UNIVERSIDADE FEDERAL DE MINAS GERAIS
Escola de Educação Física, Fisioterapia e Terapia Ocupacional
Programa de Pós-Graduação em Ciências da Reabilitação

Maria Teresa Ferreira dos Reis

EQUAÇÕES DE PREDIÇÃO DA FREQUÊNCIA CARDÍACA MÁXIMA COM ADEQUADA APLICABILIDADE CLÍNICA PARA PRESCRIÇÃO DO EXERCÍCIO AERÓBIO EM INDIVÍDUOS PÓS-ACIDENTE VASCULAR ENCEFÁLICO

Belo Horizonte
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Equações de predição da frequência cardíaca máxima com adequada aplicabilidade clínica para prescrição do exercício aeróbio em indivíduos pós-acidente vascular encefálico

MARIA TERESA FERREIRA DOS REIS

Dissertação submetida à Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em CIÊNCIAS DA REABILITAÇÃO, como requisito para obtenção do grau de Mestre em CIÊNCIAS DA REABILITAÇÃO, área de concentração DESEMPENHO FUNCIONAL HUMANO.

Aprovada em 16 de dezembro de 2021, pela banca constituída pelos membros:

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RESUMO

Para a adequada prescrição da intensidade do exercício aeróbio em indivíduos pós-acidente vascular encefálico (AVE) é necessária a obtenção da frequência cardíaca máxima (FR_{max}). Essa medida é idealmente obtida por meio de um teste de esforço máximo, como o Teste de Esforço Cardiopulmonar (TECP). Entretanto esse teste apresenta baixa aplicabilidade clínica. Como alternativa, diversas equações de predição da FC_{max} baseadas na idade foram desenvolvidas, nenhuma delas específicas para indivíduos pós-AVE. A presente dissertação teve como objetivos: 1-investigar a validade de seis equações de predição baseadas na idade para predizer a FC_{max} de indivíduos pós-AVE; 2-desenvolver duas equações específicas para indivíduos pós-AVE; e, 3-investigar a validade das equações desenvolvidas. Trata-se de um estudo transversal, realizado com indivíduos pós-AVE na fase crônica. Para atender o objetivo-1, 60 indivíduos (54±12 anos; 64±69 meses pós-AVE) foram incluídos. Seis equações de predição foram selecionadas para investigação da validade: 1- 220-idade, 2- 206,9 – (0,67 x idade), 3- 208 – (0,7 x idade), 4- 216,6 – (0,84 x idade) (todas desenvolvidas para indivíduos saudáveis); 5- 164 – (0,72 x idade) e 6- 200 – (0,92 x idade) (ambas desenvolvidas para indivíduos com doença arterial coronariana). A concordância entre a FC_{max} obtida pelo TECP e a FC_{max} predita pelas equações foi analisada utilizando o coeficiente de correlação intraclasse (CCI) com intervalo de confiança de 95% (IC95%) e pelo método de Bland-Altman (α=5%). Não houve concordância significativa para as equações 1-5 (-0,18≤ IC95% ≤0,79) e houve concordância significativa (IC95%= 0,05-0,75), mas de magnitude moderada (CCI=0,51), para a equação-6. As equações de 1-4 e 6 superestimaram a FC_{max} obtida pelo TECP, sendo que a equação-6 apresentou a menor média da diferença (2,4 batimentos por minuto (bpm)). Portanto, as equações testadas não foram consideradas válidas para predizer a FC_{max} de indivíduos pós-AVE. Para atender o objetivo-2, duas análises de regressão múltipla foram realizadas. Os seguintes modelos de regressão foram obtidos: Equação-1 (Teste de Caminhada de Seis Minutos (TC6)): FC_{max}= 87,655 + 0,726 (FC_{pico} no TC6) – 0,386 (idade), (R^2=0,53, p<0,001) e Equação-2 (*Incremental Shuttle Walking Test* (ISWT)): FC_{max}= 96,523 + 0,681 (FC_{pico} no ISWT) – 0,039 (distância caminhada no ISWT) – 0,400 (idade), (R^2=0,53, p<0,001). Para responder o objetivo-3, 20 indivíduos foram incluídos (58±8 anos; 60±46 meses pós-AVE). A concordância entre a FC_{max} obtida pelo TECP e a FC_{max} predita pelas novas equações foi analisada utilizando o CCI com IC95% e pelo método de Bland-Altman (α=5%). A equação-1 apresentou concordância significativa (IC95%= 0,63 – 0,94) com uma alta magnitude (CCI=0,85), e uma média da diferença de 3,2 bpm. A equação-2 apresentou concordância significativa (IC95%= 0,29 – 0,89) com uma alta magnitude (CCI=0,72), e uma média da diferença de – 1,3 bpm. Conclui-se que as equações previamente desenvolvidas e que não são válidas para indivíduos pós-AVE não devem ser utilizadas para se determinar a FC_{max} desses indivíduos. Recomenda-se o uso de uma das duas equações desenvolvidas especificamente para essa população, pois elas apresentaram adequada validade e podem ser facilmente utilizadas na prática clínica para predição da FC_{max}, sendo necessárias apenas a idade e a medida da FC_{pico} e/ou a distância caminhada obtidas com um dos testes clínicos: TC6 ou ISWT.

Palavras-chave: Acidente Vascular Cerebral. Frequência Cardíaca. Teste de Esforço. Teste de Caminhada.

ABSTRACT

For adequate prescription of aerobic exercise intensity for individuals after stroke it is necessary to obtain the maximum heart rate (HR_{max}). This measurement is ideally obtained through a maximal exercise test, such the Cardiopulmonary Exercise Test (CPET). However this test has low clinical applicability. Alternatively, several age-based HR_{max} prediction equations have been developed, none of them specific for individuals after stroke. This dissertation aimed: 1-to investigate the validity of six age-based prediction equations to predict the HR_{max} of individuals after stroke; 2-to develop two specific equations for individuals after stroke; and 3-to investigate the validity of the developed equations. This is a cross-sectional study. Individuals after stroke in the chronic phase were recruited. To answer objective-1, 60 individuals (54±12 years; 64±69 months after stroke) were included. Six HR_{max} prediction equations were selected for the investigation of validity: 1- 220-age, 2- 206.9 – (0.67 x age), 3- 208 – (0.7 x age), 4- 216.6 – (0.84 x age) (all designed for able-bodied individuals); 5- 164 – (0.72 x age) and 6- 200 – (0.92 x age) (both developed for individuals with coronary heart disease. The agreement between the HR_{max} obtained by the CPET and the HR_{max} predicted by the equations was analyzed using the intraclass correlation coefficient (ICC) with a 95% confidence interval (95%CI) and the Bland-Altman method (α=5%). There was no significant agreement for equations 1-5 (-0.18≤ 95%CI ≤0.79) and there was significant agreement (95%CI= 0.05-0.75), but of moderate magnitude (ICC=0.51) for equation-6. The Bland-Altman method showed that equations 1-4 and 6 overestimated the HR_{max} obtained by the CPET, and equation-6 had the lowest mean difference (2.4 beats per minute (bpm)). Therefore, the equations tested were not considered valid to predict the HR_{max} of individuals after stroke. To answer objective-2, two multiple regression analyzes were performed. The following regression models were obtained: Equation-1 (Six-minute Walking Test (6MWT)): HR_{max}= 87.655 + 0.726 (HR_{peak} in 6MWT) – 0.386 (age) (R^2=0.58, $p<0.001$) and Equation-2 (Incremental Shuttle Walking Test (ISWT)): HR_{max}= 96,523 + 0.681 (HR_{peak} in ISWT) – 0.039 (walking distance on ISWT) – 0.400 (age). (R^2=0.58, $p<0.001$) To answer objective-3, 20 individuals were included (58±8 years; 60±46 months after stroke.) The agreement between the HR_{max} obtained by the CPET and the HR_{max} predicted by the new equations was analyzed using the ICC with 95%CI and by the Bland-Altman method (α=5%). Equation-1 showed significant agreement (95%CI= 0.63 – 0.94) with a high magnitude (ICC=0.85), and a mean difference of 3.2 bpm. Equation-2 showed significant agreement (95%CI= 0 .29 – 0.89) with a high magnitude (ICC=0.72), and a mean difference of – 1.3 bpm. In conclusion, previously developed equations that are not valid for individuals after stroke should not be used to determine the HR_{max} of these individuals. The use of one of the two equations specifically developed for these individuals is recommended, as they have adequate validity and can be easily used in clinical practice to predict the HR_{max}, requiring only age and HR_{peak} measurement and/or walking distance obtained with one of the clinical tests: 6MWT or ISWT.

Keywords: Stroke. Heart Rate. Stress Test. Walking Test.

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6MWT	Six-minute walking test
AVE	Acidente vascular encefálico
BB	Beta-blocker
BPM	Batimentos por minuto
CCI	Coeficiente de correlação intraclasse
CPET	Cardiopulmonary exercise test
CI	Confidence interval
$FC_{máx}$	Frequência cardíaca máxima
FC_{pico}	Frequência cardíaca pico
ICC	Intraclass correlation coefficient
IC	Intervalo de confiança
ISWT	Incremental shuttle walking test
$HR_{máx}$	Maximum heart rate
RER	Respiratory exchange ratio
SD	Standard deviation
TC6	Teste de caminhada de 6 minutos
TECP	Teste de esforço cardiopulmonar

SUMÁRIO

PREFÁCIO

Esta dissertação foi elaborada seguindo as orientações estabelecidas na regulamentação para elaboração das Dissertações e Teses do Programa de Pós-Graduação em Ciências da Reabilitação da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da Universidade Federal de Minas Gerais (Nº004 /2018, de 03 de abril de 2018), e é composta por quatro partes. A primeira é constituída pela introdução, que contém uma revisão bibliográfica sobre o tema proposto, a problematização, e a justificativa do estudo, e os três objetivos. A segunda parte é composta pelo Artigo-1, que contempla o objetivo-1 da presente dissertação, e foi redigido de acordo com as normas do periódico *Annals of Physical and Rehabilitation Medicine* (ISSN: 1877-0657). Esse artigo foi submetido e está em processo de revisão. A terceira parte é composta pelo Artigo-2, que contempla os objetivo-2 e 3 da presente dissertação. Este artigo foi redigido de acordo com as normas do periódico *Physiotherapy* (ISSN: 0031-9406), e a sua submissão será realizada após as considerações da banca. A quarta e última parte contém as considerações finais acerca dos resultados encontrados. Por fim, é apresentado um mini currículo da autora desta presente dissertação.

