, including, where applicable, hyperlinks to publicly archived datasets analysed or generated during the study. Data availability statements can also indicate whether data are available on request from the authors and where no data are available, if appropriate.

Data Availability statements can take one of the following forms (or a combination of more than one if required for multiple datasets):

- 1. The datasets generated during and/or analysed during the current study are available in the [NAME] repository, [PERSISTENT WEB LINK TO DATASETS]
- 2. The datasets generated during and/or analysed during the current study are not publicly available due [REASON WHY DATA ARE NOT PUBLIC] but are available from the corresponding author on reasonable request.
- 3. The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.
- 4. Data sharing not applicable to this article as no datasets were generated or analysed during the current study.
- 5. All data generated or analysed during this study are included in this published article [and its supplementary information files].

More examples of template data availability statements, which include examples of openly available and restricted access datasets, are available:

- Data availability statements

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ANEXO B – Parecer do CEP

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Fototerapia associada ao treinamento de força em idosos: Efeitos sobre a força, massa muscular e capacidade funcional **Pesquisador:** Bruno Manfredini Baroni **Área Temática:**

Versão: 2

CAAE: 59328316.9.0000.5345

Instituição Proponente: Universidade Federal de Ciências da Saúde de Porto Alegre

Patrocinador Principal: Financiamento Próprio

DADOS DO

PARECER

Número do Parecer:

1.783.982

Apresentação do Projeto:

Introdução: A Laserterapia de Baixa Potência (LBP), largamente utilizada na prática clínica de profissionais de fisioterapia, é uma modalidade de fototerapia com um robusto corpo de evidências acerca de seus efeitos analgésicos, anti-inflamatórios e regenerativos. Mais recentemente, a LBP vem sendo estudada com a finalidade de potencializar os efeitos do treinamento de força em indivíduos jovens e saudáveis. Entretanto, a literatura carece de evidências a cerca dos seus efeitos na população idosa, a qual poderá ser amplamente beneficiada devido ao declínio muscular apresentado. Objetivo: Verificar o efeito da fototerapia sobre as adaptações promovidas pelo treinamento de força em indivíduos idosos. Métodos: Este estudo se caracteriza como um ensaio clínico randomizado, duplo-cego e placebo-controlado. Serão incluídos 30 idosos com idades entre 60 e 80 anos, os quais serão randomizados entre Grupo Placebo (LBP placebo + treinamento de força) e Grupo Fototerapia (LBP ativa + treinamento de força). Todos os voluntários serão submetidos a um período controle (sem treinamento) de quatro semanas, seguido por um período de 12 semanas de treinamento de força de membros inferiores. As avaliações serão realizadas em três momentos do estudo: (1) quatro semanas antes de iniciar o período de treinamento (basal); (2) imediatamente antes de iniciar o período de treinamento (pré-treinamento); (3) após o término do período de treinamento (pós-treinamento). As sessões de

treinamento serão realizadas duas vezes por semana e será respeitada uma periodização progressiva pelo método de repetições máximas. A LBP será aplicada previamente às sessões de treinamento em oito pontos dos músculos extensores de
joelho, totalizando uma dosagem de 240 J em cada quadríceps. A aplicação placebo será realizada da mesma forma, mas com o equipamento desligado. As avaliações contemplarão análises de: propriedades estruturais do quadríceps por meio de imagens ultrassonografia; capacidade de produção de força do quadríceps pela dinamometria isocinética; e capacidade funcional dos voluntários através do Teste de subir degraus, Teste de sentar e levantar em uma cadeira, Teste de caminhada de seis minutos e Teste "Timed Up-and-Go".

Objetivo da Pesquisa:

Verificar o efeito da fototerapia sobre as adaptações promovidas pelo treinamento de força em sujeitos idosos.

Avaliação dos Riscos e Benefícios:

Adequados

Comentários e Considerações sobre a Pesquisa:

Sem comentários

Considerações sobre os Termos de apresentação obrigatória:

Adequados

Recomendações:

Sem recomendações

Conclusões ou Pendências e Lista de Inadequações:

Ajustadas a solicitação do CEP.

Considerações Finais a critério do CEP:

Dea acordo com o parecer do Relator.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_753253.pdf	23/09/2016 10:25:36		Aceito
Outros	Carta_resposta_CEP.pdf	23/09/2016 10:25:03	Bruno Manfredini Baroni	Aceito

TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE_round2.pdf	23/09/2016 10:24:37	Bruno Manfredini Baroni	Aceito
Projeto Detalhado / Brochura Investigador	ProjetoCEP_round2.pdf	23/09/2016 10:23:57	Bruno Manfredini Baroni	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	Termo_Anuencia_Lab_UFCSPA.pdf	29/08/2016 22:42:27	Bruno Manfredini Baroni	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	Termo_Anuencia_ESEF_UFRGS.pdf	29/08/2016 22:42:11	Bruno Manfredini Baroni	Aceito
Declaração de Pesquisadores	Termo_Entrega_Relatorio.pdf	29/08/2016 22:41:48	Bruno Manfredini Baroni	Aceito
Folha de Rosto	Folhaderosto.pdf	25/07/2016 21:48:18	Carolina Gassen Fritsch	Aceito

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

PORTO ALEGRE, 20 de Outubro de 2016

Assinado por:
Julia Fernanda Semmelmann Pereira Lima
(Coordenador)

ANEXO C – Termo de Consentimento Livre e Esclarecido

TERMO DE CONSENTIMENTO INFORMADO

____ Dados de Identificação do Participante:

Nome: ....
Identidade: .... Sexo: : .... Data de Nascimento: : .... Endereço: .... Cidade: .... Estado:............... País:...................................... Telefone: .... E-mail: ....

