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Murilo Rezende Oliveira

EFEITOS DA CORRENTE INTERFERENCIAL SOBRE VARIÁVEIS CARDIOVASCULARES EM VOLUNTÁRIOS NORMOTENSOS

Santa Maria, RS
2018

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Dissertação apresentada ao Programa de Pós-Graduação em Reabilitação Funcional, da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para obtenção do título de **Mestre em Reabilitação Funcional**.

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RESUMO

EFEITOS DA CORRENTE INTERFERENCIAL SOBRE VARIÁVEIS CARDIOVASCULARES EM VOLUNTÁRIOS NORMOTENSOS

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ORIENTADOR: Luis Ulisses Signori

O sistema nervoso autônomo (SNA) atua na modulação do sistema cardiovascular e da pressão arterial (PA). Os efeitos da eletroterapia sobre o sistema cardiovascular vêm sendo amplamente estudada. Dentre as correntes de eletroestimulação sensorial, a estimulação elétrica nervosa transcutânea (TENS) tem apresentado resultados favoráveis quando aplicada sobre os gânglios paravertebrais, pois altera o balanço autonômico e, dependendo dos parâmetros de aplicação, reduz a pressão arterial (PA) em voluntários normotensos e hipertensos. Outra forma de estimulação sensorial é a corrente interferencial (CI), mas seus efeitos sobre o sistema cardiovascular foram pouco estudados. Esta corrente elétrica apresenta características especiais, em relação a TENS, pois devido a sua menor impedância, pode gerar efeitos mais profundos nos tecidos, o que poderia apresentar resultados mais pronunciados sobre sistema cardiovascular. O objetivo da presente pesquisa foi avaliar os efeitos da aplicação da CI com diferentes AMF (100Hz e 10Hz) sobre o balanço autonômico e a PA de voluntários saudáveis. Neste sentido, se realizou um ensaio clínico randomizado, duplo cego e crossover. A amostra foi composta por 30 voluntários saudáveis, de ambos os sexos (21 mulheres) com idade média de 23.7±2.7 anos e índice de massa corporal (IMC) de 23,2±2.7 kg/m^2. Os voluntários foram submetidos à intervenção placebo, CI com AMF 100Hz e CI com AMF 10Hz aplicadas na região paravertebral ganglionar por 30 minutos. Todas as intervenções e as avaliações foram realizadas no intervalo de uma semana. O balanço autonômico foi avaliado pela técnica da variabilidade da frequência cardíaca (VFC) e os sinais capturados por frequencímetro (Polar 810i). As medidas de PA foram mensuradas através do monitor multiparamétrico (Dixtal, modelo 2021). As avaliações foram realizadas antes e imediatamente após as intervenções. A pesquisa demostrou que a CI modificou o balanço autonômico, onde a AMF 10Hz diminuiu a atividade simpática e aumentou atividade parassimpática, enquanto que a AMF 100Hz apresentou resultados opostos. A PA não se modificou ao longo do estudo. Esses resultados sugerem que CI com AMF 10Hz apresenta um potencial terapêutico no manejo não farmacológico da hipertensão.

Palavras-chaves: Sistema Nervoso Autônomo. Sistema Nervoso Simpático. Sistema Nervoso Parassimpático. Frequência Cardíaca. Pressão Arterial. Eletroestimulação.

ABSTRACT

EFFECTS OF INTERFERENTIAL CURRENT ON CARDIOVASCULAR VARIABLES IN NORMOTENS VOLUNTEERS

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The autonomic nervous system (ANS) acts on modulation of the cardiovascular system and blood pressure (BP). The effects of electrotherapy on the cardiovascular system have been widely studied. Among the currents of sensorial electrical stimulation, Transcutaneous electrical nerve stimulation (TENS) has presented favorable results when applied to the starred ganglia, since it alters the autonomic balance and depending of the parameters, favoring the reduction of BP in normotensive and hypertensive volunteers. Another form of sensory stimulation is the interferential current (IC), but its effects on the cardiovascular system have been little studied. This electrical current presents special characteristics in relation to TENS, because due to its lower impedance, it can generate deeper effects in the tissues, which could present more pronounced results on cardiovascular system. The aim of the present study is to evaluate the effects of the application of IC with different amplitude-modulated frequency (AMF) (100Hz and 10Hz) on the autonomic balance and BP of healthy volunteers. A randomized, double-blind, crossover clinical trial was performed. The sample consisted of 30 healthy volunteers of both sexes (21 women) with a mean age of 23.7 ± 2.7 years and a body mass index (BMI) of 23.2 ± 2.7 kg/m². The volunteers were submitted to the placebo intervention, IC with AMF 100Hz and CI with AMF 10Hz applied in the paravertebral ganglion region for 30 minutes. All interventions and evaluations were performed with interval of one week. The autonomic balance was evaluated by the technique of heart rate variability (HRV) and the signals captured by frequency meter (Polar 810i). The BP measurements were measured using a multiparameter monitor (Dixtal, model 2021). Evaluations were performed before and immediately after the interventions. The research showed that IC modified the autonomic balance, where AMF 10Hz decreased sympathetic activity and increased parasympathetic activity, while the AMF 100Hz presented opposite results. BP did not change over the course of the study. These results suggest that AMF 10Hz presents a therapeutic potential in the nonpharmacological management of hypertension.

Keywords: Autonomic nervous system. Sympathetic nervous system. Parasympathetic nervous system. Heart Rate. Blood Pressure. Electric Stimulation.

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LISTA DE ABREVIATURAS E SIGLAS

AMF	Amplitude de Modulação da Frequência
CI	Corrente Interferencial
HA	Hipertensão Arterial
HF	*High Frequency*
Hz	Hertz
LF	*Low Frequency*
LF/HF	Razão simpatovaga
PA	Pressão Arterial
PAD	Pressão Arterial Diastólica
PAS	Pressão Arterial Sistólica
SNA	Sistema Nervoso Autônomo
TENS	Estimulação Elétrica Nervosa Transcutânea
UFSM	Universidade federal de santa maria
VFC	Variabilidade da Frequência Cardíaca
VLF	*Very Low Frequency*
WHA	*World Health Association*

SUMÁRIO

1 INTRODUÇÃO

A hipertensão arterial (HA) é o principal fator de risco para doenças cardiovasculares, sendo considerada um grave problema de saúde pública responsável por cerca de 7,1 milhões de mortes ao ano no mundo e 50% das mortes por doença cardiovascular, atingindo 32,5% dos brasileiros adultos e mais de 60% dos idosos (WHA, 2013). A HA é caracterizada como uma doença crônica não transmissível, de causas multifatoriais associada a alterações funcionais, estruturais e metabólicas (MALACHIAS et al., 2016).

O sistema cardiovascular sofre efeitos diretos do sistema nervoso através da ação do sistema nervoso autônomo (SNA). O SNA divide-se em vias simpática e parassimpática, estabelecendo um papel importante na regulação da pressão arterial (PA) e na frequência cardíaca (ERDOGAN et al., 2011). Neste sentido, o desequilíbrio neste sistema, através da maior ativação simpática e a redução da atividade parassimpática, leva a disfunção no balanço autonômico e pode ser considerada um importante fator fisiopatológico no desenvolvimento da HA (MONTANO *et al*., 2009), gerando redução da variabilidade da frequência cardíaca (VFC) (LUCINI *et al*., 2002).

O manejo não farmacológico desta doença é um importante recurso, em especial em pacientes com hipertensão resistente (DUDENBOSTEL et al., 2016) ou refratária (MODOLO et al., 2015) que não evoluem bem com o manejo farmacológico. As principais medidas não medicamentosas são as modificações no estilo de vida, que compreendem as mudanças na dieta alimentar (SALES et al., 2012), a prática de exercícios físicos e/ou atividades físicas (GKALIAGKOUSI; GAVRIILAKI; DOUMA, 2015) e exercícios respiratórios (BERNARDI et al., 2001; HERING et al., 2013).

Dentre os recursos terapêuticos não farmacológicos, a eletroterapia vem se destacando através da aplicação da eletroestimulação sensorial, como a Corrente Interferencial (CI) e a Estimulação Elétrica Nervosa Transcutânea (TENS). A TENS, corrente de baixa frequência (<1000 Hz) (ROBINSON; SNYDER-MACKLER, 2008) mostrou ser capaz de modificar as variáveis cardiovasculares, como a PA e frequência cardíaca, de voluntários saudáveis e pacientes hipertensos (STEIN et al., 2011; TOMASI et al., 2015; VIEIRA et al., 2012; VILELA-MARTIN et al., 2016; WONG; JETTE, 1984). Por outro lado, correntes de média frequência, como a CI, devido à impedância mais baixa da pele, penetram mais profundamente nos tecidos (DOHNERT; BAUER; PAVÃO, 2015; SANTOS et al., 2013), o que poderia apresentar melhores efeitos que a TENS. Entretanto, ainda pouco se sabe os efeitos da CI sobre este sistema em voluntários normotensos e hipertensos (JIN; HWANG; CHO, 2017; NOBLE et al., 2000; SANTOS et al., 2013).

Neste sentido, estudar as alterações da CI sobre o balanço autonômico e a PA, apresentam potencial terapêutico e consequentemente relevância clínica. Este recurso eletroterápico pode ser uma ferramenta não farmacológica coadjuvante no manejo da hipertensão. Diante do exposto, a seguir será apresentado uma revisão de literatura referente ao tema e posteriormente os resultados do ensaio clínico randomizado desenvolvido para avaliar os efeitos da CI com AMF em 100Hz e AMF em 10Hz sobre variáveis cardiovasculares em voluntários saudáveis.

2 REFERENCIAL TEÓRICO

2.1 SISTEMA NERVOSO AUTÔNOMO (SNA)

O sistema nervoso autônomo (SNA) representa uma interface entre o sistema nervoso central (SNC) e o corpo (MONTANO et al., 2009). Este sistema é considerado é o principal mecanismo de defesa endógena projetado para manter a homeostase (SHAFI et al., 2017), atuando na regulação e função do corpo após eventos cotidianos, como as emoções, o estresse físico e mental, o sono, a ansiedade, e as interações sociais (MONTANO et al., 2009).

O SNA cardíaco, mais especificamente, pode ser dividido em componentes extrínsecos e intrínsecos. O componente extrínseco pode ser subdividido em componentes simpáticos e parassimpáticos (SHEN; ZIPES, 2014). As fibras simpáticas formam-se, em sua maioria, dos gânglios autonômicos, localizados ao longo da medula espinhal cervical e torácica. Estes gânglios autonômicos incluem gânglios cervicais superiores, que se comunicam com C1-3; os gânglios estreitos, que se comunicam com C7-8 a T1-2; e os gânglios torácicos. Os corpos celulares dos neurônios simpáticos pós-ganglionares são armazenados nesses gânglios, dos quais os axônios formam nervos cardíacos superiores, médios e inferiores e terminam na superfície do coração (SHEN; ZIPES, 2014).

A ativação da atividade simpática causa a constrição arterial, no qual resulta no aumento da resistência vascular periférica, vasoconstrição, aumentando o retorno venoso ao coração e aumento da frequência cardíaca. Além disso, a ativação desta atividade resulta no aumento da contratilidade cardíaca através de efeitos, como o efeito cronotrópico (regularidade e frequência do ritmo cardíaco), o dromotrópico (velocidade de condução no nódulo atrioventricular) e os efeitos inotrópicos (capacidade de contração da musculatura cardíaca) positivos. O resultado é o aumento da pressão arterial (PA), mediada pela liberação de norepinefrina das terminações nervosas e pelos seus efeitos sobre receptores α adrenérgicos nos vasos sanguíneos e receptores β_1 adrenérgicos no coração (SHAFI et al., 2017).