1 INTRODUÇÃO

O número absoluto de indivíduos que foram acometidos por um acidente vascular encefálico (AVE) e que morreram ou sobreviveram com incapacidades aumentou nas duas últimas décadas em todo o mundo (FEIGIN *et al*., 2015). O maior número de casos de AVE continua a ocorrer nos países subdesenvolvidos ou em desenvolvimento, como o Brasil (FEIGIN *et al*., 2015). Apesar da prevalência de AVE ser maior em idosos, devido ao processo de envelhecimento da população, as internações por AVE isquêmico aumentaram para adultos jovens com idade entre 18 e 54 anos (VIRANI *et al*., 2020). Houve um aumento da incidência de AVE de 42% em homens com idade entre 35 e 44 anos entre 2003 a 2012 (VIRANI *et al*., 2020). Projeções indicam um aumento de mais de 20% da prevalência do AVE entre 2012 e 2030 (VIRANI *et al*., 2020). Assim, estima-se que os custos relacionados a cuidados de saúde dos sobreviventes mais que dobrem até 2035 (VIRANI *et al*., 2020).

Além da elevada prevalência, o AVE é também uma das principais causas de incapacidade crônica no mundo (VIRANI *et al*., 2020). Os indivíduos pós-AVE comumente apresentam diversas deficiências em estruturas e funções do corpo, como redução da aptidão cardiorrespiratória (MARSDEN *et al*., 2013), fraqueza muscular (HILL *et al*., 2012) e custo energético elevado do movimento (KRAMER *et al*., 2016). Essas deficiências contribuem para limitações nas atividades diárias, tendo esses indivíduos maior probabilidade de necessitar de auxílio para mobilidade, atividades de autocuidado e realização de atividades domésticas (SKOLARUS *et al*., 2014). Além disso, essas deficiências e limitações também contribuem para restrições na participação social (SKOLARUS *et al*., 2014) e baixa percepção de qualidade de vida (POLESE *et al*., 2014).

A ocorrência do AVE é atribuída principalmente a fatores de risco metabólicos, como hipertensão arterial sistêmica (HAS), obesidade, dislipidemia, hiperglicemia e disfunção renal, e a fatores de risco comportamentais, como tabagismo, dieta inadequada e inatividade física (FEIGIN *et al*., 2013). Alcançar o controle desses fatores de risco modificáveis poderia evitar em mais de três quartos a ocorrência global do AVE (FEIGIN *et al*., 2013). Sendo assim, é necessário a elaboração de estratégias mais eficientes de prevenção e manejo da ocorrência e recorrência do AVE e de suas diversas incapacidades associadas (FEIGIN *et al*., 2017) por meio de métodos custo-efetivos de avaliação e tratamento (VAN WIJCK *et al*., 2019). Além disso, ações de recuperação e promoção da saúde e funcionalidade também devem ser direcionadas a esta população (BILLINGER *et al*., 2013).

O exercício aeróbio ajuda a reduzir os fatores de risco modificáveis que levam a ocorrência e recorrência do AVE (VAN WIJCK *et al*., 2019). Os resultados de alguns estudos mostraram que o exercício aeróbio pode ser eficaz para reduzir a pressão arterial sistólica (D'ISABELLA *et al*., 2017), aumentar as lipoproteínas de alta densidade (colesterol HDL) (D'ISABELLA *et al*., 2017) e melhorar o nível de atividade física (AGUIAR *et al*., 2018) em indivíduos pós-AVE. Além disso, o exercício aeróbio pode ajudar a quebrar o ciclo vicioso de incapacidades decorrentes do AVE, melhorando a aptidão cardiorrespiratória (SALTYCHEV *et al*., 2016), a capacidade de caminhada, incluindo resistência e velocidade de marcha (SAUNDERS *et al*., 2016), a saúde vascular (D'ISABELLA *et al*., 2017) e a qualidade de vida (CHEN *et al*., 2011). Portanto, essa intervenção deve ser incorporada na rotina de reabilitação desses indivíduos (MACKAY-LYONS *et al*., 2019). Os guias clínicos atuais recomendam que adultos devem realizar pelo menos de 150 a 300 minutos por semana de exercício aeróbio de intensidade moderada, ou 75 a 150 minutos por semana de exercício aeróbio de intensidade alta, ou uma combinação equivalente desses (PIERCY *et al*., 2018). Essas recomendações também se aplicam a indivíduos pós-AVE. Caso esses não sejam capazes de aderir a essas recomendações devido à severidade da doença e/ou deficiências associadas, ainda é indicado a realização do exercício aeróbio de acordo com as habilidades individuais, a fim de prevenir a inatividade física (PIERCY *et al*., 2018).

O exercício aeróbio pode ser definido como qualquer exercício físico que envolva a ativação repetida de grandes grupos musculares de maneira rítmica e por um período de tempo prolongado (PANG *et al*., 2013), podendo consistir em caminhada no solo ou na esteira, ciclismo e natação, por exemplo (BILLINGER *et al*., 2014). Para a adequada prescrição do exercício aeróbio deve-se estabelecer quatro parâmetros: tipo ou modalidade (utilização de cicloergômetros ou esteiras ergométricas), frequência (dias/semanas), duração (minutos ou horas) e intensidade (nível de esforço) (BILLINGER *et al*., 2014, PIERCY *et al*., 2018). Considerando indivíduos acometidos pelo AVE, as recomendações para estes parâmetros são: a modalidade do treino deve ser baseada nas deficiências e limitações decorrentes do AVE, comorbidades associadas, preferência do indivíduo, disponibilidade de equipamentos e objetivos de tratamento (BOYNE *et al*., 2017, IVEY *et al*., 2016). Cicloergômetros de membro superior e/ou membro inferior, além de esteiras ergométricas ou caminhada no solo podem ser utilizados como modalidades de treinamento (SAUNDERS *et al*., 2016); a frequência recomendada para realização do exercício aeróbio é de no mínimo três vezes por semana (MACKAY-LYONS *et al*., 2019) e nos demais dias os indivíduos devem ser estimulados a praticar outra atividade física leve (MACKAY-LYONS *et al*., 2019); a duração recomendada do exercício aeróbio é de 20 a 60 minutos por sessão (SAUNDERS *et al.*, 2016, BILLINGER *et al.*, 2014) , com períodos de aquecimento e resfriamento de três a cinco minutos (MACKAY-LYONS *et al.*, 2019). Para aqueles indivíduos com condicionamento cardiorrespiratório muito baixo ou que apresentem muitos déficits motores, o exercício pode ser realizado em intervalos de 10 minutos, com períodos de descanso ou de atividade de intensidade leve entre os intervalos (MARSDEN *et al.*, 2013); a duração do programa recomendada é de pelo menos oito semanas (IVEY *et al.*, 2008), entretanto a prática de atividade física deve ser estimulada continuamente.

A intensidade do exercício aeróbio deve ser determinada individualmente, com base nas respostas a um teste de exercício, além de frequência e duração planejadas do exercício (MACKAY-LYONS *et al.*, 2019). Estabelecer e monitorar a intensidade do exercício aeróbio determina o nível de estresse fisiológico imposto, diminui as chances de respostas adversas decorrentes da prescrição inadequada e é a principal responsável para garantir uma dosagem adequada a fim de provocar um efeito de treinamento (MACKAY-LYONS *et al.*, 2019).

A intensidade do treino aeróbio pode ser prescrita e monitorada de diversas maneiras, como com a mensuração da frequência cardíaca (FC), da taxa de consumo do oxigênio e da percepção subjetiva de esforço (PESCATELLO *et al.*, 2014). Na reabilitação de indivíduos pós-AVE, a intensidade do exercício aeróbio é comumente prescrita de forma similar aos programas de reabilitação cardíaca (REGAN *et al.*, 2019), com base na porcentagem da frequência cardíaca máxima (FC_{max}) (FC alvo = %alvo x FC_{max}) ou pela porcentagem da frequência cardíaca de reserva (FCR) (FC alvo = ([FC_{max} – FC de repouso] x %alvo) + FC de repouso) (BILLINGER *et al.*, 2014). A utilização dessas fórmulas permite classificar o exercício aeróbio em três intensidades: baixa (<40% da FCR ou <64% da FC_{max}), moderada (40-60% da FCR ou 64-76% da FC_{max}) e alta (>60% da FCR ou >76% da FC_{max}) (MACKAY-LYONS *et al.*, 2019, PESCATELLO *et al.*, 2014). A intensidade recomendada para realização do exercício aeróbio em indivíduos pós-AVE é de 40 a 70% da FCR ou 55 a 80% da FC_{max} (BILLINGER *et al.*, 2014).

A principal forma para se obter a FC_{max} de um indivíduo, que é utilizada em ambas as fórmulas para a prescrição da intensidade do exercício aeróbio, é por meio da realização de um teste de esforço máximo, como o teste ergométrico convencional ou o Teste de Esforço Cardiopulmonar (TECP) com análise de gases expirados, durante o processo de avaliação (SAUNDERS *et al.*, 2016). O TECP é um teste não invasivo e considerado um critério de referência para avaliação da aptidão cardiorrespiratória (DOYLE *et al.*, 2013, MENENGHELO *et al.*, 2010). Entretanto, para realização do teste é necessária uma equipe especializada, que deve envolver um médico com capacidade e habilitação para realizar suporte de vida avançado, além da aquisição de equipamentos de alto custo, como esteira, analisador de gases e desfibrilador. Esses fatores tornam a aplicabilidade clínica do TECP limitada (TYSON *et al*., 2009).

Uma alternativa empregada na prática clínica é a estimativa da FC_{max} por meio de equações de predição baseadas na idade (PESCATELLO *et al*., 2014), sendo a mais utilizada, a equação proposta por Fox *et al*. (1972) (220 - idade) (FOX *et al*., 1972). Essa equação é uma estimativa baseada em observações de uma série de dados no ano de 1971 de um grupo de indivíduos saudáveis, porém nenhuma análise de regressão foi realizada com esses dados (FOX *et al*., 1972). Outras equações também foram desenvolvidas, baseadas em dados de homens e mulheres adultos saudáveis (ROBERGS *et al*., 2002, ASTRAND *et al*., 1952, GELLISH *et al*., 2007). Na maior parte desses estudos foram obtidas equações tendo como única variável preditora a idade, que nesses estudos determinou até 80% da variabilidade da FC_{max} em indivíduos adultos saudáveis (TANAKA *et al*., 2001). De acordo com um estudo realizado em uma amostra brasileira (CAMARDA *et al*., 2008), as equações de Fox e Tanaka são semelhantes para a predição da FC_{max} e apresentam boa correlação com a FC_{max} mensurada pelo TECP. Apesar disso, essas equações de predição podem não ser adequadas para todos os indivíduos.