____ Dados de Identificação do Pesquisador Responsável:

Prof. Bruno Manfredini Baroni
Universidade Federal de Ciência da Saúde de Porto Alegre (UFCSPA)
Departamento de Fisioterapia
Rua Sarmento Leite, 245 – Centro Histórico – Porto Alegre, RS. CEP: 90050-170;
Telefone: (51) 3303-8876

____ **Termo de Consentimento Informado:**

Este termo de consentimento, cuja cópia lhe foi entregue, é apenas parte de um processo de consentimento informado de um projeto de pesquisa ao qual você está sendo convidado a participar. Ele deve lhe dar uma ideia básica do que se trata o projeto, e o que sua participação envolverá. Se você quiser mais detalhes sobre algo mencionado aqui, ou informação não incluída aqui, sinta-se livre para solicitar. Por favor, leia atentamente esse termo, a fim de que você tenha entendido plenamente o objetivo desse projeto e o seu envolvimento nesse estudo como sujeito participante. O investigador tem o direito de encerrar o seu envolvimento nesse estudo, caso isso se faça necessário. De igual forma, você pode retirar o seu consentimento em participar no mesmo a qualquer momento.

O objetivo deste estudo é analisar o efeito da aplicação de Laser de Baixa Potência (LBP), um equipamento comumente utilizado na prática clínica de fisioterapia, sobre as adaptações decorrentes de um programa de treinamento de força de membros inferiores (exercício para os músculos da coxa). Todos os voluntários realizarão o mesmo programa de treinamento. A única diferença entre os participantes é que metade receberá aplicação de LBP antes das sessões de treino e a outra metade dos indivíduos receberá placebo (aplicação com o equipamento desligado). Salienta-se que a LBP é uma terapia totalmente segura, de aplicação não-invasiva, que consiste na emissão de uma fonte luminosa de natureza específica sobre a pele do indivíduo. Quando utilizada nas doses apropriadas (como no caso do presente estudo), tal terapia não provoca qualquer dano à pele ou tecidos subjacentes do indivíduo, sendo nulos os riscos de queimaduras, cicatrizes ou outros tipos de alterações estéticas no local das aplicações. Da mesma forma, a aplicação de LBP não causa nenhum tipo de sensação tátil, desconforto ou dor.

O estudo será realizado em dois locais: (1) Laboratório de Fisioterapia da UFCSPA, onde serão realizadas as avaliações; e (2) sala de musculação das ESEFID-UFGFRS, onde serão realizadas as sessões de treinamento. Os pesquisadores informarão como chegar a cada um desses locais.

As avaliações serão realizadas em três momentos: quatro semanas antes de começar o programa de treinamento, na semana anterior ao início do treinamento e na semana seguinte ao término do programa de treinamento. Essas avaliações incluem a massa muscular da região anterior da coxa (avaliada por exame de ultrassom), a capacidade de gerar força da musculatura anterior da coxa e o desempenho do voluntário em testes funcionais que envolvem movimentos do dia-a-dia.

O programa de treinamento terá duração de 12 semanas ininterruptas. As sessões de treino ocorrerão duas vezes por semana e em horários a serem acertados com cada voluntário. Em cada sessão, o participante executará um aquecimento em bicicleta ergométrica, seguido de um protocolo de exercícios para os músculos da coxa em equipamentos de musculação.

É importante destacar que a participação no presente estudo não acarretará despesas aos voluntários. Da mesma forma, não haverá qualquer espécie de remuneração financeira aos mesmos pela participação no estudo. Os benefícios para os participantes que fizerem parte dos grupos LBP e placebo se encontram nos incrementos de força que são esperados com o treinamento, assim como possíveis melhoras da capacidade de realização de tarefas do dia-a-dia que estejam relacionadas à força dos membros inferiores.

Os riscos à saúde dos participantes são mínimos, e consistem principalmente em dor ou desconforto nos músculos treinados nos dias subsequentes à realização das sessões de treino. Em caso de ocorrência de qualquer lesão musculoesquelética (estiramentos musculares, contraturas musculares e inflamações em tendões ou cartilagens) em função do treinamento, os pesquisadores se responsabilizam por fornecer reabilitação fisioterapêutica completa e gratuita nas dependências do Laboratório de Fisioterapia da UFCSPA. O tratamento será realizado por alunos do curso de Fisioterapia da instituição sob a supervisão do pesquisador responsável.

A sua assinatura nesse formulário indica que você entendeu satisfatoriamente a informação relativa à sua participação nesse projeto e você concorda em participar como sujeito. De forma alguma esse consentimento lhe faz renunciar aos seus direitos legais, e nem libera os investigadores, patrocinadores, ou instituições envolvidas de suas responsabilidades pessoais ou profissionais. A sua participação continuada deve ser tão bem informada quanto o seu consentimento inicial, de modo que você deve se sentir à vontade para solicitar esclarecimentos ou novas informações durante a sua participação. Se surgir qualquer dúvida referente a esta pesquisa, favor contatar os pesquisadores nos telefones indicados no início desse termo de consentimento ou o Comitê de Ética em Pesquisa com Seres Humanos da Universidade Federal de Ciências da Saúde de Porto Alegre, localizado na Rua Sarmento Leite, 245 (sala 407 – prédio III), telefone (51) 3303-8804 ou e-mail cep@ufcspa.edu.br, de segunda à sexta-feira, das 8h às 12h e das 13h às 17h.

Porto Alegre, ____ de __________ de 20__.

________________________________ ________________________________

Pesquisador responsável Participante