A inervação parassimpática se origina predominantemente no núcleo ambíguo da medula oblonga. As fibras pré-ganglionares parassimpáticas são localizadas no nervo vago e são divididas em ramos superior, médio e inferior. A maioria das fibras do nervo vago estão entre a veia cava superior e a aorta, no caminho para os túneis atrioventriculares (SHEN; ZIPES, 2014). A ativação da atividade parassimpática provoca resultados opostos da atividade simpática, reduzindo a frequência cardíaca e a contratilidade cardíaca, exercendo seus efeitos nos receptores muscarínicos através dos nervos parassimpáticos, no qual secretam acetilcolina (SHAFI et al., 2017).

Desta forma, o equilíbrio entre as porções simpáticas e parassimpáticas é um importante regulador do sistema cardiovascular e consequentemente da PA de sujeitos normotensos e hipertensos (BRUNO et al., 2011).

Mecanismos do SNA aferente, no sistema cardiovascular, também são explicados por barorreceptores e quimiorreceptores, localizados no Sistema Nervoso Periférico (SNP). Os barorreceptores são localizados no seio carotídeo, acima da bifurcação da artéria carótida e na parede do arco aórtico. Estes receptores se estendem em resposta a aumentos na pressão arterial (PA), transmitindo sinais através do nervo vago (barorreceptores aórticos) e nervo glossofaríngeo (barorreceptores carotídeos) ao núcleo traqueal solitário na região medular do tronco encefálico. A função dos barorreceptores é manter a PA estável, dentro de uma faixa estreita de variação, esteja o indivíduo em repouso ou desenvolvendo diferentes atividades comportamentais, através do aumento na estimulação vagal do coração e inibição da atividade nervosa simpática. Os efeitos dos barorreceptores são a dilatação arteriolar, vasodilatação, bradicardia, diminuição do débito cardíaco e diminuição da PA (SHAFI et al., 2017; SHEN; ZIPES, 2014).

Já os quimiorreceptores estão localizados em pequenos órgãos nos corpos aórticos e carotídeos (na bifurcação da artéria carótida). Esses receptores são sensíveis alto teor de dióxido de carbono (CO_2), aos baixos níveis de oxigênio (O_2), um pH baixo e as mudanças que podem ocorrer na PA. Os sinais desses receptores são transmitidos através do nervo vago para o centro do tronco encefálico. A ativação dos quimiorreceptores é inibido pela ativação dos barorreceptores em situações de aumento da PA e a desativação dos barorreceptores potencializa a resposta ventilatória e vasoconstritora dos quimiorreceptores Assim, os barorreceptores ajudam a manter a PA, enquanto os quimiorreceptores influenciam o controle respiratório, sendo fundamentais para manter a PA (SHAFI et al., 2017).

2.2 BALANÇO AUTONÔMICO

Normalmente, quando a atividade dessas fibras simpáticas e parassimpáticas está em equilíbrio dinâmico, é chamado de balanço autonômico. No entanto, a atividade das duas podem ser moduladas rapidamente em resposta a mudanças ambientais, ocorrendo um desequilíbrio e/ou disfunção autonômica, onde uma das atividades do SNA domina sobre a outra (MCCRATY; SHAFFER, 2015; THAYER; YAMAMOTO; BROSSCHOT, 2010).

Há evidências que sugerem que o desequilíbrio autonômico, em que tipicamente o sistema simpático é hiperativo e o sistema parassimpático é hipoativo, está associado a várias condições patológicas, incluindo doenças cardiovasculares, como arritmias cardíacas, hipertensão arterial (HA), paradas cardíacas e mortalidade (MONTANO et al., 2009; SHIELDS, 2009; THAYER; YAMAMOTO; BROSSCHOT, 2010). Sendo que a HA é caracterizada fisiopatologicamente por uma alteração na regulação do sistema autonômico, indicado pela redução da variabilidade da frequência cardíaca, hiperatividade simpática e a redução da sensibilidade parassimpática (LUCINI et al., 2002). Logo, a correção terapêutica do desequilíbrio autonômico está associada à redução substancial da mortalidade cardiovascular (LA ROVERE et al., 1998; MANCIA et al., 2013).

Portanto, a avaliação do balanço autonômico é considerada de extrema importância na compreensão da fisiopatologia das doenças cardiovasculares. Durante anos, os níveis de catecolaminas de plasma e urinário proporcionaram a única maneira de avaliar a atividade simpática (MONTANO et al., 2009). Entretanto, novas técnicas para avaliação da atividade simpática e parassimpática foram incorporadas ao longo dos tempos, dentre essas a variabilidade da frequência cardíaca (VFC).

2.3 VARIABILIDADE DA FREQUÊNCIA CARDÍACA (VFC)

A avaliação do SNA é considerado de extrema importância na compreensão da fisiopatologia das doenças cardiovasculares (MONTANO et al., 2009). E dentre as técnicas utilizadas para avaliar tal sistema, uma das mais comuns é através da variabilidade da frequência cardíaca (VFC) (TARVAINEN et al., 2014).

VFC está sendo estudada desde 1965, a partir da monitorização do sofrimento fetal, até em 1987, ser associada ao risco de mortalidade após infarto agudo do miocárdio (IAM). A partir disto, passou a ser considerado como um preditor de mortalidade pós IAM (ANIS JUNIOR, 2000). Esta técnica relata oscilações dos intervalos entre batimentos cardíacos consecutivos (intervalos R-R), que estão relacionadas às influências do SNA sobre o nódulo sinusal. É uma medida não-invasiva, que pode ser utilizada para identificar fenômenos relacionados ao SNA em indivíduos saudáveis, atletas e portadores de doenças cardiovasculares (VANDERLEI et al., 2009).

Um indivíduo saudável com mecanismos autonômicos eficientes é representado através da alta VFC, caracterizando um sinal de boa adaptação. Já a baixa VFC pode indicar uma adaptação anormal e insuficiente do SNA, que pode significar uma presença de mau funcionamento fisiológico no indivíduo. A partir disso, é possível estudar a modulação autonômica do coração, sendo que a baixa VFC reflete um tônus simpático excessivo ou um tônus parassimpático inadequado (PUMPRLA et al., 2002).

Os índices de VFC são obtidos por instrumentos como eletrocardiógrafos, conversores analógicos digitais e cardiofrequencímetros (VANDERLEI et al., 2009) e sua análise pode ser feita por meio de métodos lineares e não-lineares (MCCRATY; SHAFFER, 2015).

Os métodos lineares são divididos em domínios do tempo e da frequência. Para a análise no domínio do tempo, mede-se cada intervalo RR normal (batimentos sinusais) durante um determinado intervalo de tempo, em milissegundos, com base nos métodos estatísticos ou geométricos (média, desvio padrão e índices derivados do histograma ou do mapa de coordenadas cartesianas dos intervalos RR) (ANIS JUNIOR, 2000). São índices no domínio do tempo:

- SDNN: desvio padrão de todos os intervalos RR normais gravados em um intervalo de tempo, expresso em ms;
- SDANN: desvio padrão das médias dos intervalos RR normais, a cada 5 minutos, em um intervalo de tempo, expresso em ms;
- SDNNi: média do desvio padrão dos intervalos RR normais a cada 5 minutos, expresso em ms;
- rMSSD: raiz quadrada da média do quadrado das diferenças entre intervalos RR normais adjacentes, em um intervalo de tempo, expresso em ms;
- pNN50: porcentagem dos intervalos RR adjacentes com diferença de duração maior que 50ms.

Os SDNN, SDANN e SDNNi são obtidos a partir de registros de longo prazo e representam a atividade simpática e parassimpática, mas não permitem distinguir quando as alterações na VFC são devidas ao aumento da atividade simpática ou parassimpática. Os índices rMSSD e pNN50 representam a atividade parassimpática (ANIS JUNIOR, 2000; MCCRATY; SHAFFER, 2015; VANDERLEI et al., 2009).

Outra possibilidade para processar intervalos RR no domínio do tempo é a partir de métodos geométricos, através do índice triangular e o gráfico de Lorenz (ou Poincaré Plot). Estes apresentam intervalos RR em padrões geométricos e diversas abordagens são utilizadas para derivar medidas de VFC a partir deles (VANDERLEI et al., 2009). O índice triangular é calculado com base na construção de um histograma de densidade de intervalos RR normais, que mostra no eixo horizontal (eixo x), o comprimento dos intervalos RR e o eixo vertical (eixo y), a frequência em que cada intervalo ocorre. A junção dos pontos das colunas do histograma forma uma figura em forma de triângulo e a largura da base do triângulo expressa a variabilidade dos intervalos RR. O índice triangular (correspondente à base do triângulo) pode ser calculado dividindo a área (correspondente ao número total de intervalos RR usados na construção da figura) e a altura (correspondente ao número de intervalos RR com frequência modal) do triângulo (JOHN CAMM et al., 1996; VANDERLEI et al., 2009). O gráfico de Poincaré é um método para análise dinâmica da VFC, que representa uma série temporal dentro de um plano cartesiano. A análise do gráfico de Poincaré pode ser realizada de forma qualitativa (visual), avaliando a forma da figura formada, ou quantitativo, ajustando a elipse do intervalo (JOHN CAMM et al., 1996; VANDERLEI et al., 2009).

No domínio da frequência, a densidade de potência espectral é a mais utilizada quando se trata de indivíduos em condições de repouso. Este domínio decompõe a VFC em componentes oscilatórios fundamentais, sendo os principais:

- HF (*High Frequency*) - componente de alta frequência: corresponde à modulação respiratória e é um indicador da atuação do nervo vago sobre o coração (de 0,15 a 0,4Hz);

- LF (*Low Frequency*) - componente de baixa frequência: decorrente da ação conjunta dos componentes vagal e simpático sobre o coração, com predominância do simpático (de 0,04 e 0,15Hz);

- VLF (*Very Low Frequency*) - componente de muito baixa frequência e ULF (*Ultra Low Frequency)* - ultrabaixa frequência: índices menos utilizados cuja explicação fisiológica não está bem estabelecida e parece estar relacionada ao sistema renina-angiotensina-αldosterona, à termorregulação e ao tônus vasomotor periférico (JOHN CAMM et al., 1996; VANDERLEI et al., 2009).

A razão LF/HF reflete as alterações absolutas e relativas entre os componentes simpático e parassimpático do SNA, caracterizando o balanço autonômico ou também chamado de balanço simpatovagal do coração (MONTANO et al., 2009).

Além disso, a normalização dos dados da análise espectral pode ser usada para minimizar os efeitos das mudanças na banda VLF. Isso é determinado pela divisão do poder de um determinado componente (LF ou HF) pelo espectro total de potência, menos o componente VLF e multiplicado por 100 (LF ou HF/(Total Power – VLF) x 100) (JOHN CAMM et al., 1996; VANDERLEI et al., 2009). Para análise dos índices da VFC usando métodos lineares e múltiplos, softwares são utilizados (TARVAINEN et al., 2014).

O método não-linear é determinado por interações complexas de variáveis hemodinâmicas, eletrofisiológicas e humorais, bem como por regulações nervosas autonômicas e centrais. Especulou-se que a análise da VFC com base nos métodos não linear poderia elucidar informações valiosas para a interpretação fisiológica da VFC e para a avaliação do risco de morte súbita (JOHN CAMM et al., 1996).

2.4 HIPERTENSÃO ARTERIAL (HA)

A hipertensão arterial (HA) é o principal fator de risco para doenças cardiovasculares, sendo considerada um grave problema de saúde pública responsável por cerca de 7,1 milhões de mortes ao ano no mundo e 50% das mortes por doença cardiovascular, atingindo 32,5% dos brasileiros adultos, e mais de 60% dos idosos (MALACHIAS et al., 2016). Mundialmente, estima-se que 54% dos casos de acidente vascular cerebral e 47% dos infartos agudos do miocárdio estejam relacionados a elevados níveis pressóricos (LAWES; HOORN; RODGERS, 2008).