De acordo com os resultados de uma revisão sistemática, as equações de predição baseadas na idade elaboradas a partir de dados de adultos não foram aplicáveis em crianças e adolescentes (CICONE *et al*., 2019). O resultado cumulativo de sete estudos demonstrou que a equação sugerida por Fox *et al.* (1972) superestimou a FC_{max} em cerca de 12,4 bpm (p<0,05). Esco *et al*. (2015) concluíram que equações de predição baseadas na idade devem ser usadas com cautela em mulheres atletas universitárias. Eles identificaram que as equações sugeridas por Fox *et al*. (1972), Tanaka *et al*. (2001) e Astrand *et al*. (1952) superestimaram a FC_{max} atingida no TECP (p<0,001), sendo que o erro total da estimativa foi de 13,9 e 13,3 bpm para as equações de Fox *et al*. (1972) e Astrand *et al*. (1952), respectivamente. Silva *et al.* (2006) identificaram que as equações de Fox *et al*. (1972) e Tanaka *et al*. (2001) superestimaram a FC_{max} atingida no TECP em idosas brasileiras, por uma diferença média de 7,5 e 15,5 bpm, respectivamente. Devido a estes resultados, diversos estudos propuseram a criação de novas equações de predição da FC_{max}, específicas para determinadas populações, incluindo indivíduos com deficiência intelectual (FERNHALL *et al*., 2001), doenças cardíacas (BRAWNER *et al*., 2004, CASILLAS *et al*., 2015, GODLASKY *et al*., 2018), jogadores de futebol (NIKOLAIDIS *et al.*, 2015), crianças e adolescentes (GELBART *et al.*, 2017) e indivíduos obesos (MILLER *et al.*, 1993).

Casillas *et al.* (2014), por exemplo, desenvolveram uma equação de predição da FC_{max} para indivíduos coronariopatas. Nessa equação foram incluídas idade e FC atingida ao final de um teste clínico (teste de caminhada rápida de 200 metros). Entretanto, não foi encontrado nenhum estudo que tenha proposto uma equação de predição da FC_{max} para indivíduos pós-AVE. Apenas Boyne *et al.* (2015) desenvolveram uma equação de predição da FC do limiar ventilatório para indivíduos pós-AVE na fase crônica. A equação proposta não incluía a idade, mas incluía a FC_{max} obtida no TECP, o sexo e a velocidade de marcha mensurada no teste de caminhada de 10 metros. Entretanto, essa equação não se mostra aplicável no contexto clínico, visto que ainda seria necessário a realização do TECP para determinar a FC_{max}, já que essa variável está incluída na equação.

Alguns estudos já realizados tiveram como objetivo avaliar as respostas fisiológicas de indivíduos pós-AVE, nas fases aguda (MACKAY-LYONS *et al.*, 2002) e crônica (MACKO *et al.*, 1997), durante a realização do TECP. Eles identificaram que a FC_{max} atingida no TECP ocorre em média entre 75 a 85% da FC_{max} estimada (MACKAY-LYONS *et al.*, 2002) pela equação de predição mais utilizada (220-idade). Isso demonstra que a FC_{max} real é inferior a FC_{max} estimada pela equação de Fox *et al.* (1972). Sendo assim, utilizar a FC alvo determinada por meio da FC_{max} estimada por essa equação, ao determinar a intensidade do exercício, provavelmente resultará em uma intensidade mais alta do que o apropriado.

Segundo Robergs *et al.* (2002), há uma necessidade de elaboração de equações que sejam específicas para populações e também multivariadas, incluindo variáveis além da idade, que possam determinar a FC_{max} dos indivíduos. Assim, os dados de testes clínicos submáximos, como o Teste de Caminhada de Seis Minutos (TC6) (HOLLAND *et al.*, 2014) e o *Incremental Shuttle Walking Test* (ISWT) (SINGH *et al.*, 1992), que são amplamente utilizados na prática clínica para avaliar a capacidade de exercício e que se mostram como alternativas ao TECP, poderiam ser utilizados para estabelecer uma equação de predição da $FC_{max.}$ Ambos os testes são considerados de baixo custo e de fácil aplicação (PARREIRA *et al.*, 2014).

O principal desfecho mensurado pelo TC6 é a distância total percorrida ao caminhar em um corredor de 30 metros durante seis minutos (SINGH *et al.*, 2014). Além da distância, também são coletados o maior valor de FC atingida no teste, a saturação periférica de oxigênio e a percepção subjetiva de esforço (HOLLAND *et al.*, 2014). Já o ISWT é um teste progressivo e incremental, composto por 12 estágios e realizado em um corredor de 10 metros, com velocidade cadenciada e controlada por sinais sonoros (SINGH *et al*., 1992). O principal desfecho mensurado também é a distância total percorrida, mas além dessa também são coletados o maior valor da FC atingida no teste, velocidade máxima de marcha alcançada e tempo total do teste (HOLLAND *et al*., 2014).

Considerando a importância da adequada prescrição da intensidade do exercício aeróbio em indivíduos pós-AVE, se faz necessária a obtenção da FC_{max}, o que pode ser feito por meio do TECP. Considerando a dificuldade de realização do TECP no contexto clínico, a utilização de equações de predição se torna uma alternativa viável. Contudo, as equações de predição existentes podem não se aplicar a população de indivíduos pós-AVE. Não foi encontrado nenhum estudo que tenha investigado a validade dessas equações já disponíveis na literatura para predição da FC_{max} de indivíduos pós-AVE. Também não foi encontrada nenhuma equação de predição que tenha sido desenvolvida especificamente para estimar a FC_{max} de indivíduos pós-AVE. Sendo assim, é importante investigar a validade das equações já desenvolvidas para estimar a FC_{max} de indivíduos pós-AVE, e determinar se uma nova equação elaborada especificamente para esses indivíduos, incluindo variáveis que possam explicar melhor a variância da FC_{max} e que possam contribuir para uma adequada prescrição do exercício aeróbio pós-AVE. Tendo em vista que testes clínicos como o TC6 e o ISWT são amplamente utilizados no processo clínico de avaliação desses indivíduos, os dados obtidos com esses testes podem ser utilizados para elaboração das equações de predição, além de apresentarem o potencial de contribuírem para o desenvolvimento de equações com maior poder preditivo.

1.1 OBJETIVOS

A presente dissertação apresentou três objetivos que foram abordados por meio do desenvolvimento de dois estudos transversais, apresentados em dois artigos distintos:

1. Artigo-1 (abordou o objetivo-1 da presente dissertação): (1) Investigar a validade de seis equações de predição da FC_{max} baseadas na idade já disponíveis na literatura para predizer este desfecho em indivíduos pós-AVE na fase crônica;
2. Artigo-2 (abordou os objetivo-2 e 3 da presente dissertação): (2) Desenvolver duas equações de predição da FC_{max} para indivíduos pós-AVE na fase crônica, com adequada aplicabilidade clínica, tendo como variáveis preditoras características dos indivíduos e desfechos mensurados em testes clínicos (TC6 e ISWT); e (3) Investigar

a validade das equações desenvolvidas para predizer a FC_{max} com um grupo de indivíduos pós-AVE na fase crônica que não tenham participado dos estudos desenvolvidos para atender os dois objetivos anteriores.

2 ARTIGO-1

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Title: Age-predicted equations are not valid in predicting maximum heart rate in individuals after stroke

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Abstract

Background and purpose: To investigate the validity of six age-predicted maximum heart rate (HR_{max}) equations in individuals after stroke. **Methods:** In this cross-sectional study sixty individuals (54 (12) years; 64 (69) months after stroke) were included. The HR_{max} was obtained by a Cardiopulmonary Exercise Test (CPET). The six most used equations recommended by clinical guidelines to predict the HR_{max} were investigated: 1- 220-age, proposed by Fox et al.; 2- 206.9 – (0.67 x age), proposed by Gellish et al.; 3- 208 – (0.7 x age), proposed by Tanaka et al.; 4- 216.6 – (0.84 x age), proposed by Astrand et al. (all developed for able-bodied individuals); 5- 164 – (0.72 x age) and 6- 200 – (0.92 x age) proposed by Brawner et al. (both developed for individuals with Coronary Heart Disease (CHD)). **Results:** Non-significant agreement was found between the HR_{max} obtained by the CPET and the one predicted by the equations 1-5 (-0.18≤ 95% confidence interval (CI) ≤0.79). Significant and moderate agreement was found between the HR_{max} obtained by the CPET and the one predicted by the equation-6 (95% CI= 0.05 to 0.75; Intraclass Correlation Coefficient (ICC)= 0.51). Bland-Altman plots showed that the equations 1-4 and 6 overestimated the HR_{max}. Equation-6 presented the lower mean difference (2.4 beats per minute). **Discussion and conclusions:** The equations developed for able-bodied individuals are not adequate to be used in individuals after stroke. Equation-6 (developed for individuals with CHD) showed the best results, however it should be used with caution.

Key words: Aerobic exercise; Cardiopulmonary exercise test; Heart rate; Stroke.

INTRODUCTION

Stroke is a major cause of chronic disability worldwide [1], leading to muscle weakness [2] and increased energy cost of movement [3] that can contribute for a reduction of cardiorespiratory fitness [4], which generate a vicious cycle of impairments [5]. In addition, these individuals have limitations in essential daily activities and more participation restrictions than matched control individuals [6].

Aerobic exercise is one of the strategies that contributes to the reduction of stroke modifiable risk factors [7], in addition to help in reducing disabilities resulting from this condition [4], such as reduced cardiorespiratory fitness [8], walking ability [9] and vascular health [10]. The most important parameter of the aerobic exercise prescription is the intensity [11], from both a safety and efficacy point of view, related to a greater improvement in cardiorespiratory fitness [9]. Establishing and monitoring the intensity of aerobic exercise decreases the chances of adverse responses and is primarily responsible for an effective training [9].

The intensity of aerobic exercise is commonly prescribed by the percentage of the heart rate reserve (HRR), through the Karvonen formula [12]: target heart rate (HR)= ([maximum heart rate (HR_{max}) - resting HR] x %target) + resting HR [13]. The ideal way to obtain the HR_{max} of an individual, which is used in this previous formula, is through a maximum Cardiopulmonary Exercise Test (CPET) [4]. However this test requires a specialized team and the acquisition of high-cost equipment [14], which limits its clinical applicability. In a study developed with physical therapists in Canada, only 2% of the respondents declared that they use the CPET as a tool for screen for safety and indications to participate in aerobic exercise in adult neurological rehabilitation [14]. In another study developed with physical therapists in the United States, only 4% determine initial aerobic exercise intensity by %HRR based on HR_{peak} from a CPET in stroke rehabilitation [15]. An alternative to solve this problem is the estimation of the HR_{max} by age-predicted equations [16], which have been more used to determine the intensity of aerobic exercise, both in able-bodied individuals and in individuals after stroke [11,16]. In the study of Boyne et al. [15], 17% of the physical therapists used the HRR based on predicted HR_{max}. In addition, most respondents used subjective methods, such as general observed response (95%) [15].

In addition to the limitations regarding clinical applicability, the CPET has other limitations regarding its validity in individuals after stroke. These individuals have motor and neurological impairments, which can interfere with the ability to reach maximum levels of effort during the test [17]. Despite this, whenever feasible, the CPET remains a component of pre-participation screening for aerobic training after stroke. In this way, an individualized aerobic exercise program can also be guaranteed, when possible [11]. The age-predicted equations are only predictions of the HR_{max}, that were built with data from able-bodied individuals and that also have their limitations [18].