Atualmente, a hipertensão acomete um bilhão de pessoas em todo o mundo e, estima-se que para 2025, a prevalência desta doença seja superior a 1,5 bilhões de pessoas (BENJAMIN et al., 2017). Segundo a *World Health Association*, este aumento se deve aos fatores de risco comportamentais e ao envelhecimento populacional (WHA, 2013).

A HA é caracterizada como uma doença crônica não transmissível, de causas multifatoriais associada a alterações funcionais, estruturais e metabólicas (MALACHIAS et al., 2016). De acordo com a *American Heart Association* (2017) e com a *World Health Association (WHA)* (2013), os principais fatores de risco para a HA são divididos em modificáveis, como hábitos de vida, os quais incluem: o sobrepeso ou obesidade, o sedentarismo, o consumo abusivo de bebidas alcoólicas, o tabagismo, o consumo excessivo de sal e o estresse. E não modificáveis, como idade, raça, sexo e a predisposição genética (BENJAMIN et al., 2017; WHA, 2013).

Segundo a *American Heart Association* e *Americann College of Cardiology*, a classificação de acordo com a medida casual no consultório, para pessoas acima de 18 anos é dividida da seguinte maneira (WHELTON et al., 2017):

Tabela 1 - Classificação da Pressão Arterial.

Classificação	**Pressão sistólica** *(mmHg)*	**Pressão diastólica** *(mmHg)*
Normal	<120	<80
Elevada	120 - 129	<80
Hipertensão estágio 1	130-139	80-89
Hipertensão estágio 2	≥140	≥90
Crise Hipertensiva	>180	>120

Fonte: (*American Heart Association* e *Americann College of Cardiology,* 2017).

Diferentes mecanismos de controle estão envolvidos na manutenção da PA, regulando o calibre e a reatividade vascular, a distribuição de fluido dentro e fora dos vasos e o débito cardíaco. Os mecanismos de controle da PA interagem para garantir a PA em níveis adequados nas mais diversas situações. E quando ocorrem disfunções desses mecanismos de controle há uma alteração na PA (IRIGOYEN; CONSOLIM-COLOMBO; KRIEGER, 2001). Dentre estes mecanismos de controle da PA, destacam-se os neurais. (SANJULIANI, 2002).

Os reflexos cardiovasculares (barorreflexo e quimiorreflexo) promovem ajustes cardiovasculares por meio do SNA, através das porções simpática e parassimpática, cuja atividade é gerada e modulada no SNC. Alterações na PA geram potenciais de ação que são transmitidos aos neurônios sensitivos dos gânglios até o Núcleo Trato Solitário (NTS) na medula. A partir deste local, os sinais são enviados para os núcleos centrais que incluem os neurônios pré-ganglionares simpáticos, pré-ganglionares parassimpáticos e o nervo vago (OLIVA; BAKRIS, 2014). Esses sistemas reflexos aferentes envolvidos no controle da circulação têm como objetivo principal monitorar a PA e informar ao SNC sobre possíveis alterações nesse parâmetro fisiológico a fim de que a mesma seja mantida constante (ACCORSI-MENDONÇA et al., 2005).

Com isto, como dito anteriormente, o SNA, através de desequilíbrios em sua atividade, torna-se um dos principais fatores desencadeantes no desenvolvimento e na manutenção da HA (CHOBANIAN et al., 2003; HERING et al., 2013; SALES et al., 2012). Este sistema tem uma importante participação no controle da PA e pode estar alterado em pacientes com HA, pois seu inadequado funcionamento induz aumento do débito cardíaco (DC) e da resistência vascular periférica (RVP), mantendo a PA elevada (SANJULIANI, 2002). E os altos índices sustentados ao longo do tempo contribuem para desencadear as lesões nos órgão alvos (rins, coração, cérebro), além das doenças renais, metabólicas e cardiovasculares (NOBRE et al., 2010; WHA, 2013).

Para o controle e adequado manejo da PA elevada e de suas consequências é imprescindível a identificação e o acompanhamento dos pacientes hipertensos pelos serviços de saúde, pois tratamentos farmacológicos e não farmacológicos são capazes de melhorar o prognóstico da doença e a qualidade de vida das pessoas (ZATTAR et al., 2013).

2.5 TRATAMENTOS

A medida medicamentosa é o principal tratamento para a hipertensão (WHELTON et al., 2017). Dentre os medicamentos tem-se os diuréticos, inibidores da enzima conversora de angiotensina (ECA), bloqueador do receptor de angiotensina (BRA), bloqueadores do canal de cálcio (CCB), os antagonistas dos receptores beta-adrenérgicos (β-bloqueadores), entre outros (WHELTON et al., 2017). Entretanto, estes medicamentos podem causar efeitos colaterais, tais como hipotensão arterial, insuficiência cardíaca, broncoespasmo (BOSCO; BRAZ, 2001) ou doenças como acidente vascular encefálico (AVE) e diabetes mellitus (KUYPER; KHAN, 2014). Além destes efeitos colaterais, pacientes com hipertensão resistente (hipertensão descontrolada apesar do uso de ≥3 medicamentos anti-hipertensivos) (DUDENBOSTEL et al., 2016) ou refratária (nova definição para um subgrupo fenotípico extremo que permanecem descontrolados apesar do uso de ≥5 agentes anti-hipertensivos) (MODOLO et al., 2015) não evoluem bem com o manejo farmacológico.

Estudos têm demostrado à eficácia do manejo não farmacológico da hipertensão, na redução do sistema nervoso simpático e consequentemente no aumento do sistema nervoso parassimpático (BERNARDI et al., 2001; GKALIAGKOUSI; GAVRIILAKI; DOUMA, 2015; HERING et al., 2013). Dentre as principais medidas não medicamentosa encontram-se as mudanças na dieta alimentar (SALES et al., 2012), a prática de exercícios físicos e/ou atividades físicas (GKALIAGKOUSI; GAVRIILAKI; DOUMA, 2015) e exercícios respiratórios (BERNARDI et al., 2001; HERING et al., 2013).

Além das terapias não farmacológicas já citadas, a eletroterapia vem sendo estudada, pois apresenta-se com potencial terapêutico no manejo da hipertensão.

2.6 ELETROTERAPIA

A eletroterapia compreende uma série de recursos terapêuticos para o tratamento de diferentes disfunções e/ou patologias. Para isto, é necessário conhecermos suas diferentes características e parâmetros. Dentre estes, temos:

2.6.1 Classificação das correntes elétricas

- Corrente Contínua: caracterizada por um fluxo contínuo de elétrons, sempre no mesmo sentido ou na mesma direção. Esta corrente é polarizada. Exemplo: corrente galvânica (ROBINSON; SNYDER-MACKER, 2010).

- Corrente Alternada ou Bidirecional: caracterizada por um fluxo bidirecional contínuo de elétrons. O fluxo desta corrente muda constantemente de direção, revertendo à polaridade, tornando-a uma corrente não polarizada. Terapeuticamente, possui frequência na faixa de 1.000 Hz a 10.000 Hz (média frequência). Os impulsos se alternam entre as fases positivas e negativas. Nesta corrente não há polaridade. Exemplo: Corrente Interferencial (CI) (ROBINSON; SNYDER-MACKER, 2010).

- Corrente Pulsada: fluxo não-contínuo de correntes diretas ou alternadas, caracterizada por um fluxo uni ou bidirecional de elétrons que periodicamente param por um período finito. Terapeuticamente, possui frequência na faixa de 1 a 1.000 Hz (baixa frequência). Exemplo de corrente: Estimulação elétrica nervosa transcutânea (TENS) e estimulação elétrica funcional (FES) (NELSON; HAYES; CURRIER, 2003; ROBINSON; SNYDER-MACKER, 2010).

As frequências das correntes são classificadas como: baixa (<1000 Hz), média (1.000 Hz a 10.000 Hz) ou alta (>10.000 Hz). (ROBINSON; SNYDER-MACKER, 2010).

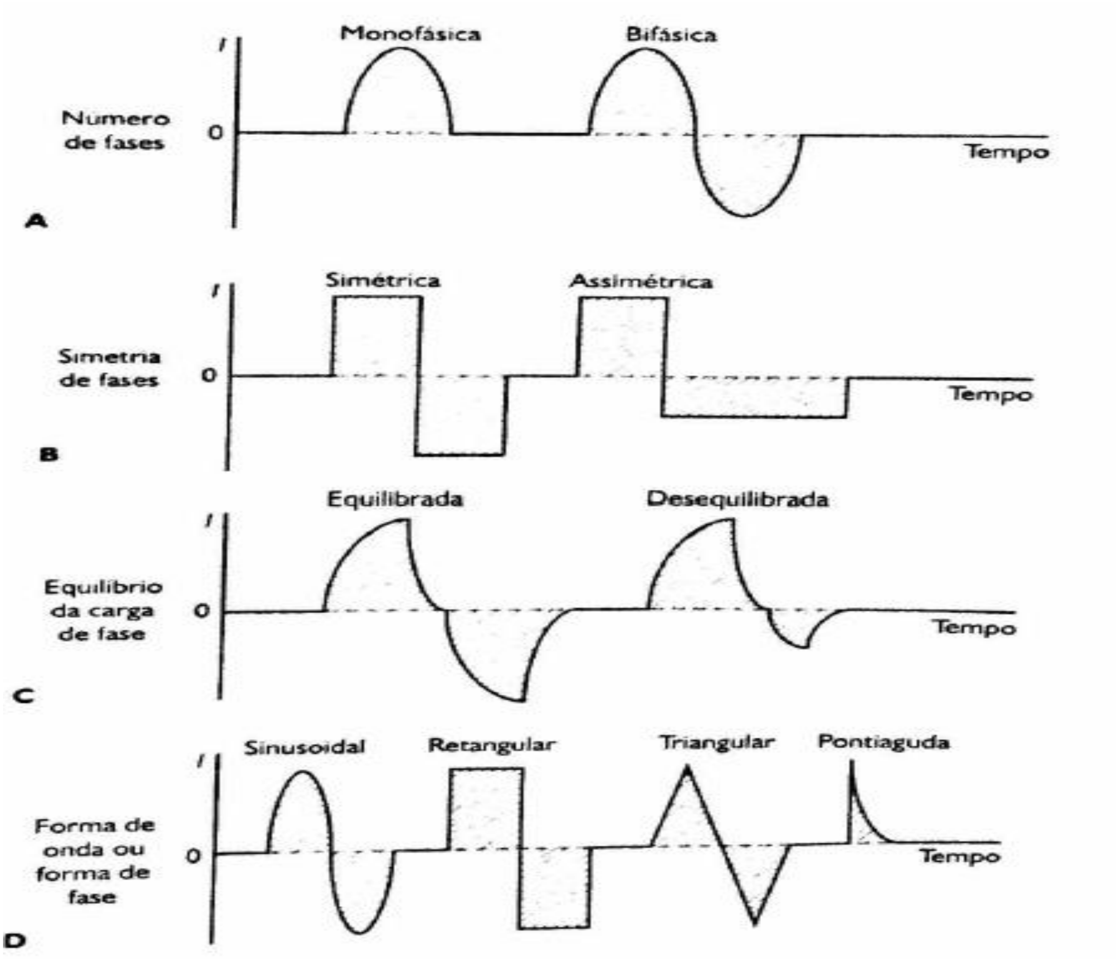
2.6.2 Formas de ondas elétricas

As ondas elétricas se diferenciam pelas suas características, as quais compreendem o número de fases, a simetria e as formas de onda. Essas características estão representadas na Figura 1. As formas de onda podem diferenciar-se quanto ao número de fases. Assim, os pulsos podem ser monofásicos (as partículas carregadas movem-se em uma mesma direção, de acordo com sua carga, indicando que existe apenas uma fase para cada pulso), bifásicos (as partículas carregadas movem-se primeiro em uma direção e depois na direção oposta, indicando que duas fases opostas estão contidas em um único pulso) e até mesmo trifásica ou polifásica (Figura 1A).