The HR_{max} is defined as the highest HR achieved during the CPET and is also characterized by a plateau despite an increase in workload [19]. However, this is not reliably achieved by individuals with chronic diseases such people with coronary heart disease (CHD) [20] and individuals after stroke [21]. Despite that, it is still possible to measure the HR reached at the peak of exercise during the CPET, which would be the value used in these situations [22-24].

The equation proposed by Fox et al. [25] (HR_{max}= 220 - age) has being the most used to predict HR_{max} of the general population [26]. The origin of this equation has been questioned because it was observationally derived from reviewed research from a group of able-bodied individuals, and not from original data using regression modeling [26]. It has been reported that this equation significantly overestimates the HR_{max} in young adults and underestimates it in older adults [22,23]. Other equations have also been developed, especially based on data from able-bodied adults [16,26]. A major limitation of these equations is their lack of applicability to specific populations [26]. Some studies have identified that some equations may overestimate the measured HR_{max} of children and adolescents [27], young university adults [28], female university athletes [29] and older woman [30]. Thus, we can see that these equations have their limitations even in able-bodied individuals, as shown in the studies mentioned [27-30].

A recent guideline developed in 2019 [11], with aerobic exercise recommendations for individuals after stroke, recommend the use of the prediction equations of Fox [25], Gellish [22] and Brawner [24]. The last one been indicated for individuals on use of beta-blocker (BB) medication. However, none of the equations were developed with data from individuals after stroke. In addition, it was not found any study that has investigated whether these equations are valid for this population. Therefore, the purpose of this study was to investigate the validity of the main six age-predicted HR_{max} equations in individuals after stroke.

METHODS

Design and Participants

This is a cross-sectional validity study approved by the Institutional Review Board. Individuals were recruited by contact with those who have participated in previous research projects and by advertising in public spaces in the city and on social networks. All participants gave written informed consent before data collection began.

The following inclusion criteria were adopted: have a clinical diagnosis of stroke in the chronic phase (≥ 6 months) [31]; be aged ≥ 20 years; and be able to walk independently, with or without the aid of a walking device, for at least 10 minutes (this time was established because it is the average acceptable time for the duration of the CPET) [32]. The exclusion criteria were: positive result in screening for possible cognitive impairments through the

Mini-Mental State Exam, using the cutoff points based on the educational level [33]: 13 points for individuals who had no schooling, 18 points for those with low and medium schooling and 26 points for those with high schooling, and/or aphasia of comprehension, analyzed by the competence to respond, through body movements, to verbal commands [34]; and the presence of pain or other health condition that impairs the performance of the CPET. To perform the sample size calculation, the recommendation of the Consensus-Based Standards for the Selection of Health Measurement Instruments (COSMIN) [35] was used. Therefore, a minimum sample size of 50 individuals was required.

Procedures

Data collection was performed at a university laboratory and were collected by previously trained examiners in all procedures. Initially, the examiners checked the eligibility criteria and then clinical demographic information (age, sex, time since stroke, type of stroke, hemiparetic side, use of BB medication, comfortable gait speed by the ten-meter walk test [36] and lower limb motor recovery by the lower limb section of the *Fugl-Meyer* scale [37]) were collected for the characterization of the sample.

Maximum heart rate (HR_{max})

The HR_{max} was obtained by the CPET that is considered safe to be performed in individuals after stroke [17]. This test was conducted by a team of trained health professionals and according to the recommendations of the American College of Sports Medicine (ACSM) [16]. The ergometer used for the test was a treadmill [38]. A progressive ramp protocol was used [32] and a warm-up period was carried out for three minutes and increments were applied at each one-minute interval. After the end of the test, the participants performed three minutes of walking without inclination and had more three minutes of seated rest [32].

The initial and incremental speed in km/h, the initial inclination and the percentage of increment was determined for each participant, based on a previously established ramp protocol [32]. A table with minimum and maximum velocity and inclination to be reached in the exercise test for each age decade and sex was used [32]. However, in some cases it needed to be individually adapted for each participant, so that the maximum effort was achieved.

The following variables were recorded during the test: blood pressure measured manually every two minutes during the incremental; electrocardiographic records; expired gases and the HR_{max}. The last 30 seconds of the test were divided into 3 blocks of 10 seconds and the HR_{max} was obtained by the highest average of these 3 blocks [39].

No gold standard about the criteria for achieving maximum effort during the CPET in individuals after stroke has been identified. Some of that are: levelling of the maximum oxygen consumption (VO_{2max}) despite increase in workload, percentage of the age-predicted HR_{max} and a respiratory exchange ratio (RER) exceeding a certain level [21]. Since most individuals terminate the CPET before the criteria for VO_{2max}, it is common to report secondary criteria with the objective to judge the individual maximum effort and interpret the test results. The most common one is a RER cut-off value ranging from 1.0 to 1.15. Therefore, the test was considered to be of maximum effort if the RER was greater than 1.0 [21]. The CPET was interrupted if the participant requests it or if the professionals detect any adverse signs or symptoms [40].

Age-predicted maximum heart rate (HR_{max}) equations

Six previously developed equations were selected [22-25,41] to investigate the validity (Table 1).

[Table 1 here]

The equations of Fox, Gellish, Tanaka and Astrand (1 to 4) [22,23,25,41] were developed for able-bodied adults, while the equations of Brawner (5 and 6) [24] for individuals with CHD, being the equation-5 developed for individuals in use of BB medication and the equation-6 for individuals without using BB. The equations of Fox [25] and Gellish [22] were selected because they are recommended to be used to prescribe aerobic exercise in individuals after stroke, according to a recent guideline [42]. The equations of Tanaka [23] and Astrand [41] were selected because they are recommended by the ACSM [16]. The equations of Brawner [24] were selected considering that stroke is also a vascular condition, in addition to some individuals making use of BB medication [1]. Moreover, the equation of Brawner (for individuals that use BB) [24] was also recommended to be used for prescribing aerobic exercise in individuals after stroke [42] that use this medication.

Data Analysis

Descriptive statistics was performed for all variables of characterization of the sample and main outcomes. The intraclass correlation coefficient (ICC) with 95% confidence interval (CI) [43] was used to verify the agreement between the HR_{max} obtained by the CPET and the predicted HR_{max} by the six selected prediction equations. The validity of the ICC analysis was verified considering the p value of the F test, as recommended by Portney and Watkins (2015) [43]. Significant agreement was classified considering the 95% CI since it provided more information than the p value [43,44]. In addition, the 95% CI can indicates the statistical significance, providing a plausible range of values for the true effect, besides revealing the precision of the estimate [44]. The magnitude of the significant agreements was classified as follows: 0-0.25 very low; 0.26-0.49 low; 0.50-0.69 moderate; 0.70-0.89 high; 0.90-1.00 very high [45]. The accuracy and variability of the prediction equations was assessed using the Bland-Altman analysis [46]. On the plots, in the y axis the difference of the measures was reported and in the x axis their mean [47]. All analyses were performed using the SPSS statistical package for Windows® (SPSS Inc., Chicago, IL, USA, version 19.0). The level of significance was set at 5%.

RESULTS

One hundred and eighty-four individuals were contacted by telephone. One hundred and thirteen individuals were not available to participate in the study. A total of 71 individuals were assessed and 60 individuals were included in the study. The mean age was 54 (12) years and the median time since stroke onset was 64 (69) months. The majority of these individuals were men (n=40; 66.7%) and did not use BB (n=37; 61.7%). Clinical-demographic characteristics of the participants are presented in Table 2.

[Table 2 here]

All statistical analyzes of the ICC proved to be adequate ($0.002 \leq p \leq 0.044$). An imprecise and non-significant agreement with all 95% CI wide and going through zero (-0.18≤ 95% CI ≤0.63) was found between the HR_{max} obtained by the CPET and the predicted HR_{max} by the equations 1-4 (Fox, Gellish, Tanaka and Astrand) [22,23,25,41]. (Table 3). To exclude the possibility that this result occurred due to the fact that equations 1-4 were developed for individuals who did not use BB, a second analysis was performed. Equations 1-4 were applied only to part of the sample that did not use BB (n=37). Once again, an imprecise and non-significant agreement with all 95% CI wide and going through zero (-0.20≤ 95% CI ≤0.60) was found between the HR_{max} obtained by the CPET and the predicted HR_{max} by the equations 1-4 (Fox, Gellish, Tanaka and Astrand) [22,23,25,41] (Supplementary material).

Equation-5 was applied only with the part of the sample that used BB (n=23), while equation-6 was applied only with the part of the sample that did not use BB (n=37), considering that in the study development of these equations [24], they were developed for individuals with CHD who did not use/ use BB. Once again, imprecise and non-significant agreement (-0.06≤95% CI≤0.79) was found between the HR_{max} obtained by the CPET and the predicted HR_{max} by the equations-5 (Brawner-BB) [24]. Significant (0.05≤95% CI≤0.75) and moderate (ICC=0.51) agreement was found only between the HR_{max} obtained by the CPET and the predicted HR_{max} by the equations-6 (Brawner- no BB) [24]. The results were also shown in Table 3.

[Table 3 here]

Bland-Altman plots are shown in Figures 1 and 2. The mean difference of the equations varied between -7.7 to 29.1 beats per minute (bpm). Equations 1-4 and 6 (Fox, Gellish, Tanaka, Astrand and Brawner-no BB) [22-25,41] overestimated $HR_{max,}$ with the greatest difference occurring in equation-4 (29.1 bpm) and the smallest in equation-6 (2.4 bpm). Equation-5 (Brawner-BB) [24] underestimated HR_{max} by a difference of -7.7 bpm. Considering the limit of over/underestimation of the HR_{max} considered inacceptable established by Robergs et al. [26] (above 8 bpm), equation-1 presented 70% of the predicted values above 8 bpm, equation-2 presented 80%, equation-3 presented 78.3%, equation-4 presented 83.3%, equation-5 presented 52.2% and equation-6 presented 73% of the predicted values above 8 bpm. The plots generated with the application of equations 1-4 only in the part of the sample that not used BB (n=37) were also generated. All equations overestimated the HR_{max} values obtained by the CPET (Supplementary material).

[Figures 1 and 2 here]

DISCUSSION

The results of the present study showed that the main equations used to predict the HR_{max} that were developed with data of able-bodied individuals did not present an adequate agreement with the HR_{max} obtained by the CPET when used in individuals after stroke. The equations developed with data from individuals with CHD presented a moderate magnitude of agreement with the HR_{max} obtained by the CPET. The equation-6 (Brawner-no BB) [24] presented the best results, which indicates that within the available ones, it should be chosen to be used, but with caution.

Some previous studies had the objective of evaluating the physiological responses of individuals after stroke, in the acute [48] and chronic phases [49], during the performance of the CPET. They identified that the HR_{max} reached in CPET occurs on average between 75 to 85% of the HR_{max} estimated by Fox's equation [48]. This demonstrates that the HR_{max} obtained by the CPET is lower than the HR_{max} estimated by this equation, which was also observed in the present study. Many studies have long questioned the limitations of the Fox's equation [22,23,26], which despite being recommended and widely used in the clinical context, it was observationally derived from reviewed research and not from original data using regression modeling [26].

Cleary et al.[28] investigated the validity of the equations from Fox, Gellish, and Tanaka [22,23,25] to predict the HR_{max} of 96 able-bodied volunteers aged 18 to 33 years recruited from health and physical education classes from a university. They found that the predicted HR_{max} by Fox's equation was significantly different ($p<0.0001$) from measured HR_{max}. The Fox's equation overestimates the measured HR_{max} by a mean of 12 (7) bpm. Due to these questions, as mentioned, other studies have emerged with the proposal to create others HR_{max} prediction equations.

Gellish et al. [22] develop a retrospective study that examined data of 132 able-bodied individuals with 44 (9.6) years. They created new equations to predict the HR_{max}, (being the most indicate equation used in this study). This equation is also considered to be more accurate than the Fox's equation and recommended for use in individuals after stroke in a recent clinical guideline for prescribing aerobic exercise in these individuals [42]. However, as shown in the present study, Gellish's equation did not prove adequate to be used in individuals after stroke, as was also observed in the study of Cleary [28], proving that this equation overestimates the HR_{max} in individuals after stroke.

Esco et al. [29] evaluated a sample of 30 female collegiate athletes aged 19 to 25 years and found that the equations of Fox, Astrand and Tanaka [23,25,41] significantly overestimated mean HR_{max} obtained by the CPET ($p<0.01$). The trend between the mean and difference of the HR_{max} values were significantly negative for all prediction equations, showing the overprediction of the HR_{max} by more than 10 bpm [29]. The Bland-Altman plots of the present study showed that the mean difference in equations-1, 2 and 4 (Fox, Gellish and Astrand) [22,25,41] was between 23.8 to 29.1 bpm, showing large values of overestimation of the HR_{max}.

The equation proposed by Tanaka et al. [23] is also considered one of the most accurate general HR_{max} prediction equations developed for able-bodied adults [22]. In their research, age alone explained almost 80% of the individual variance in HR_{max} [23]. However, as observed in the present study, Tanaka's equation was not adequate to predict the HR_{max} of individuals after stroke, since this equation overestimated the HR_{max} in these individuals. In the studies of Cleary [28] and Esco [29] performed with other populations, Tanaka's equations also overestimated the HR_{max}.

In all previous equations included in these studies, age was the only variable included. Age has been established as the best predictor of HR_{max} in able-bodied individuals and has been demonstrated that the HR_{max} decrease with age [22, 23,25] approximately 3-5% per decade [22]. However, the results of the present study demonstrate that age alone may not be the best predictor of HR_{max} in individuals after stroke, considering that all equations that have only this variable as a predictor were not considered accurate to be used in this population.

Another factor that can influence the HR_{max} is the use of medications with negative chronotropic action (especially BB), significantly decreasing the HR_{max} [50]. As this medication is widely used in individuals with CHD, Brawner et al. [24] developed two HR_{max} prediction equations: one for individuals who use BB medication and another for individuals who did not use. The presence of the zero in the 95% CI in the equation-5 (use of BB) and the large 95% CI (0.05 – 0.75) in the equation-6 (not use of BB), demonstrate that these equations are not totally suitable for use in individuals after stroke. However, the equations proposed by Brawner [24] were those that showed the best results when compared to the equations of the other included studies. In the Bland-Altman analysis, the equation-5 had an average difference of -7.7 bpm and the equation-6 an average difference of only 2.4 bpm. This probably occurred due to the fact that stroke is also a vascular health condition, and both individuals after stroke and individuals with CHD have similar disabilities, such as reduced cardiorespiratory fitness [1].

Clinical Implications

The low agreement between the HR_{max} obtained by the CPET and the values predicted by the evaluated equations directly interfere in the prescription of aerobic exercise for individuals after stroke. Considering the average HR_{max} obtained by the CPET and the one predicted using the equation-3 (Astrand) [41] (which obtained the highest overestimation value), the use of this equation will result in a targeted exercise intensity above the recommended. This can compromise the safety of the individuals during exercise.

Considering a moderate intensity of aerobic exercise (40-60% of the HRR) and a resting HR of 70 bpm, the real target HR would be 99-113 bpm. In contrast, the target HR using the Astrand's equation would be 110-131 bpm. According to Robergs et al. [26], for purposes of prescribing training HR ranges, individual errors greater than 8 bpm are considered inacceptable. Only the equations-5 and 6 showed a mean error within this limit. Considering these limits established by Robergs et al. [26], all equations (1-5) resulted in more than 50% of participants with unacceptable errors in predictions, varying between 52.2 and 83.3%.

Limitations

This study has some limitations, such as the recruitment of a convenience sample with individuals in the chronic phase post-stroke who were able to walk for at least 10 minutes, all of which were classified as having limited or complete community ambulation status, which limits the generalization of the results.

The assessment of the cardiorespiratory fitness of individuals after stroke using the CPET is more challenging when compared to able-bodied individuals. This is due to the fact of the occurrence of stroke-specific impairments, such as muscle weakness, fatigue, contractures, spasticity and balance problems, which can compromise the test results. Marzolini et al. [17] reported that, at the start of an exercise intervention, 68.4% of the CPETs (n=98) provided sufficient information to prescribe aerobic exercise intensity in persons after stroke (≥3 months), suggesting that some individuals do not reach the limits of their aerobic capacity. After 6 months of the exercise intervention (n=85), the percentage was 84.7%, when the participants were already in the chronic phase of the stroke. In spite of this, all CPETs protocols were followed in order to achieve maximum effort. The average peak of the RER (1.1) is above the value established to confirm the maximum effort (1.0), which is the main criterion used in the previous studies conducted with this population, to determine the maximum effort in the CPET [21].

CONCLUSIONS

The present study was the first to investigate the validity of the main HR_{max} prediction equations available in the literature to predict this outcome in individuals after stroke. The results showed that the age-predicted HR_{max} equations developed for able-bodied individuals are not valid in predicting this outcome in individuals after stroke. Since these equations have been used to prescribe aerobic exercise, some of them recommended in specifically clinical guidelines regarding aerobic training in stroke [42], this training might not have been prescribed in the most appropriate way in these individuals, due to an overestimation of HR_{max} values, which consequently can lead to higher intensity than adequate. Therefore, the results of this study can change the current recommendations presented in these guidelines.

The age-predicted HR_{max} equation developed for individuals with CHD (equation-6) showed better results. However, it should still be used with caution, considering the large 95% CI and that only a moderate magnitude agreement was found.

The CPET, when available, is indicated to be used in individuals after stroke, as part of the evaluation for the participation in an aerobic exercise program [42]. However, it is important to consider that this test has limitations, both in relation to its clinical applicability, as well as its limitations for individuals with motor impairments. Considering that most of the widely used HR_{max} prediction equations have not been shown to be adequate for use, it is necessary to think of an appropriate exercise test that determines the best exercise prescription. Some submaximal tests are already used in this population. However, it is still necessary to investigate their usefulness as a way of prescribing the intensity of aerobic exercise. Another alternative is to think about the possibility of developing a specific prediction equation for these individuals, that may be more accurate in predicting the HR_{max}.

Declarations of Interest: None.

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Table 1. Age-predicted maximum heart rate (HR_{max}) equations selected.

Age-predicted equations	
Equation 1 (Fox)[25]	HR_{max}= 220 - age
Equation 2 (Gellish)[22]	HR_{max}= 206.9 - (0.67 x age)
Equation 3 (Tanaka)[23]	HR_{max}= 208 - (0.7 x age)
Equation 4 (Astrand)[41]	HR_{max}= 216.6 - (0.84 x age)
Equation 5 (Brawner- BB)*[24]	HR_{max}= 164 - (0.72 x age)
Equation 6 (Brawner- no BB)†[24]	HR_{max}= 200 - (0.92 x age)

BB: beta-blocker medication.

*proposed by Brawner for individuals who use BB;

†proposed by Brawner for individuals who do not use BB.

Table 2. Characteristics of participants.

Characteristics	n=60
Age (years): mean (SD); [min-max]	54 (12) [27-82]
Sex: male, n (%)	40 (66.7)
Time since stroke (months): mean (SD)	64 (69)
Type of stroke, ischemic, n (%)	49 (81.7)
Hemiparetic side: right, n (%)	32 (53.3)
BB: no, n (%)	37 (61.7)
Lower limb motor impairments (Fugl-Meyer scores: 0-34), n (%)	
Mild	40 (66.7)
Moderate	14 (23.3)
Moderately severe	3 (5.0)
Severe	3 (5.0)
Comfortable gait speed (m/s): mean (SD); [min-max]	1.0 (0.3) [0.5-1.7]
Classification of gait speed, n (%)	
Limited community ambulation status	16 (26.7)
Complete community ambulation status	44 (73.3)
Test duration (minutes): median (interquartile range); [min-max]	9.1 (5.0) [5.4-15.4]
Peak speed (km/h): mean (SD); [min-max]	4.6 (1.2) [2.2-7.7]
Peak incline (%): mean (SD); [min-max]	10.3 (3.4) [4.2-18.3]
Peak RER: median (IQR); [min-max]	1.1 (0.1) [1.0-1.5]
VO_{2peak} ($ml.kg^{-1}.min^{-1}$): mean (SD); [min-max]	20.7 (4.8) [11.9-40.9]

SD: standard deviation; IQR: interquartile range; Min: minimum; Max: maximum; BB: beta-blocker medication; RER: respiratory exchange ratio; VO_{2peak}: peak oxygen consumption; $Ml.kg^{-1}.min^{-1}$: milliliter per kilogram per minute.

Table 3. Mean values of the maximum heart rate (HR_{max}) and intraclass correlation coefficient (ICC) with 95% confidence interval (CI) between the age-predicted HR_{max} equations and the HR_{max} obtained by the Cardiopulmonary Exercise Test (CPET).