Em relação à simetria, estas podem ser simétricas (quando a primeira for à imagem de espelho da segunda fase de um pulso bifásico, sendo o fluxo da corrente iguais nas duas direções) ou assimétricas (a primeira fase de um pulso bifásico não for à imagem espelho da segunda fase, sendo o fluxo das correntes diferente em cada uma das direções) (Figura 1B).

Além disso, são classificadas quanto ao equilíbrio de cargas (equilibrada ou desequilibrada) (Figura 1C). As formas de onda e a forma geométrica de um único pulso ou ciclo da corrente alternada em um gráfico de corrente versus tempo. Estas formas podem ser: retangular, quadrada, triangular, dente-de-serra, exponencial e sinusoidal (Figura 1D) (NELSON; HAYES; CURRIER, 2003; ROBINSON; SNYDER-MACKER, 2010).

Figura 1 - Características descritivas de formas de onda.



Fonte: (ROBINSON; SNYDER-MACKER, 2010).

2.6.3 Frequência

É o número de pulsos elétricos produzidos por segundos. Sua unidade é medida em Hertz (Hz). Por exemplo: 10 Hz = 10 potencias de ação (ROBINSON; SNYDER-MACKER, 2010). As frequências de pulso podem ser classificadas em correntes, como a TENS, como: baixa (≤50 Hz) ou alta (≥50 Hz). Além disso, há relação inversa entre frequência e largura do pulso (f=1/T). Assim, para aumentar a frequência é necessário diminuir a largura de pulso (ROBINSON; SNYDER-MACKER, 2010).

2.6.4 Largura ou duração de pulso

A largura de pulso é definida pela quantidade de tempo que as cargas elétricas irão passar em um pulso. É expresso geralmente em segundos, milissegundos (ms) ou microssegundos (µs). (ROBINSON; SNYDER-MACKER, 2010).

2.6.5 Amplitude ou intensidade da corrente

Definida pelo tamanho do estímulo aplicado. Geralmente é medido em miliampéres (mA). Sendo que, quanto maior a intensidade, maior é o efeito de despolarização nas estruturas subjacentes aos eletrodos e deve ser aumentada ao longo da aplicação para evitar acomodação. Este parâmetro contribui para a fadiga (ROBINSON; SNYDER-MACKER, 2010).

2.6.6 Tempo *on/off*

O período de estimulação (*on*) com relação ao período de repouso (*off*) em uma sessão. O tempo *on* determina por quanto tempo (em segundos) vai ser mantida a contração. Neste tempo, o trem de pulso é fornecido em aplicação terapêutica. O tempo *off* é o tempo entre os trens de pulso, garantindo um período de recuperação para os nervos e músculos estimulados (ROBINSON; SNYDER-MACKER, 2010).

2.6.7 Rampa de subida e rampa de descida

Permite ajustar o número de segundos sobre os quais a amplitude ou o pulso irá aumentar ou diminuir de forma gradual até um valor máximo ajustado pelo controle de amplitude. O início gradual de estimulação produz contrações que imitam de forma mais exata aquelas produzidas em atividades funcionais durante a ativação muscular voluntária (ROBINSON; SNYDER-MACKER, 2010).

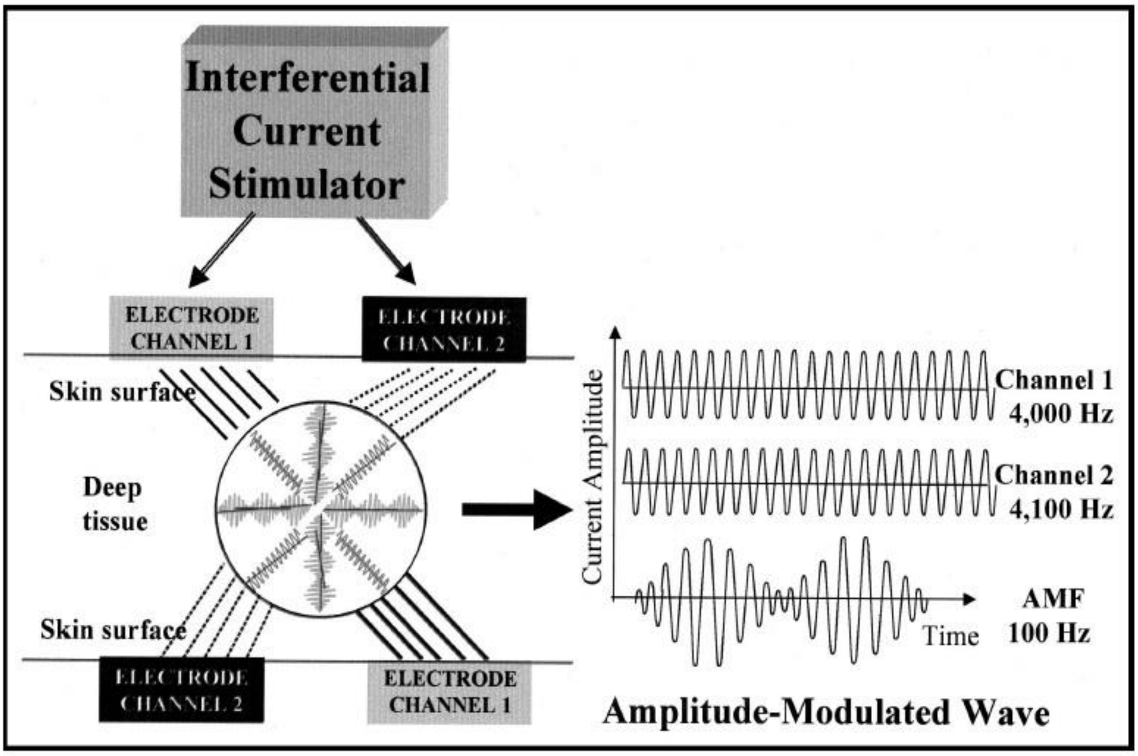
2.7 CORRENTE INTERFERENCIAL (CI)

A corrente interferencial (CI) foi descrita pela primeira vez por Neméc na Áustria no final dos anos 50 e foi introduzida comercialmente depois dos anos 70 (GANNE, 1976). Trata-se de uma forma de estimulação elétrica transcutânea, descrita como a aplicação de duas fases de correntes de média frequência (2 ou 4 KHz) que são transmitidas através da superfície da pele (PIVETTA; BERTOLINI, 2012; YOUN; LEE; LEE, 2016).

A CI é uma das modalidades eletroterapêuticas mais utilizadas na prática clínica. É indicada para aumentar a força e a resistência muscular, reeducação muscular, para produzir analgesia, promover a recuperação do tecido, redução de edemas e diminuir a espasticidade (OZCAN; WARD; ROBERTSON, 2004; PIVETTA; BERTOLINI, 2012; ROBINSON; SNYDER-MACKER, 2010).

O princípio da CI é produzir duas correntes de média frequência com frequências levemente diferentes que interfiram uma com a outra. Assim, uma nova corrente é estabelecida, denominada amplitude de modulação da frequência (AMF). A frequência de corrente resultante será a média das duas. Por exemplo: se a corrente A for 4.000 Hz e a B de 4.100 Hz, a resultante será de 4050 Hz (AMF de 100 Hz). As correntes de média frequência (faixa de 1.000 Hz a 10.000 Hz) (ROBINSON; SNYDER-MACKER, 2010) passarão mais facilmente através da pele do que correntes de baixa frequência devido à impedância mais baixa, gerando efeitos mais profundos nos tecidos (DOHNERT; BAUER; PAVÃO, 2015; SANTOS et al., 2013) (figura 2).

Figura 2 – Amplitude de modulação da frequência (AMF).

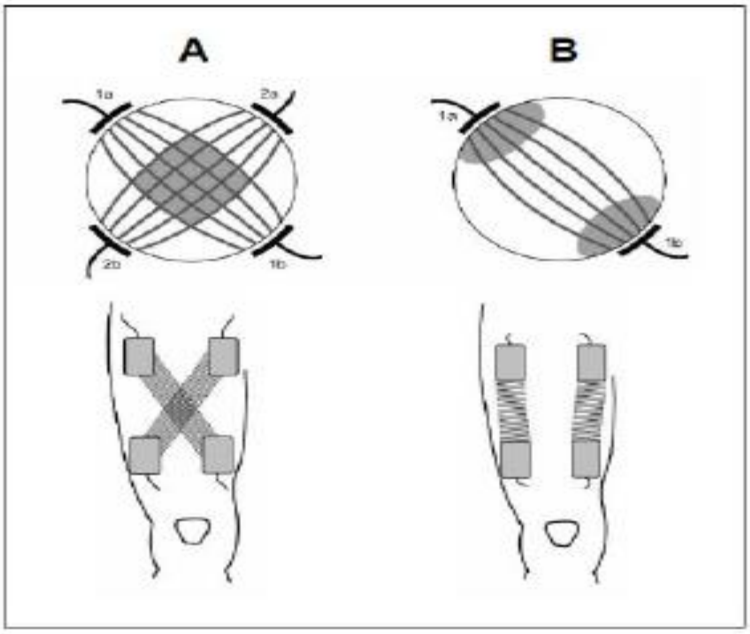


Fonte: (JOHNSON; TABASAM, 2003).

A AMF, tradicionalmente é considerada como sendo o componente efetivo da CI, simulando as correntes de baixa frequência e criando a estimulação diferencial de nervos e certos tipos de tecidos. A partir dessa definição, observa-se que a CI é uma forma semelhante à estimulação elétrica nervosa transcutânea (TENS) (PALMER et al., 1999). A importância da AMF é questionável, uma vez que existe uma falta de efeitos que evidenciam diferenças significativas com diferentes valores de AMF (PALMER et al., 2004).

Além disso, há diferentes formas de aplicação da CI. Está pode ser fornecida na pele de forma bipolar ou de forma tetrapolar. Na tetrapolar há máxima estimulação ocorrerá a 45º aos eletrodos. Nesta forma, a modulação deve-se ao fato de tanto as amplitudes de corrente quanto suas direções precisarem ser somadas, ou seja, uma adição de vetores, aumentando a área efetiva de tratamento. Por outro lado, na aplicação bipolar ocorre a propagação da onda interferencial de forma linear, onde a corrente passa de um eletrodo para outro (Figura 3) (AGNE, 2013; ROBINSON; SNYDER-MACKER, 2010). Entretanto, ainda não foram demostradas uma maior superioridade em relação à eficácia do método bipolar comparado ao tetrapolar (OZCAN; WARD; ROBERTSON, 2004).

Figura 3 - Exemplo de aplicação da CI nos métodos tetrapolar (A) e bipolar (B) na região anterior da coxa.



Fonte: (OZCAN; WARD; ROBERTSON, 2004).

Existem diferentes características elétricas disponíveis no dispositivo interferencial, algumas delas permite ao usuário ajustar tais características (JOHNSON; TABASAM, 2003).

Uma dessas características na qual é possível ajustar é o ΔF. Este é uma variação no AMF que provoca aumento e diminuição da frequência em padrões pré-definidos no equipamento, que varia de 1 a 100 Hz. Assim, se AMF de 100 Hz, com ΔF de 50 Hz, a variação de modulação ocorrerá entre 100-150 Hz. Esse fato também é usado para evitar o acomodação, pois, além da intensidade, a alteração de frequência é outro fator que combate a acomodação (PIVETTA; BERTOLINI, 2012).

A aplicação da CI em locais onde se concentram maiores quantidades de estruturas como vasos sanguíneos ou gânglios podem produzir modulações diferentes. Um exemplo é a aplicação na região do gânglio estrelado, podendo influenciar a perfusão vascular periférica (JIN; HWANG; CHO, 2017; SANTOS et al., 2013). O gânglio estrelado é composto por um grupo de nervos localizado na região cervical (C8-T4) e é formado pela fusão dos gânglios cervical e inferior primeiro torácico (BARKER et al., 2007). Porém, os efeitos da CI, neste local, sobre o fluxo sanguíneo ainda não está totalmente comprovados devido à falta de evidências (GUGLIELMIN, 2013).

2.8 EFEITOS DA CORRENTE INTERFERENCIAL (CI) NO BALANÇO AUTONÔMICO E PRESSÃO ARTERIAL (PA)

A aplicação da eletroestimulação sensorial com corrente de baixa frequência através da estimulação elétrica nervosa transcutânea (TENS) vem sendo pesquisadas com foco nos seus efeitos sobre o balanço autonômico, fluxo sanguíneo, mecanismos de vasodilatação e consequentemente na PA. Tem-se sugerido que a aplicação dessa corrente nos gânglios estrelados pode induzir a uma vasodilatação local (DA SILVA et al., 2015), ter impacto favorável no aumento da atividade parassimpática e da redução da atividade simpática (SARTORI et al., 2018; STEIN et al., 2011) e gerar efeitos sobre o reflexo pressórico (VIEIRA et al., 2012), apresentando-se com potencial terapêutico no manejo da hipertensão. A neuromodulação, gerada por essas correntes, pode variar dependendo dos parâmetros utilizados (STEIN et al., 2011). Porém, estudos com média frequência, como a Corrente Interferencial, ainda são escassos nestas variáveis. Para entendermos melhor os possíveis efeitos da CI, será necessária uma breve relação desta corrente com a TENS.

Lembrando que essas correntes (TENS e CI) diferenciam-se desde os tipos de corrente (TENS é pulsada, já a CI alternada), frequência (TENS é de baixa frequência e a CI média), o modo de aplicação (TENS bipolar somente e a CI pode ser tanto bipolar quanto tetrapolar) (AGNE, 2013; ROBINSON; SNYDER-MACKER, 2010) e a profundidade no qual cada uma dessas correntes alcança nos tecidos (CI é mais profunda) (DOHNERT; BAUER; PAVÃO, 2015).

Em um estudo de Wong e Jette (1984) realizado com voluntários saudáveis, submetidos à aplicação da TENS (2 e 85 Hz) nos membros superiores, houve aumento na modulação simpática, embora os resultados não sejam conclusivos quanto ao efeito de cada frequência. Os autores oferecem duas explicações para este aumento simpático. As fibras nervosas vasoconstritoras simpáticas podem ter sido estimuladas pela TENS e que a vasoconstrição de vasos sanguíneos pode ter ocorrido devido a um aumento na demanda de sangue pela contração dos músculos gerada pela TENS (WONG; JETTE, 1984).

A TENS de baixa frequência (10Hz) foi capaz de reduzir a atividade do sistema nervoso simpático e aumentar a do sistema nervoso parassimpático, quando aplicada na região ganglionar paravertebral em voluntários saudáveis. Já a TENS de alta frequência promoveu efeitos opostos (STEIN et al., 2011). Stein et al. (2011) afirma que a região onde a TENS é aplicada pode interferir nesses resultados.

As diferentes frequências da TENS aplicadas ao longo do plexo braquial foi estudada por De Nardi et al. (2017). Observou-se que houve modificação no equilíbrio simpático-vagal, onde a TENS de baixa frequência (10 Hz) aumentou a atividade simpática e diminuiu a atividade parassimpática. Por outro lado, a TENS de alta frequência (100 Hz) apresentou efeitos opostos, o que reforça os efeitos sobre o balanço autonômico em voluntários saudáveis (NARDI et al., 2017). Utilizando os mesmos parâmetros e locais de aplicação, Franco et al. (2014) afirmou que a TENS modificou a resposta venosa e que a baixa frequência (10Hz) aumenta e a alta frequência (100Hz) diminui a sensibilidade dos receptores a1-adrenérgicos, demonstrando que diferentes frequências de estímulos promovem efeitos opostos sobre esses receptores. No sistema cardiovascular, o receptor a1-adrenérgico altera a vasomotricidade, modulando a resistência vascular periférica por venoconstrição e cooperando com ajustes da pressão arterial sistêmica pelo retorno venoso (FRANCO et al., 2014). Além disso, a TENS (80Hz) em pacientes com insuficiência cardíaca crônica, aplicada perifericamente na região do pé para avaliar atividade barorreflexa, mostrou aumentar esta variável (GADEMAN et al., 2011).

Já Kamali et al. (2017) comparou a TENS baixa frequência (4Hz) nos gânglios simpáticos toracolombares, pontos de acupuntura (perna) e no pé. Avaliaram o fluxo sanguíneo periférico. Os resultados demostraram que a TENS nos gânglios simpáticos nos níveis de T12, L1 e L2 aumentou o fluxo sanguíneo dos membros inferiores comparado pontos de acupuntura (KAMALI et al., 2017).

A TENS (80Hz) também mostrou atenuar a redistribuição do fluxo sanguíneo durante a oclusão circulatória pós-exercício em indivíduos saudáveis, o que suporta a hipótese de que o TENS num momento agudo melhora o fluxo sanguíneo do músculo periférico e diminui a atividade simpática avaliada pela VFC. Sugeriu-se que esses efeitos podem estar ligados à liberação de β-endorfina por um efeito agonista sobre os receptores μ-opióides locais, o que parece ser um mecanismo fundamental para a modulação da PA, aumentando a liberação de oxigênio para o músculo (TOMASI et al., 2015).

Da Silva et al. (2015) demonstram que a TENS (80 Hz) aumentou o efeito vasodilatador local, o que pode contribuir para reduzir a PA (DA SILVA et al., 2015). Entre os mecanismos que podem explicar esta ação anti-isquêmica estão: a inibição da vasoconstrição simpática, a liberação de peptídeos vasodilatadores de neurônios sensoriais e o efeito da bomba de contrações musculares (VILELA-MARTIN et al., 2016).

Sartori et al. (2017) avaliaram efeitos agudos da baixa (4Hz) e alta (100Hz) frequência da TENS localizada na região paravertebral ganglionar na modulação do sistema nervoso em indivíduos com hipertensão. A TENS de baixa frequência melhorou o controle autonômico cardiovascular, reduzindo a modulação simpática e aumentando a modulação parassimpática. Porém na PA esta frequência não gerou mudanças. A TENS de 100Hz aumentou a PAD. Além disso, citam que as respostas distintas das interações do sistema nervoso autônomo, podem ser determinadas de acordo com a metodologia dos estudos (SARTORI et al., 2018). Vieira et al. (2012) mostraram que a estimulação da TENS (80Hz), também na região paravertebral ganglionar, atenua a PA e as respostas vasoconstritoras durante a ativação do exercício e metaborreflexo, associadas à melhora do equilíbrio simpatovagal em indivíduos saudáveis jovens e idosos (VIEIRA et al., 2012). Porém Lazarou et al. (2009) trouxeram que a TENS, aplicada no nervo radial, foi incapaz de produzir um efeito significativo sobre a BP, independentemente da intensidade (LAZAROU et al., 2009). Assim como Silverdal et al. (2012) que comparou a TENS baixa frequência (2Hz) com medicação anti-hipertensiva (felodipina), aplicada em pontos de acupuntura no braço, e não obteve diferenças da PA com a TENS (SILVERDAL et al., 2012).

Guglielmin (2013) comparou os efeitos da TENS alta frequência (80 Hz) e da CI com AMF em alta frequência (100 Hz) aplicados na região ganglionar (de C7 a T4) sobre a variabilidade da frequência cardíaca (VFC) em voluntários jovens saudáveis durante exercício físico. Demonstraram que ambas foram eficazes para aumentar o fluxo sanguíneo muscular periférico através de uma maior atenuação em metaborreflexo muscular e tônus vasoconstritor durante o exercício, porém a CI indicou um maior efeito vasodilatador do que a TENS. Além disso, a CI diminuiu a modulação VFC em indivíduos saudáveis, com o aumento do componente HF e diminuindo LF e LF/HF após o exercício com ou sem oclusão circulatória do músculo (GUGLIELMIN J.Z, 2013).

Santos et al. (2013) também avaliaram os efeitos da CI com AMF de 100Hz no metaborreflexo muscular antes do exercício na região ganglionar paravertebral em indivíduos saudáveis. A CI atenuou as respostas periféricas causadas pela atividade do metaborreflexo muscular, mantendo o fluxo sanguíneo periférico e a resistência vascular periférica dentro da normalidade. Esses achados contribuem para uma melhor compreensão dessa terapia.

Em outro estudo, investigaram as mudanças no fluxo sanguíneo nos diferentes parâmetros da CI (AMF 100Hz + 10-20 mA, AMF 5 Hz + 45-50 mA e AMF 100 Hz + 80-90 mA). A AMF 100 Hz à nível sensorial (10-20 mA) reduziu do diâmetro do vaso e aumentou levemente o fluxo sanguíneo avaliados imediatamente e 30 minutos após a aplicação, mas na estimulação AMF 5Hz ao nível sensório-motor (45-50 mA) os resultados sobre os aumentos do diâmetro do vaso e do fluxo sanguíneo foram muito mais pronunciados. Os autores sugeriram que a AMF de 5Hz e a alta intensidade apresentam resultados mais promissores no aumento do fluxo sanguíneo local (JIN; HWANG; CHO, 2017).

Noble e Henderson (2000) mostraram que a CI (10-20 Hz), aplicada através de eletrodos de sucção no quadríceps, produziu um aumento no fluxo sanguíneo cutâneo com um aumento concomitante na temperatura da pele. Estes resultados sugerem que o efeito fisiológico subjacente é a vasodilatação, através da inibição do sistema nervoso simpático (NOBLE et al., 2000). Por outro lado, a CI (AMF 90-100 Hz) aplicada no gânglio estrelado em indivíduos assintomáticos por 10 minutos não causou vasodilatação do antebraço em indivíduos assintomáticos. Tal estudo questionou a teoria de que o IC é capaz de bloquear os impulsos vasoconstritores simpáticos nos nervos periféricos (INDERGAND; MORGAN, 1995). Percebe-se que ainda há poucas publicações a respeito de sua utilidade clínica ou mesmo de suas premissas fisiológicas básicas desta corrente. A seguir será apresentada tabela com variáveis dos estudos citados anteriormente.

Tabela 2 – Revisão das variáveis dos estudos.

Estudo	Desfechos	População	Local aplicado	Corrente	Frequência
Vieira et al. (2012)	Metaborreflexo e VFC (no exercício)	Jovens e idosos saudáveis	Central (C7-T4)	TENS	80 Hz
Tomasi et al. (2015)	VO2, VE/VCO2, VO2/FC	Saudáveis	Central (C7-T4)	TENS	80 Hz
Sartori et al. (2018)	VFC	Hipertensos	Central (T1-L2)	TENS	4 Hz x 100 Hz
Stein et al. (2011)	VFC	Saudáveis	Central (T1-L2)	TENS	10 Hz x 100 Hz
Kamali et al. (2017)	Fluxo sang.		Central (T12, L1 e L2), periférico (Perna) e periférico (Pé)	TENS	4 Hz
De Nardi et al. (2017)	VFC	Saudáveis	Periférico (Plexo braquial)	TENS	10 x 100 Hz
Franco et al. (2014)	Reatividade vascular venosa	Saudáveis	Periférico (Plexo braquial)	TENS	10 x 100 Hz
Gademan et al. (2011)	Barorreflexo	Insuficiência Cardíaca	Periférico (Pé)	TENS	80 Hz
Silverdal et al. (2012)	PA (tens x medicação)	Hipertensos	Periférico (braço)	TENS	2 HZ
Da Silva et al. (2015)	Rigidez arterial	Saudáveis	Central (C7-T4)	TENS	80 Hz
Lazarou et al. (2009)	Dor e PA	Saudáveis	Periférico (braço)	TENS	2 Hz (diferentes intensidades)
Noble et al (2000)	Fluxo sanguíneo cutâneo	Saudáveis	Periférico (Quadríceps)	CI	10-20 Hz x 80-100 Hz x 10-100 Hz
Santos et al. (2013)	Metaborreflexo	Saudáveis	Central (C7-T4)	CI	25 Hz x 100 Hz
Jin et al. (2017)	Fluxo sanguíneo	Saudáveis	Central (T1- T4)	CI	100Hz (10-20mA) x 5 Hz (45-50mA) x 100hz (80-90mA)
Indergand e Morgan (1995)	Fluxo Sanguíneo	Saudáveis	Central (C7)	CI	90-100 Hz

CI: Corrente Interferencial; TENS: Estimulação elétrica nervosa transcutânea; VFC: Variabilidade da frequência cardíaca; PA: Pressão arterial; Hz: Hertz.