Method of obtaining the HR_{max}	***N***	**Mean HR_{max} (bpm) ± SD of the difference between values**	**Mean HR_{max} (bpm) (SD)**	**ICC**	**95% CI**
CPET	60	-	142 (22)	-	-
Equation 1 (Fox)[25]	60	23.8 ± 19.7	166 (12)	0.33	-0.18 to 0.63
Equation 2 (Gellish)[22]	60	27.1 ± 19.7	170 (8)	0.20	-0.16 to 0.50
Equation 3 (Tanaka)[23]	60	28.1 ± 19.7	170 (8)	0.21	-0.17 to 0.51
Equation 4 (Astrand)[41]	60	29.1 ± 19.6	171 (10)	0.24	-0.18 to 0.55
Equation 5 (Brawner- BB)†[24]	23	-7.7 ± 18.4	125 (8)	0.51	-0.06 to 0.79
Equation 6 (Brawner- no BB)†[24]	37	2.4 ± 18.6	150 (11)	0.51	0.05 to 0.75*

SD: standard deviation; ICC: intraclass correlation coefficient; CI: confidence interval; BB: beta-blocker medication; HR_{max}: maximum heart rate; bpm: beats per minute. *p <0.05 and 95% CI indicating significant agreement

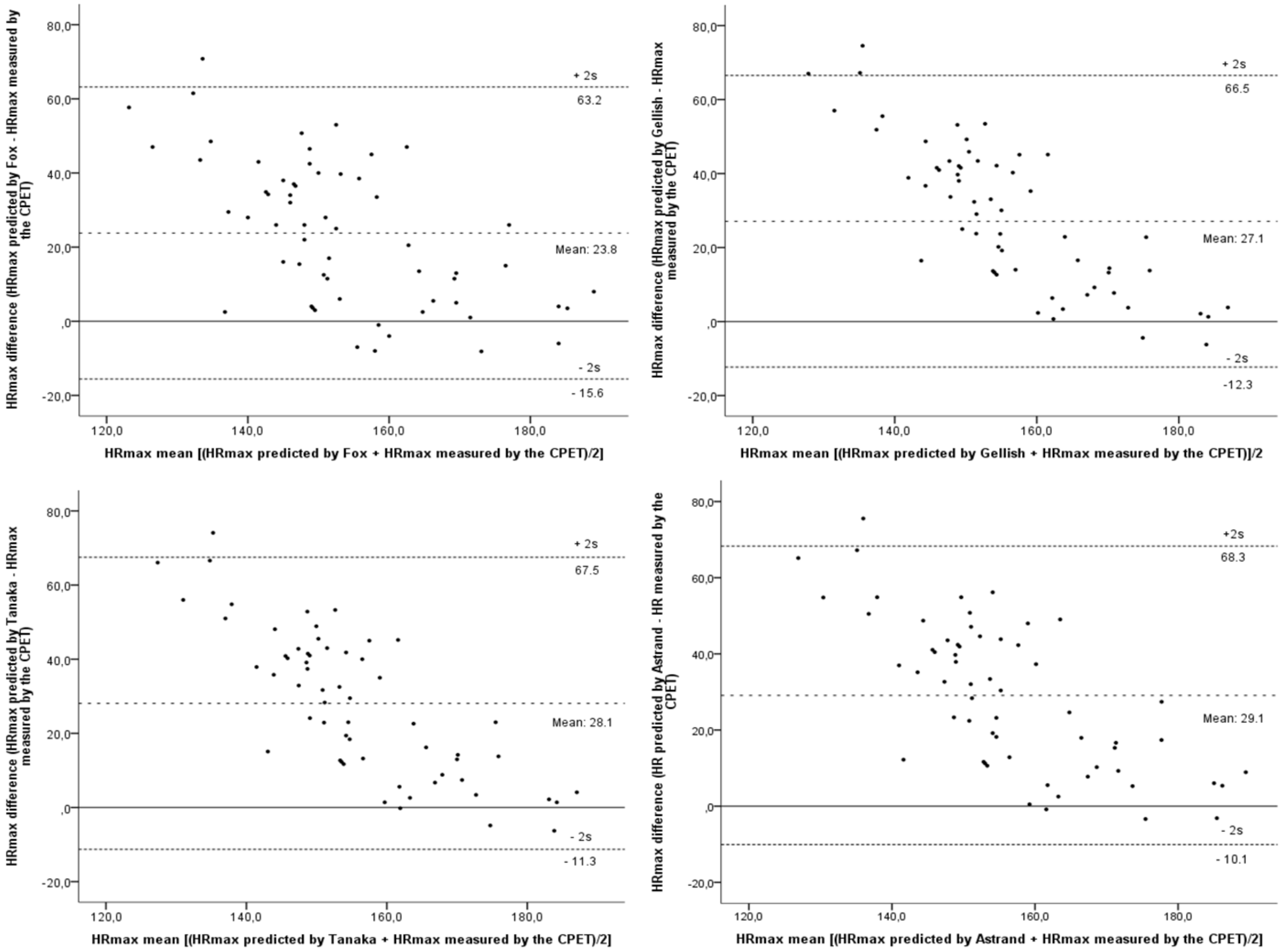
†As these two equations were applied separately, considering the use of BB, the *n* was different for each of them.

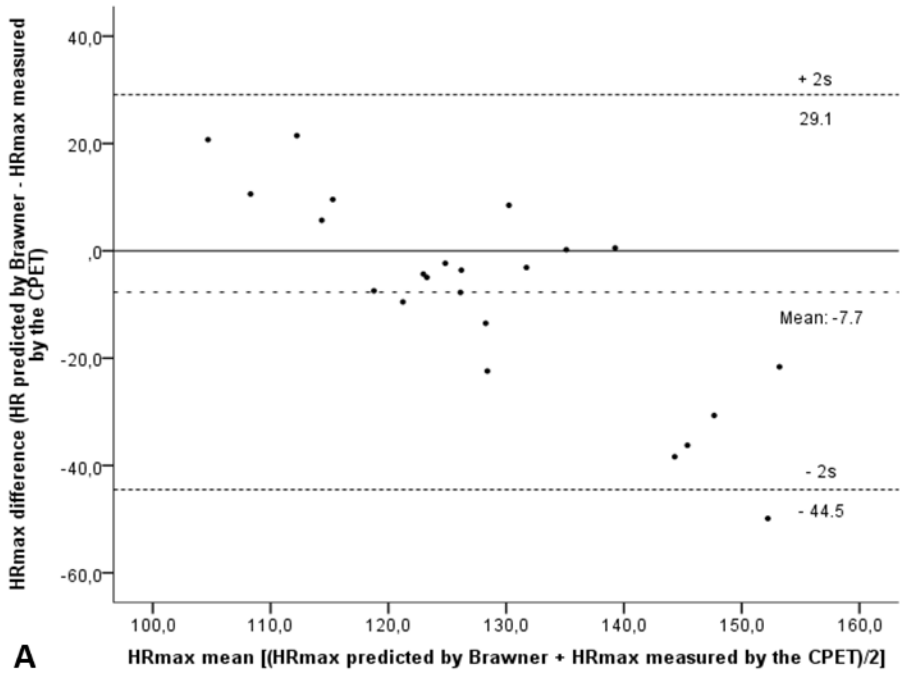
Figure 1. Bland-Altman plot comparing maximum heart rate (HR_{max}) predicted by the equations of Fox, Gellish, Tanaka and Astrand and measured by the Cardiopulmonary Exercise Test (CPET) (*n*=60).

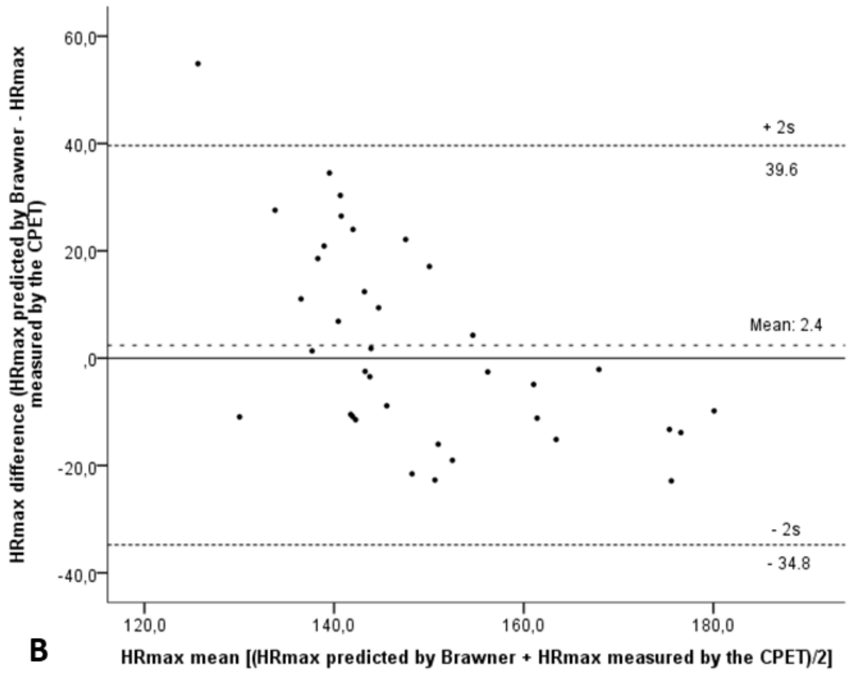
The middle solid line represents the mean difference between the measures. The bias is represented by the gap between the X axis, corresponding to a zero difference, and the parallel line to the X axis. The 2 outside dashed lines indicate the 95% limits of agreement.

Figure 2. Bland-Altman plot comparing maximum heart rate (HR_{max}) predicted by the equations of Brawner, and measured by the Cardiopulmonary Exercise Test (CPET);

A: for the group that use Beta-Blocker (BB) medication (*n*=23) and B: for the group that do not use BB medication (*n*=37). The middle solid line represents the mean difference between the measures. The bias is represented by the gap between the X axis, corresponding to a zero difference, and the parallel line to the X axis. The 2 outside dashed lines indicate the 95% limits of agreement.


HRmax difference (HRmax predicted by Fox - HRmax measured by the CPET)
HRmax mean [(HRmax predicted by Fox + HRmax measured by the CPET)/2]
+ 2s
63.2
Mean: 23.8
- 2s
- 15.6
HRmax difference (HRmax predicted by Gellish - HRmax measured by the CPET)
HRmax mean [(HRmax predicted by Gellish + HRmax measured by the CPET)]/2
+ 2s
66.5
Mean: 27.1
- 2s
-12.3
HRmax difference (HRmax predicted by Tanaka - HRmax measured by the CPET)
HRmax mean [(HRmax predicted by Tanaka + HRmax measured by the CPET)/2]
+ 2s
67.5
Mean: 28.1
- 2s
- 11.3
HRmax difference (HR predicted by Astrand - HR measured by the CPET)
HRmax mean [(HRmax predicted by Astrand + HRmax measured by the CPET)/2]
+2s
68.3
Mean: 29.1
- 2s
- 10.1
80,0
60,0
40,0
20,0
,0
-20,0
120,0
140,0
160,0
180,0


HRmax difference (HR predicted by Brawner - HRmax measured by the CPET)
40,0
20,0
,0
-20,0
-40,0
-60,0
+ 2s
29.1
Mean: -7.7
- 2s
- 44.5
100,0
110,0
120,0
130,0
140,0
150,0
160,0
HRmax mean [(HRmax predicted by Brawner + HRmax measured by the CPET)/2]
A


HRmax difference (HRmax predicted by Brawner - HRmax measured by the CPET)
60,0
40,0
20,0
,0
-20,0
-40,0
+ 2s
39.6
Mean: 2.4
- 2s
- 34.8
120,0
140,0
160,0
180,0
HRmax mean [(HRmax predicted by Brawner + HRmax measured by the CPET)/2]
B

Supplementary material

Table 4. Mean values of the maximum heart rate (HR_{max}) and intraclass correlation coefficient (ICC) with 95% confidence interval (CI) between the age-predicted HR_{max} equations and the HR_{max} obtained by the Cardiopulmonary Exercise Test (CPET).

Method of obtaining the HR_{max}	***N***	**Mean HR_{max} (bpm) ± SD of the difference between values**	**Mean HR_{max} (bpm) (SD)**	**ICC**	**95% CI**
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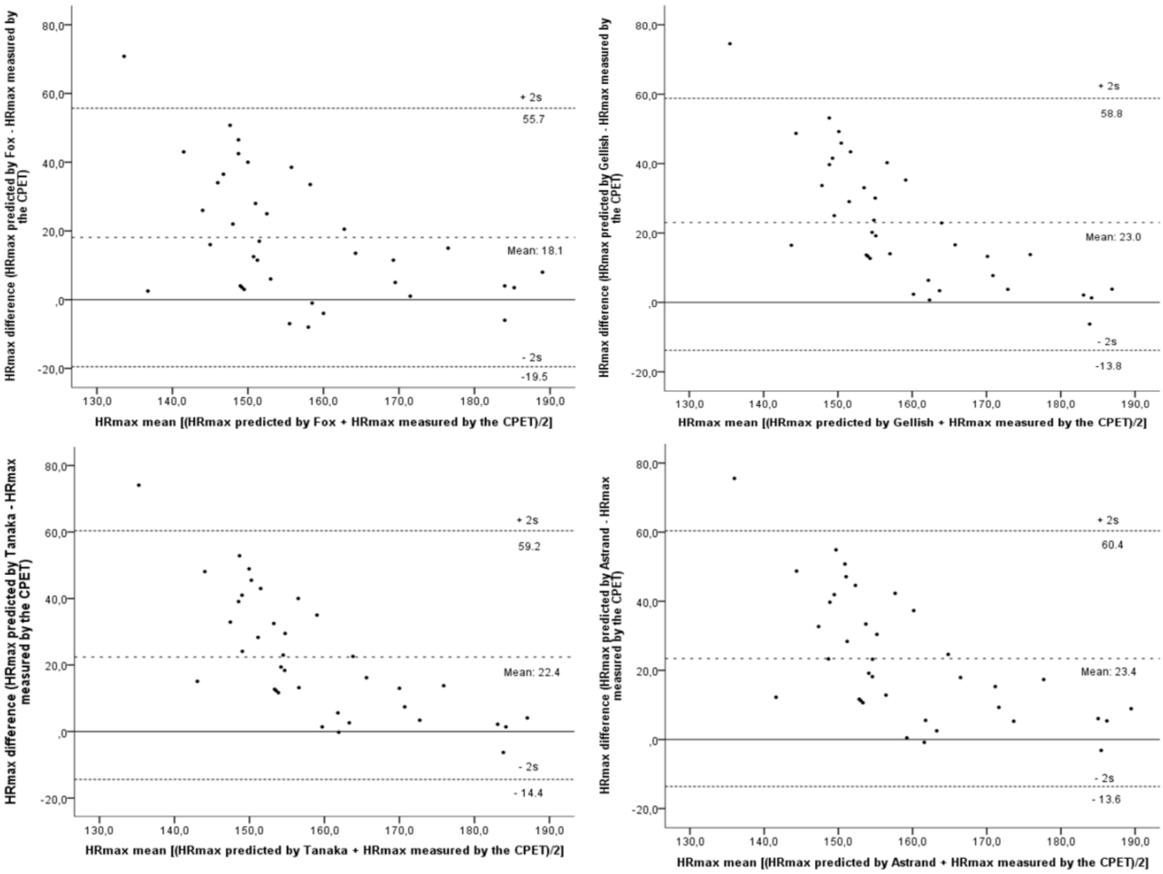
Equation 1 (Fox)†[25]	37	18.1 ± 18.8	166 (12)	0.37	-0.16 to 0.51
Equation 2 (Gellish)†[20]	37	23.0 ± 18.4	171 (8)	0.24	-0.19 to 0.56
Equation 3 (Tanaka)†[21]	37	22.4 ± 18.4	170 (8)	0.25	-0.20 to 0.57
Equation 4 (Astrand)†[41]	37	23.4 ± 18.5	171 (10)	0.27	-0.20 to 0.60

SD: standard deviation; ICC: intraclass correlation coefficient; CI: confidence interval; BB: beta-blocker medication; HR_{max}: maximum heart rate; bpm: beats per minute.

† Equations 1-4 were applied again only to part of the sample that did not use BB (*n*=37)

Figure 3. Bland-Altman plot comparing maximum heart rate (HR_{max}) predicted by the equations of Fox, Gellish, Tanaka and Astrand, and measured by the Cardiopulmonary Exercise Test (CPET) (*n*=37).

The middle solid line represents the mean difference between the measures. The bias is represented by the gap between the X axis, corresponding to a zero difference, and the parallel line to the X axis. The 2 outside dashed lines indicate the 95% limits of agreement.



3 ARTIGO-2

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Tipo de artigo: Artigo original

Title: Maximum heart rate prediction equations with adequate clinical applicability for aerobic exercise prescription to individuals after chronic stroke

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Word count: 2571

Abstract

Objectives: 1) to develop two maximum heart rate (HR_{max}) prediction equations for individuals after stroke; and 2) to investigate the validity of the equations developed. **Design:** Cross-sectional study. **Setting:** University laboratory. **Participants:** 60 individuals (54 (12) years; 64 (69) months after stroke) were included. Twenty individuals (58 (10) years; 67 (61) months after stroke) were included in the cross-validation group. **Main outcome measures:** The HR_{max} was obtained by a Cardiopulmonary Exercise Test (CPET). Participants also completed the Six-minute Walking Test (6MWT) and the Incremental Shuttle Walking Test (ISWT). **Results:** For the first model, the following variables were retained, generating equation-1: HR_{max}= 87.655 + 0.726 (HR_{peak} in the 6MWT) – 0.386 (age in years), (R^2=0.53; Standar Error of the Estimate (SEE)= 15.35; p<0.0001). For the second model, the following variables were retained, generating equation-2: HR_{max}= 96.523 + 0.681 (HR_{peak} in the ISWT) – 0.039 (walking distance in meters in the ISWT) – 0.400 (age in years), (R^2=0.53; SEE=15.51; p<0.0001). Significant and high magnitude agreement was found between the HR_{max} obtained by the CPET and the predicted HR_{max} by equation-1 (6MWT) (ICC= 0.85; 95% CI= 0.63 – 0.94) and equation-2 (ISWT) (ICC= 0.72; 95% CI= 0.29 – 0.89). Equation-1 showed a mean difference of 3.2 beats per minute (bpm) and equation-2 a mean difference of -1.3 bpm. **Conclusion:** Two HR_{max} prediction equations have been developed and showed adequate validity for prediction of the HR_{max} of individuals after stroke. In clinical practice, professionals will have the option of choosing one of the two equations to use with their patients.

Contribution of the paper:

- HR_{max} prediction equations specific to the population of individuals after stroke contribute to a more adequate and safer prescription of aerobic exercise intensity.

- Both equations developed are viable to be used in clinical practice, as they are composed of variables that are easy to obtain.

Key words: Aerobic exercise; Cardiopulmonary exercise test; Heart rate; Stroke.

INTRODUCTION

Current clinical guidelines recommend that adults should perform at least 150-300 minutes per week of moderate-intensity aerobic exercise, or 75-150 minutes per week of high-intensity aerobic exercise, or an equivalent combination of these [1]. These recommendations also apply to individuals after stroke in order to avoid physical inactivity [2]. For the proper prescription of aerobic exercise, four parameters must be established: modality, frequency, duration and intensity [2]. The intensity is a critical parameter to be defined. Insufficient intensity may lead to limited improvement in cardiorespiratory fitness whereas excessive intensity may lead to higher safety risks and limited adherence [3].

Maximum heart rate (HR_{max}) is used to prescribe aerobic exercise intensity usually obtained by the Karvonen formula based upon the heart rate reserve (HRR) [4]. The most appropriate way to obtain the HR_{max} is through a Cardiopulmonary Exercise Test (CPET) [5]. However, this test has limited clinical applicability and is not widely used in clinical practice [6]. Thus, one of the alternatives recommended in guidelines for aerobic exercise prescription for individuals after stroke [7] and that is commonly employed is the use of HR_{max} prediction equations [8].

Several equations have been developed, based on data from able-bodied individuals, and are frequently used due to their simplicity [9-12]. However, a recent study [13] identified that previous equations developed based on data from able-bodied individuals were not valid for use in individuals after stroke [13]. According to the results of this study, the equation proposed by Brawner, developed for individuals with coronary heart disease, who did not use beta-blocker medication, showed better results. However, it should be used with caution since the magnitude of agreement that was found was moderate and the confidence interval was large [13].

Considering the importance of adequate prescription of aerobic exercise intensity and the difficulty of performing the CPET in the clinical context to obtain the HR_{max}, the use of prediction equations becomes a viable alternative. No previous study has developed a HR_{max} prediction equation for individuals after stroke. Therefore, the purposes of this study were: 1) to develop two HR_{max} prediction equations for individuals after stroke with adequate clinical applicability and 2) to investigate the validity of the equations developed with an independent group of individuals after stroke.

METHODS

Design

This is a cross-sectional study approved by the Institutional Review Board. All participants gave written informed consent before data collection.

Participants

The inclusion criteria were: diagnosis of stroke for at least 6 months (chronic phase) [14]; be aged ≥ 20 years; and be able to walk independently, with or without the aid of a walking device, for at least 10 minutes. The exclusion criteria were: possible cognitive impairment assessed through the Mini-Mental State Exam (cutoff points based on the educational level [15]: 13 points for those illiterates, 18 points for people with low/medium schooling and 26 points for individuals with high schooling), and/or comprehension aphasia assessed by the ability to respond, through body movements, to verbal commands [16]; and the presence of pain or other health condition that impairs the performance of the tests.

Sample size

The following formula was used: n= 10 x (number of predictor variables +1) to perform the sample size calculation for the first objective [17]. Aiming at a greater clinical applicability of the equations developed, five predictor variables were included in the regression model, totalling 60 individuals.

Previous studies that investigated the validity of HR prediction equations in specific populations used varied sample sizes [18-21]. The study of Boyne et al., [18] developed a HR prediction equation at the ventilatory threshold for individuals after stroke and a sample of eight individuals was employed to investigate the validity of the equation. In the present study, to increase sample variability, it was possible to recruit an independent sample of 20 individuals to carry out the validation of the developed equations.

Predictor and outcome variables

The following variables were considered in the first multiple regression model to predict the HR_{max}: age, sex, use of beta-blocker (BB) medication, HR_{peak} and walking distance (in meters) in the 6MWT. For the second model, the following variables were considered: age, sex, use of BB, HR_{peak} and walking distance (in meters) in the ISWT.