2.9 JUSTIFICATIVA/OBJETIVO

O presente trabalho se justifica pelos efeitos previamente demonstrados da eletroterapia sobre a pressão arterial (PA) e no balanço autonômico, e principalmente pelos potenciais efeitos da CI sobre estas variáveis em voluntários normotensos e hipertensos. As alterações dessas correntes elétricas sobre estas variáveis cardiovasculares, apresentam potencial terapêutico e consequentemente relevância clínica, em especial em pacientes hipertensos refratários ou em crises hipertensivas, onde o manejo farmacológico não se apresenta efetivo. Neste contexto, este recurso eletroterápico pode ser uma ferramenta não farmacológica coadjuvante no manejo da hipertensão.

Ressalta-se que esta dissertação compreende parte de um projeto temático intitulado “Efeitos da estimulação elétrica nervosa transcutânea (TENS) e da corrente interferencial sobre a pressão arterial (PA) e balanço autonômico de voluntários normotensos e pacientes hipertensos”. Neste sentido, o objetivo da pesquisa consistiu em estudar os efeitos da aplicação da CI com AMF em 100 Hz e com AMF em 10 Hz, aplicada na região paravertebral ganglionar (C7-T4), no balanço autonômico e na PA de voluntários saudáveis. Desta forma, determinando os melhores parâmetros dessa corrente elétrica para pacientes hipertensos.

A seguir será apresentado o artigo intitulado “Effects of interferential current on autonomic balance and blood pressure in healthy volunteers: randomized clinical trial” a ser submetido a revista *Physiotherapy* **(**Qualis A1 na área 21 da CAPES).

3 ARTIGO

EFFECTS OF INTERFERENTIAL CURRENT ON AUTONOMIC BALANCE IN HEALTHY VOLUNTEERS: RANDOMIZED CLINICAL TRIAL

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ABSTRACT

Objective: To evaluate the effects of different amplitude-modulated frequency (AMF) at 100Hz and 10Hz of the interferential current (IC) on autonomic balance in healthy volunteers.

Design: Randomized placebo-controlled, crossover study with concealed allocation and assessor blinding.

Settings: Clinical research laboratory.

Participants: Thirty healthy volunteers (21 women), with 23.7 ± 2.7 years old and body mass index (BMI) 23.2 ± 2.7 kg/m^2.

Interventions: Placebo (equipment turned off), IC with AMF 100Hz and 10Hz were randomized and applied in the paravertebral ganglionar region for 30 minutes, within the period of one week.

Outcome measure: Autonomic balance evaluated by the heart rate variability before and immediately after the interventions.

Results: AMF 10Hz intervention reduced the sympathetic activity (LF n.u.) in 6% (95%CI = -2.2 to -9.9) and an increase in the parasympathetic (HF n.u.) in approximately 6% (95% CI = 2.2 to 9.9). On the other hand, the AMF 100 Hz intervention increased 12% (95%CI = 8.5 to 16.3) to sympathetic activity (LF n.u.) and decreased 12% (95%CI = -8.8 to -16.6) to parasympathetic activity (HF n.u.).

Conclusion: IC changes the autonomic balance in healthy volunteers. The AMF of 10Hz reduces the sympathetic activity and increases parasympathetic, although the AMF of 100Hz has opposite results. The IC with AMF of 10Hz improves the autonomic balance and presents potential effects to be tested in the non-pharmacological management of patients with hyperactive sympathetic system, such as hypertensives and patients with heart failure.

Clinical trial registration number: NCT03258489.

Contribution of the Paper

- The interferential current (CI) applied on the paravertebral ganglionar region for 30 minutes modifies the autonomic balance;
- The amplitude-modulated frequency (AMF) at 10Hz decreased sympathetic activity and increased parasympathetic, but AMF of 100Hz had opposite effects.
- The AMF at 10Hz presents potential effects on the management of patients with hyperactive sympathetic system, such as hypertensives and patients with heart failure;

Key words: Autonomic nervous system. Sympathetic nervous system. Parasympathetic nervous system. Heart Rate. Blood Pressure. Electric Stimulation Therapy.

INTRODUCTION

The autonomic nervous system (ANS) is divided into sympathetic and parasympathetic components [1], where activation of the sympathetic nervous system causes increases in heart rate, peripheral vascular resistance and venous return to the heart, favoring an increase in blood pressure (BP) [2]. On the other hand, the activation of the parasympathetic nervous system favors the reduction of BP [1,2]. The autonomic imbalance, characterized by the hyperactive sympathetic system and the hypoactive parasympathetic system, is associated with cardiovascular diseases, such as hypertension and heart failure [3]. Therapeutic correction of this imbalance is associated with reduction in mortality from cardiovascular diseases [4].

Sensorial electrostimulation has been studied as a therapeutic alternative in the correction of this imbalance [5–7]. The application of transcutaneous electrical nerve stimulation (TENS), which is a low-frequency current (<1000Hz) [8], showed increased baroreflex sensitivity through a somatosensory impulse mediated by the fibers A-δ [9], increase the release of endogenous opioids [10], decrease levels of epinephrine and norepinephrine, generating attenuation of vascular response and vasodilatory responses [11], alter the sensitivity of peripheral α 1-adrenergic receptors [12] and capable of increasing peripheral blood flow through circulatory changes caused by the stimulation of sympathetic postganglionic efferent fibers, reducing peripheral vascular resistance [11,12]. However, the neuromodulation generated by this low frequency current may vary depending on the local of application and parameters used, especially on the frequency used [6,7,12].

Interferential current (IC), another form of sensory electrostimulation, is formed from two different medium-frequency currents, which interfere with each other, resulting in a new electric current, called amplitude-modulated frequency (AMF) [13,14]. A recent study has shown that different AMF (100Hz and 5Hz) of IC applied in the paravertebral region modify the vessel diameter and blood flow of healthy volunteers [15], which suggests a therapeutic potential in reducing sympathetic activity and BP, but such effects have not yet been investigated.

Medium-frequency currents (IC) pass more easily through the skin than low-frequency currents (TENS), due to their lower impedance, generating effects in the deeper tissues [16,17]. These differences in skin propagation and in the depth of the penetration of IC in relation to TENS suggest that this electrical current may be more effective in the management of autonomic imbalance and the fact that there are yet no studies of the effects of IC on this variable, requiring further investigation. In this sense, the objective of this research was to evaluate the effects of the application of different frequencies (AMF 100Hz and 10Hz) of IC on the autonomic balance in healthy volunteers.

METHODS

Design overview and Settings

The present double-blind, crossover, randomized clinical trial was approved by the institutional ethics committee (Protocol: 2.180.257) and was registered in Clinical trial (Protocol: NCT03258489). Methodologic design was based on the determinations of the 2010 CONSORT statement. The ethical precepts contained in CNS Resolution 466/2012 were respected. Volunteers were informed of the study protocol and provided written informed consent before participating. Data were collected between October 2017 and April 2018 at the Clinical Research Laboratory of Federal University of Santa Maria.

Participants

All enrolled volunteers were literate, both sexes, aged between 20 and 30 years-old, body mass index (BMI) lower than 30 kg/m^2; non-smokers; and free of skeletal muscle, rheumatic, cardiovascular, metabolic, neurologic, oncologic, immune, hematologic, psychiatric or cognitive disorders. The enrolled volunteers were not taking any type of medication (except contraceptive).

Participants were instructed not to perform exhaustive exercises (48 hours before) and not to drink beverages containing caffeine or alcohol 12 hours before the exams. On the day of the examinations, volunteers who presented values of blood pressure above normal (SBP > 120mmHg and DBP > 80mmHg) [18] or reported stressful events that occurred in the last 48 hours, would be excluded from the study. From these criteria, three volunteers, who presented BP values above normal, were excluded. The flowchart of the study design is shown in Figure 1.

Interventions

All volunteers underwent the three interventions (Placebo, IC: AMF 100Hz and IC: AMF 10Hz), which were performed within the period of one week. Autonomic balance and blood pressure (BP) measurements were evaluated simultaneously before and immediately after the interventions. Interventions were previously randomized through the website www.random.org. The information was kept in a sealed brown envelope and was randomly chosen on the day of the exams, with the evaluator and the volunteers blinded about the interventions.

The volunteers were placed in the supine position and remained in this position for one hour and a half (rest: 20min, data collection: 20min, interventions: 30min and data collection: 20min). The temperature of the room was maintained between 21 to 24ºC. The skin was duly sanitized with 70% alcohol and the self-adhesive electrodes (5x5 area) were positioned in the tetrapolar form, in the paravertebral ganglionar region, between C7 and T4 [17,19–21], according to Figure 2.

The IC (Dualpex 071® model, Quark Medical, São Paulo, Brazil) was applied for thirty minutes, in continuous flow, with biphasic pulses and a slope of 1/5/1. The IC with AMF 100Hz was used in the following parameters: the current was adjusted to 4000Hz, pulse width of 100μs and an AMF variation of 0Hz. IC with AMF 10Hz: current was adjusted to 4000Hz, pulse width of 100μs and an AMF variation of 0Hz. Intensity in milliamperes (mA) was adjusted every 5 minutes at the sensorimotor threshold level, without muscle contraction or according to the tolerance to the stimulus informed by the volunteers [6]. The placebo intervention consisted in the repetition of the previous procedures, where the intensity was increased until the sensorial threshold and later the equipment was turned off, remaining in such way until the end of the data collections.

Outcomes and follow-up

The primary outcome measure was autonomic balance, which was assessed by the heart rate variability (HRV) in the time-domain and frequency-domain. Secondary outcome measure was blood pressure (BP).

Heart Rate Variability

The autonomic balance was evaluated through the heart rate variability (HRV) technique using a pulse frequency meter (Polar brand, model 810i, Kempele - Finland). The heart rate acquisition (sample rate – 1000Hz) was performed in time series of the RR intervals and acquired at continuous intervals (10 minutes) before and immediately after the interventions. The data were collected with controlled breathing (12 breaths per minute; I/E: 2/3) for 10 minutes [6]. In HRV analysis, time and frequency domain were analyzed using an area corresponding to 5 minutes (containing at least 256 consecutive heart beats), which was moved over the visually more stable section of the 10-minute period before and immediately after the electrostimulation of IC.

The analysis was performed by spectral power density. This analysis decomposes the HRV into fundamental oscillatory components, the main ones being: high frequency component (HF) of 0.15 to 0.4Hz, corresponding to respiratory modulation and to the indicator of the vagus nerve acting on the heart; low frequency component (LF) of 0.04 and 0.15Hz, which is due to the joint action of the vagal and sympathetic components on the heart, predominantly sympathetic. Normalized units (n.u.) were obtained by dividing the power of a given component by the total power (from which VLF has been subtracted) and multiplying it by 100 (LF ou HF/(Total Power – VLF) x 100) [3]. The LF/HF ratio reflects the absolute and relative changes between the sympathetic and parasympathetic components of the ANS, characterizing the sympatho-vagal balance on the heart [3]. The data were transferred to a computer and the R-R ranges processed to calculate the HRV using the parameters of the Kubios program HRV version 2.1 (Kuopio, Finland, 2012).

The variables in the time-domain were the heart rate (HR), standard deviation of all normal to normal R-R (NN) interval (SDNN), square root of the mean of the squares of successive R-R interval differences (rMSSD), percentage of intervals differing more than 50 ms different from preceding interval (PNN50%) and Triangular Index. At the frequency-domain were total power (TP), low frequency (LF), high frequency (HF) and sympatho-vagal balance ratio (LF/HF).

Blood pressure

Blood pressure (BP) monitoring (Systolic blood pressure - SBP, Diastolic Blood Pressure – DBP and Mean Blood Pressure - MBP) was performed using a multiparametric monitor (Dixtal, model 2021, Manaus, Brazil). The cuff was positioned on the right arm with the patient positioned in the supine position on the stretcher. Data were collected before and immediately after the interventions through three measurements, with a 10 minutes interval between them and the data expressed by means of measures.

Statistical analysis

Data are presented as mean and standard deviation (SD). The Kolmogorov-Smirnov normality test was used. Variables were compared by two-way ANOVA of repeated measures, followed by Bonferroni *post hoc*. Variations between interventions are reported as mean differences and 95% confidence intervals (95% CI). The α error rate of 5% ($p < 0.05$) was considered.

Sample size

The sample size was calculated based on a previous study data [7]. It was estimated that a sample size of 30 volunteers in each group would have a power of 85% to detect a 11% difference between means (standard deviation 13%) for the sympathetic activity after TENS application, for $\alpha = 0.05$ (5%).

RESULTS

The sample was composed of thirty healthy volunteers (21 women; 13 using contraceptives), with 23.7 ± 2.7 years old, body mass index (BMI) 23.2 ± 2.7 kg/m^2 and Waist/Hip relation 0.77 ± 0.04 cm.

HRV data in the time domain and frequency in response to different AMF of IC are shown in Table 1. In the time domain, HR was within the limits of normality in all evaluations, but after interventions reduced 4 bpm (95%CI = -1 to -7) in the placebo intervention, 3 bpm (95%CI = 0.2 to -6) at AMF 100Hz and 4 bpm (95%CI = -0.2 to -7) at AMF 10Hz. SDNN remained unchanged in placebo intervention, increased 15.4 ms (95%CI = 2.3 to 28.5) at AMF 100Hz and 13.6 ms (95%CI = 20.1 to 26.7) at AMF 10Hz. rMSSD increased 13.3 ms (95%CI = 1.8 to 24.9) after the placebo intervention and 18.2 ms (95% CI = 6.7 to 29.8) after AMF 10Hz. PNN50% also increased 6.4% (95%CI = -0.4 to 13.3) in the placebo and 9.8% (95%CI = 2.9 to 16.7) at AMF 10Hz. Triangular Index presented differences in time (p = 0.020), but was not confirmed Bonferroni posttest (p> 0.05) through confidence intervals (Placebo: 95%CI = -2.20 to 2.91; AMF 100Hz: 95%CI = -1.18 to 3.93; AMF 10Hz, 95%CI = -0.41 to 4.69).

In the frequency domain (Table 1), TP presented an increase of 2627 ms^2 (95%CI = 279 to 4975) at AMF 100Hz and 2768 ms^2 (95%CI = 419 to 5116) at AMF 10Hz. The power in low frequency range (LF - ms^2) increased 784 ms^2 (95%CI = 340 to 1229) at AMF 100Hz, while the power in high frequency range (HF - ms^2) increased 1705 ms^2 (95%CI = 716 to 2694) at AMF 10Hz.

After data normalization, the placebo intervention did not modify sympathetic (LF) and parasympathetic (HF) activities. The AMF 100 Hz intervention increased 12%

(95%CI = 8.5 to 16.3) to sympathetic activity (LF n.u.) and decreased 12% (95%CI = -8.8 to -16.6) to parasympathetic activity (HF n.u.) in relation to the period prior to application (Figure 3A). On the other hand, after the application of AMF 10Hz, there were opposite effects, observing a reduction of sympathetic activity (LF n.u.) in 6% (95%CI = -2.2 to -9.9) and an increase in the parasympathetic (HF n.u.) in approximately 6 % (95% CI = 2.2 to 9.9) (Figure 3B). The AMF 100Hz and 10Hz presented different results after the application, where the AMF 100Hz increased sympathetic activity in 16% and reduced parasympathetic activity 16% (95%CI = 6.6 to 25.3) in relation to AMF 10Hz. Only the AMF 100Hz increased the LF (n.u.) in 9.7% (95%CI = 0.5 to 19.0) and reduced the HF (n.u.) in 9.7% (95%CI = -0.4 to -19.0) compared to placebo.

LF/HF ratio increased 0.4 (95%CI = 0.3 to 0.6) after application of AMF 100Hz and decreased 0.2 (95%CI = -0.02 to -0.3) after AMF 10Hz (Figure 3C). LF/HF decreased 0.5 (95%CI = -0.2 to -0.8) between frequencies (100Hz vs 10Hz). AMF 100Hz increased this ratio by 0.3 (95%CI = 0 to 0.7) compared to placebo. Data of the Blood Pressure are shown in table 2. SBP, DBP and MBP no differences were found between interventions, time and in the interaction in the study (Table 2).

DISCUSSION

The results demonstrate that the different AMF of IC applied in the paravertebral ganglionar region (C7 to T4) modify the autonomic balance of healthy volunteers. AMF 10Hz reduced sympathetic activity (LF) and increased parasympathetic (HF) of healthy volunteers. On the other hand, the AMF 100Hz presented opposite results. Also, the different AMF of IC did not modify BP.

Research on the IC effects on the cardiovascular system is scarce. AMF is considered to be the effective component of IC, simulating low frequency currents such as TENS [22]. However, these currents differ in relation to the frequency of their currents (TENS is low-frequency and IC medium-frequency) [8] and the depth in which each of them reaches the tissues [16,17]. Although these currents are electrically different and the depth reached in the tissues, studies have shown similar results when compared in analgesia [16,23]. In this sense, in part, we will refer to TENS in the discussion of the results of the present study.

The site of application was chosen according to previous studies with the use of TENS [19–21] and IC [17]. In this place, the anatomical organization of the ANS occurs with the presence of the ganglia that store the cellular bodies of the postganglionic sympathetic neurons, from which the axons forming the cardiac nerves to the periphery leave [1]. Due to this anatomical location, sensory stimulation in this region favors changes in the autonomic nervous system [5] and repercussions on peripheral blood flow [11].

In the present study, the IC with AMF 10Hz improved the autonomic balance, as it reduced sympathetic activity and increased parasympathetic activity. Previous studies have shown that the stimulation of IC with AMF 5Hz (bipolar application in T1-T4) [15] and AMF 10-20Hz (applied in the quadriceps) [24] increased blood flow, reinforcing the findings of the present study. TENS (10Hz) applied on the paravertebral ganglionar rengion presented similar results to this research [6] and meta-analysis showed that the TENS (<50Hz) reduces SBP in healthy volunteers [25], showing that lower frequencies present better results on the balance autonomic and BP in these sensory stimuli. In addition, TENS (<4Hz) demonstrated to reduce sympathetic activity by increasing the release of endogenous opioids in the ANS [10]. We believe that increasing of endogenous opioids also occur with the AMF 10Hz IC.

The AMF 100Hz increased sympathetic activity and reduced parasympathetic, which was demonstrated in the present study. Previous study has shown that the AMF 100Hz of IC decreased vessel diameter and increased blood flow (bipolar form application in T1-T4), which is due to the increase in sympathetic activity [15]. Our results also agree with a previous study using TENS 100Hz, applied to the paravertebral ganglionar region, that demonstrated the increase of the sympathetic activity and reduction of the parasympathetic evaluated by the HRV technique [6]. Wong e Jette (1984) suggest that increased sympathetic activity may be related to vasoconstricting sympathetic fiber stimulation, generated by increased blood flow demand, producing pain relief [26].

The different AMF (100Hz and 10Hz) of the IC had opposite results, which also have been demonstrated with the different frequencies and sites of TENS application [6,7,12]. Such results reinforce that the cardiovascular effects, induced by sensorial electro stimulation, depend on the parameters used (frequency, place of application of electrodes, duration of the stimulus) and on the population studied [7,12,15,25].

The BP in relation to the different frequencies of AMF of IC remained unchanged. These results have already been demonstrated in studies that applied TENS (<4Hz) and did not identify alterations in BP in healthy subjects [27] and hypertensive patients [5,28]. However, the TENS (<50Hz) reduced BP in healthy volunteers [25] and TENS (80Hz) reduced SBP in young healthy volunteers [21]. These studies suggest that TENS is more effective than IC in the reduction of BP in healthy volunteers and hypertensive patients, but studies comparing these different sensorial stimuli have not yet been performed in these populations.

The absence of evaluation of plasma catecholamines and the duration of these effects on the autonomic balance and the method of assessing blood pressure through the casual measure are presented as limitations of the study. Among the clinical implications, the effects of IC with AMF 10Hz, in the paravertebral ganglionar region, become a potential non-invasive and non-pharmacological approach to be tested to improve the autonomic balance of patients with sympathetic hyperactivity, such as resistant hypertensive and patients with heart failure.

CONCLUSION

The application of IC applied in the paravertebral ganglionar region modifies the autonomic balance of healthy volunteers. The AMF of 10Hz reduces the sympathetic activity and increases parasympathetic, although the AMF of 100Hz has opposite results. The IC with AMF of 10Hz improves the autonomic balance and presents potential effects to be tested in the non-pharmacological management of patients with hyperactive sympathetic system, such as hypertensives and patients with heart failure.

Ethical Approval: Ethics approval was obtained from the University of Santa Maria (UFSM) Human Research Ethics Committee (Protocol: 2.180.257).

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Conflict of Interest: There is no conflict of interest.

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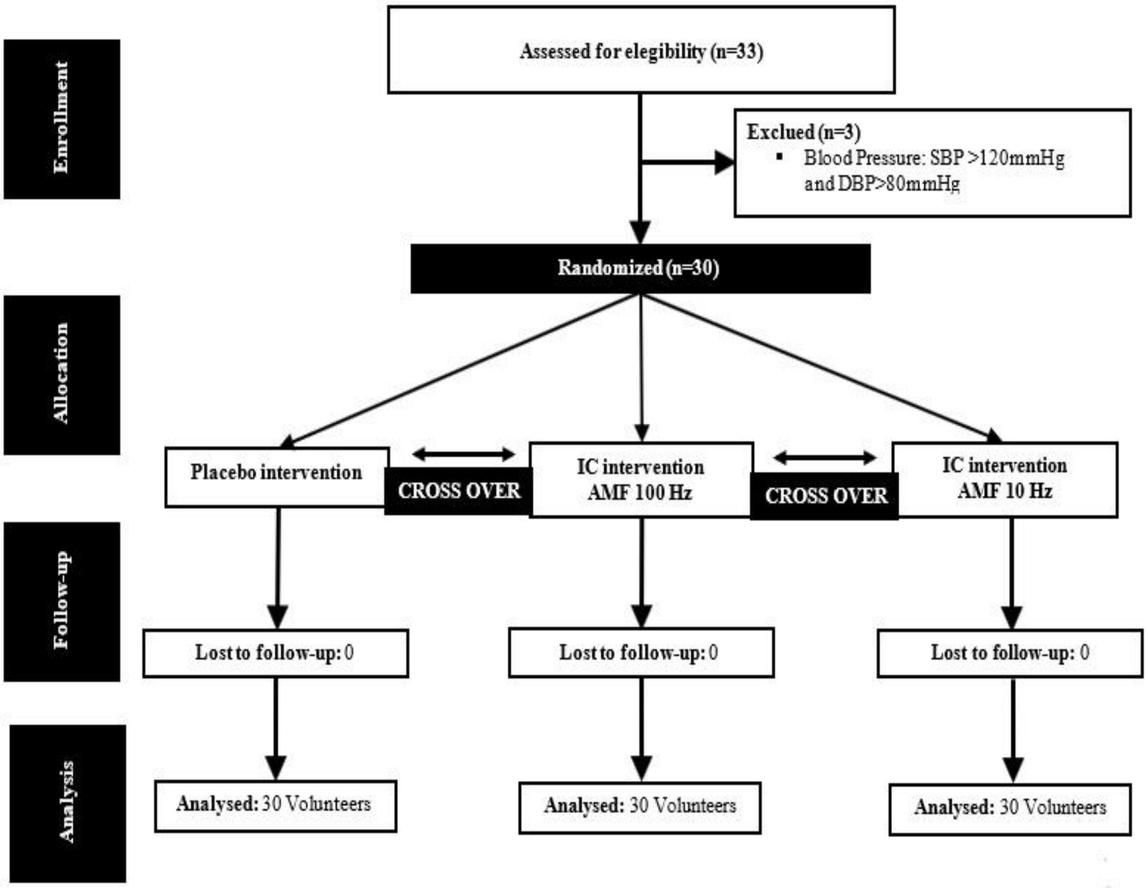

Figure 1.

Flow Diagram of study.

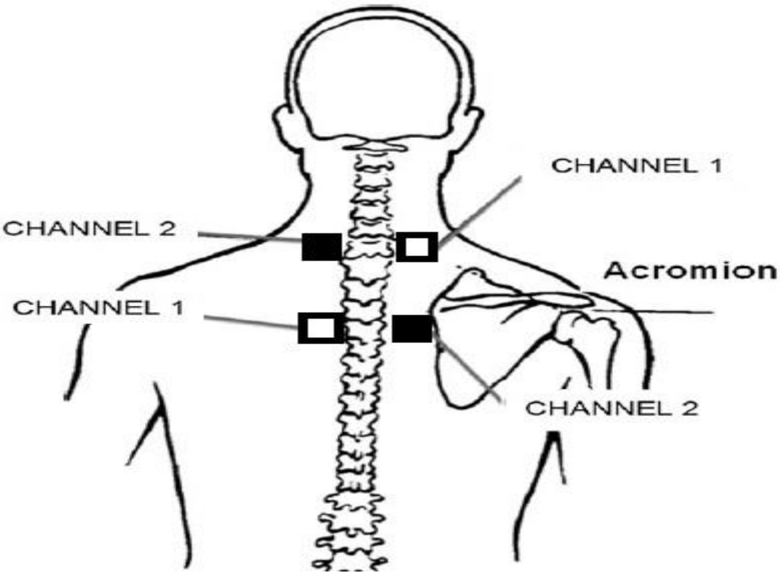

Figure 2

Local of electrodes (paravertebral ganglionar region - C7 and T4).

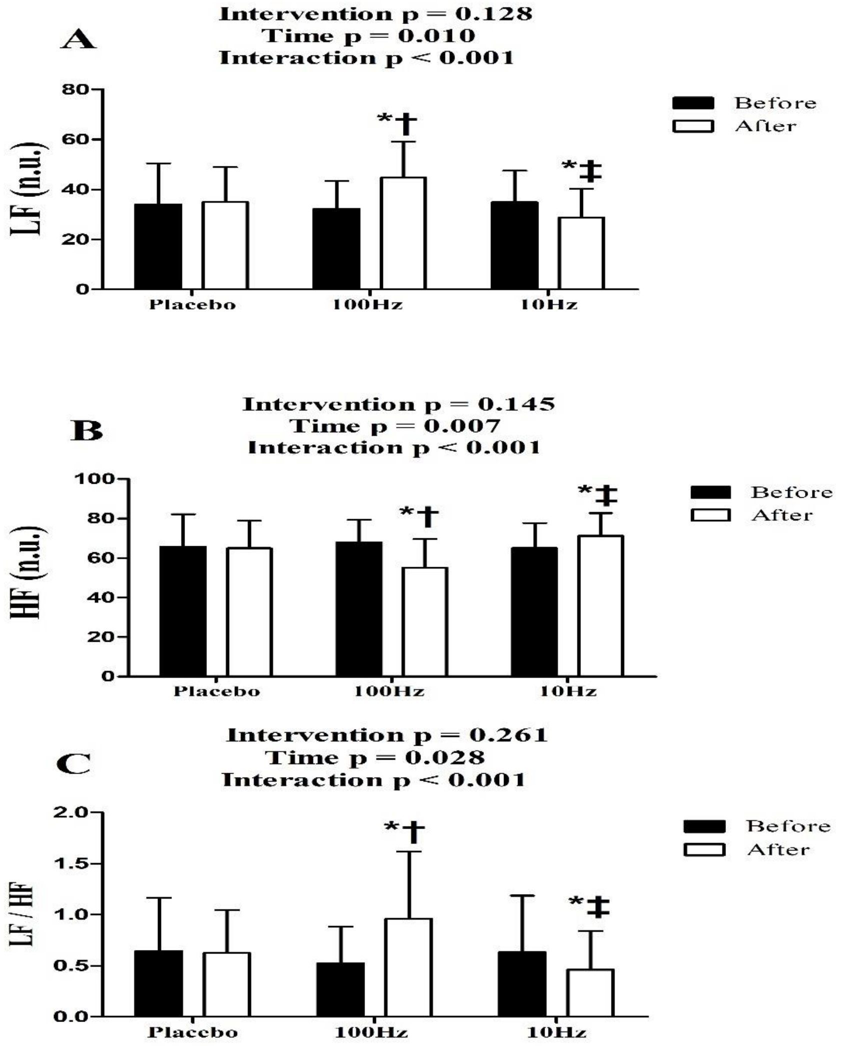

Figure 3

The sympathetic-vagal balance.

Data are presented as mean ± standard deviation (SD); A: LF (n.u.): panels of spectral parameters of low frequency normalized component; B: HF (n.u.): high frequency normalized component; C: LF/HF: sympathovagal balance ratio LF(ms^2) / HF(ms^2); * $p < 0.05$ vs Before; † $p < 0.05$ vs Placebo; ‡ $p < 0.05$ vs 100Hz.

Table 1

Results of heart rate variability data.

Variables		Placebo	AMF 100Hz	AMF 10Hz	p		
					Intervention	Time	Interaction
Time-Domain							
HR (bpm)	Before	69.6±11.0	67.8±11.4	70.1±12.4	0.828	<0.001	0.578
	After	65.4±10.0*	64.9±11.6*	65.7±8.9*			
SDNN (ms)	Before	76.7±32.4	73.7±28.0	75.1±27.6	0.997	<0.001	0.651
	After	86.0±31.5	89.1±31.3*	88.7±34.3*			
rMSSD (ms)	Before	64.7±27.6	71.1±39.3	65.6±35.9	0.937	<0.001	0.031
	After	78.0±39.2*	73.5±38.1	83.8±48.0*			
PNN50 (%)	Before	37.2±17.6	39.6±20.1	35.1±19.1	0.995	0.001	0.063
	After	43.7±18.3*	40.9±17.3	44.9±19.7*			
Triangular Index	Before	16.9±5.6	15.2±4.1	14.9±5.3	0.446	0.020	0.411
	After	17.3±4.9	16.5±4.5	17.0±4.3			
Frequency Domain							
TP (ms^2)	Before	6583±6329	5713±4969	5995±4469	0.966	0.002	0.437

	After	7762±5673	8340±5705*	8763±7326*			
LF (ms^2)	Before	1349±1017	1290±1073	1305±986	0.641	<0.001	0.068
	After	1667±1348	2075±1600*	1520±1217			
HF (ms^2)	Before	2592±2164	2950±3012	2467±2104	0.757	0.004	0.004
	After	3270±2949	2673±2733	4171±4274*			

Data are presented as mean ± standard deviation (SD); AMF: amplitude-modulated frequency; HR: Heart Rate (bpm min.-1); SDNN: standard deviation of all normal to normal R-R (NN) interval; rMSSD: Square root of the mean of the squares of successive R-R interval differences; pNN50: percentage of intervals differing more than 50 ms different from preceding interval; Total power (TP ms^2): The variance of RR intervals over the temporal segment; LF (ms^2): Power in low frequency range (0.04-0.15 Hz); HF (ms^2): Power in high frequency range (0.15-0.4 Hz); * $p < 0.05$ vs Before; † $p < 0.05$ vs Placebo; ‡ $p < 0.05$ vs 100Hz.

Table 2

Results of Blood Pressure (BP).

Variables		Placebo	AMF 100Hz	AMF 10Hz	p		
					Intervention	Time	Interaction
SBP (mmHg)	Before	109.3 ± 6.5	111.5 ± 7.1	109.4 ± 6.8	0.367	0.607	0.342
	After	110.6 ± 7.4	111.7 ± 8.9	108.7 ± 7.8			
DBP (mmHg)	Before	63.0 ± 5.4	63.5 ± 5.6	62.6 ± 5.0	0.514	0.126	0.998
	After	63.9 ± 5.6	64.6 ± 6.8	62.3 ± 4.9			
MBP (mmHg)	Before	78.5 ± 5.2	79.5 ± 5.3	78.2 ± 5.2	0.397	0.177	0.175
	After	79.4 ± 6.6	80.3 ± 6.7	77.8 ± 5.3			

Data are presented as mean ± standard deviation; AMF: amplitude-modulated frequency; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; MBP: Mean Blood Pressure.

4 CONCLUSÃO

Esta dissertação faz parte de um projeto temático intitulado “Efeitos da estimulação elétrica nervosa transcutânea (TENS) e da corrente interferencial (CI) sobre a pressão arterial e balanço autonômico de voluntários normotensos e pacientes hipertensos”. A presente dissertação apresenta os resultados das diferentes frequências da CI em voluntários saudáveis, visando estabelecer os parâmetros mais adequados dessa estimulação sensorial para futuros estudos em população hipertensa.

Neste sentido, a CI foi aplicada na região paravertebral ganglionar por 30 minutos, no modo contínuo, com pulsos bifásicos, com *slope* de 1/5/1, frequência da corrente de 4000Hz, largura do pulso de 100µs e sem variação da AMF. A CI com AMF em 10Hz modificou o balanço autonômico de voluntários saudáveis, diminuindo a atividade simpática e aumentando atividade parassimpática. Entretanto, a CI com AMF em 100Hz apresentou resultados opostos.

Os resultados sugerem que a AMF em 10Hz seja mais adequada para ser testado em pacientes hipertensos, pois este recurso eletroterápico é uma possível ferramenta não farmacológica coadjuvante no manejo da hipertensão, em especial os hipertensos refratários e resistentes a medicação. Salienta-se também que esses resultados devem ser comparados com a TENS nesta população, para verificarmos qual destas correntes apresenta um potencial de efeito maior, sabendo que os efeitos hemodinâmicos, induzidos por estas correntes, podem depender tanto da frequência, do local de aplicação dos eletrodos e da população estudada.

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ANEXOS

ANEXO 1: Normas da revista *Physiotherapy*

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The journal editor Michele Harms, welcomes articles for publication in the journal.

Physiotherapy invites papers in the following categories: Original research, systematic and scoping reviews or meta-analysis, theoretical or debate articles (aim for 3000 words excluding abstract and references, with a limit of 40 references); brief reports (750 words and 1 table/figure, with a limit of 10 references); technical reports (1000-2000 words, with a limit of 20 references); and Letters to

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2. Detailed disclosures as part of a separate Declaration of Interest form, which forms part of the journal's official records. It is important for potential interests to be declared in both places and that the information matches. More information.

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