The variables age, sex and use of BB were selected because they have been used in previous studies developed with other populations with similar objectives [11, 18-20, 22]. Some equations developed to predict the peak oxygen consumption in different populations include parameters measured during field walking tests, such as the distance walked in the 6MWT [23] and the ISWT [24,25]. Furthermore, since specific chronotropic features are incorporated, the equations developed to predict the HR_{max} may be improved [23].

Cardiopulmonary Exercise Test (CPET)

The CPET is considered safe to be performed in individuals after stroke [26]. The test was performed according to the recommendations of the American College of Sports Medicine (ACSM) [27] and was conducted by a team of trained health professionals. The CPET was performed on a treadmill [28] and a progressive ramp-type protocol was used [29]. The initial and incremental speed in km/h, the initial inclination and the percentage of increment were determined for each participant, based on a previously established protocol [29].

The test was interrupted if the participant requested it or if the professionals detected any adverse signs or symptoms [27]. It was considered to be of maximum effort if the respiratory exchange ratio (RER) was ≥ 1.0 [30]. The last 30 seconds of the test were divided into 3 blocks of 10 seconds and the HR_{max} was obtained by the highest average of these three blocks [31].

Six-Minute Walking Test (6MWT)

The 6MWT has adequate measurement properties to assess the exercise capacity in individuals after stroke [32] and was performed according to the recommendations of the American Thoracic Society (ATS) [33]. The test was performed in a 30-meter corridor [34] and only one repetition was done after the instructions [35]. The individual was instructed to walk as far as possible in six minutes [33]. The HR was recorded at the end of each minute and the HR_{peak} was defined as the highest value reached during the test. The walking distance (in meters) reached by the participant was also obtained [33].

Incremental Shuttle Walking Test (ISWT)

The ISWT has adequate measurement properties to assess the exercise capacity in individuals after stroke [36] and was performed in accordance with the ATS recommendations [33]. The ISWT was performed in a 10-meter corridor and only one repetition was performed after the instructions [35]. The test consists of 12 stages with 1-minute duration each [37] and sound signals are emitted every minute, which determines the individual's walking speed [37]. The HR was recorded at the end of each minute and the HR_{peak} was defined as the highest value reached during the test. The walking distance (in meters) reached by the participant was also obtained [33].

Procedures

The examiners checked the eligibility criteria and clinical demographic information were collected for characterization purpose (age, sex, time since stroke onset, type of stroke, hemiparetic side, use of BB medication and lower limb motor function by the lower limb section of the Fugl-Meyer scale [38]). On the first day of assessment, the 6MWT and the ISWT were performed in random order. A 10-minute interval between the tests was provided for the vital signs to return to baseline values. On the second day, the CPET was performed. In this interval, which was up to 14 days, [39] the individual should not have been affected by health conditions or events that compromise the assessed outcomes.

Data analysis

Descriptive statistics were performed. Multiple regression analysis (Stepwise) was performed to develop the equations [40]. The Intraclass Correlation Coefficient (ICC) with 95% confidence interval (CI) was calculated between the HR_{max} obtained by the CPET and the HR_{max} estimated by the equations. The accuracy and variability of the equations was also assessed using the Bland-Altman analysis [41]. On the plots, in the y axis the absolute difference of the measures was reported and in the x axis their mean [42]. All analyses were performed using the SPSS statistical package for Windows® (SPSS Inc., Chicago, IL, USA, version 19.0) (α=5%).

RESULTS

Clinical-demographic characteristics of the participants are presented in Table 1. The variables analyzed by the CPET are presented in Table 2.

[Table 1 here]

[Table 2 here]

For the first model, the following HR_{max} prediction equation was obtained: HR_{max}= 87.655 + 0.726 (HR_{peak} in the 6MWT) – 0.386 (age in years) (R^2=0.53; Standard Error of the Estimate (SEE)= 15.35; p<0.0001). For the second model the following HR_{max} prediction equation was obtained: HR_{max}= 96.523 + 0.681 (HR_{peak} in the ISWT) – 0.039 (walking distance in meters in the ISWT) – 0.400 (age in years) (R^2=0.53; SEE= 15.51; p<0.0001).

The ICC analysis for both equations showed adequate validity ($0.0001 \leq p \leq 0.005$). Significant and high magnitude agreement was found between the HR_{max} obtained by the CPET and the predicted HR_{max} by the equation-1 (6MWT) (ICC= 0.85; 95% CI= 0.63 – 0.94) and by the equation-2 (ISWT) (ICC= 0.72; 95% CI= 0.29 – 0.89) (Table 3).

[Table 3 here]

Bland-Altman plots are shown in Figure 1 and 2. Equation-1 showed a mean difference of 3.2 beats per minute (bpm) and equation-2 a mean difference of -1.3 bpm.

[Figure 1 here]

[Figure 2 here]

DISCUSSION

This was the first study to develop HR_{max} prediction equations with adequate clinical applicability for individuals after stroke. Two HR_{max} prediction equations were developed. Both had age as predictor variables. In addition, the HR_{peak} in the 6MWT was included in the first equation and the HR_{peak} and the walking distance in the ISWT were included in the second equation. Both equations showed adequate validity, being able to be used to predict the HR_{max} of individuals after stroke when performing the aerobic exercise intensity prescription.

The only study that has ever developed HR prediction equations for individuals after stroke was that of Boyne et al [18]. Different from the present study, the equation developed was for predicting the HR at the ventilatory threshold and obtained an R^2=0.70. This proposed equation included the HR_{peak} obtained from the CPET, sex and gait speed measured by the 10-meter walk test [18]. Therefore, this equation has low clinical applicability, considering that it would still be necessary to perform the CPET to obtain the HR_{peak}. In the equations developed in the present study, the R^2 values were smaller, but still adequate, and with the advantage that both equations are applicable to clinical practice.

Casillas et al. [19] developed an HR_{max} prediction equation for individuals with coronary heart disease. In addition to age, body mass index and resting HR, outcomes measured in the 6MWT and in the 200-metre fast walk test (200mFWT) were also included in the analysis, such as HR at the end of the 6MWT and 200mFWT, walking distance during the 6MWT and time do complete the 200mFWT. Only the following predictor variables were retained in the model: age and the HR at the end of 200mFWT [19]. The developed equation obtained an R^2= 0.24, lower than that obtained by the equations developed in the present study.

Other HR_{max} prediction equations have been developed for specific populations. Fernhall et al., [21] Miller et al [43] and Nikolaidis et al., [44] developed age-based prediction equations for individuals with intellectual disabilities, obese and soccer players, respectively. The equations developed in these studies obtained an R^2 ranging from 0.30 to 0.41 and an SEE ranging from 8.6 to 13.8 bpm [21,43,44]. Gelbart et al., [45] developed a HR_{max} prediction equation for children and adolescents. The following variables were included in the equation: resting HR, fitness level, body mass and fat percent (R^2= 0.25, SEE= 7.5 bpm). The equations developed in the present study had a higher coefficient of determination, when compared with these previous studies developed with different populations. In relation to the SEE, the present study showed slightly higher values when compared to the studies mentioned above. Even so, according to the study of Brawner et al., [20] these values are within the average of SEE values commonly reported in HR_{max} prediction equations (between 10-20 bpm).

Some of the mentioned studies investigated the validated of the developed equations applying different statistical methods. Fernhall et al., [21] used a one-way ANOVA to test the mean differences and used scatterplots to show the relationship between the predicted and the measured HR_{max}. Brawner et al., [20] used Student t test and X^2 to investigate the differences between the predicted and the measured HR_{max}. It was found a mean absolute difference between the predicted HR_{max} and the measured HR_{max} of 15±13 bpm (mean±SD; p<0.0001). Casillas et al. [19] used Pearson correlation between the HR_{max} obtained by the CPET and the one predicted by the developed equation. It was found a moderate correlation (r=0.53; p<.0001) [19]. In the present study, the ICC was used to verify the validity of the developed equation, which evaluates the agreement between the values found (HR_{max} predicted by the new equations and HR_{max} obtained by the CPET) [40]. In addition, the analyses were complemented with the use of the Bland-Altman plots [41,42]. These results demonstrated that the equations showed an average difference of 3.2 bpm for equation-1 (6MWT) and -1.3 bpm for equation-2 (ISWT). According to Robergs et al., [46] for purposes of prescribing training HR ranges, errors ≤8 bpm are likely to be acceptable.

It is important to note that in the studies of Fernhall et al. [21] and Casillas et al., [19] the investigation of the validity of the developed equations was not performed in an independent sample. Only in the study of Brawner et al., [20] different samples were used for the equation development and for the cross-validation investigation. In the present study, 60 individuals participated in the development group, and another 20 individuals participated in the cross-validation group, following recently recommendations.

In both equations, the age variable remained retained. In most of the HR_{max} prediction equations already developed for other populations, age was shown to be the main predictor variable [11]. Age is easy to obtain during the evaluation for exercise prescription. The other variables retained were related to the field tests used: walking distance and HR_{peak}. During the evaluation of individuals after a stroke, these tests are widely used to assess exercise capacity [30]. Although there are studies that found a relationship between sex [36] and the use of BB [47] and the HR_{max}, these variables were not retained in the regression models developed.

This study has some limitations, such as the recruitment of a convenience sample with individuals in the chronic phase after stroke who were able to walk, which limits the generalization of the results. The validation of the equation was performed in an independent sample, composed of individuals who had not participated in the first stage of the study. However, this sample was composed of only 20 individuals. This is due to the fact that it is difficult to perform a maximum stress test in this population. Future studies should consider performing the validation of the equations developed in larger samples.

In the present study, two HR_{max} prediction equations, with clinical applicability and adequate validity, were provided for individuals after stroke. Both equations include age and HR_{peak} in field walking tests (6MWT or ISWT), and the second equation also include the walking distance in the ISWT as a predictor variable. Both equations are valid and suitable for use in this population for the prescription of aerobic exercise intensity in clinical practice. The results of the present study improve the prescription of exercise intensity, contributing to safer and more effective practices of this type of training in this population.

Conflict of interest

None

Funding

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Ethical Approval

This work was approved by the Institutional Review Board of the Universidade Federal de Minas Gerais.

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Table 1. Clinical-demographic characteristics of the participants

Characteristics	Development group (*n*=60)	Cross-validation group (*n*=20)
Age (years): mean ± SD; [min-max]	54 ±12 [27-82]	58 ±10 [34-70]
Sex: male, *n* (%)	40 (67)	14 (70)
Time since stroke onset (months): mean ± SD; [min-max]	64 ± 69 [6-370]	67 ± 61 [12-260]
Type of stroke, ischemic, *n* (%)	49 (82)	14 (70)
Hemiparetic side: right, *n* (%)	32 (53)	12 (60)
Beta-blocker medication: no, *n* (%)	37 (62)	13 (65)
Lower limb motor impairments (Fugl-Meyer scores: 0-34), *n* (%)		
Mild	40 (66.7)	13 (65)
Moderate	14 (23.3)	2 (10)
Moderately severe	3 (5.0)	3 (15)
Severe	3 (5.0)	2 (10)
Walking distance in 6MWT (in meters): mean ± SD; [min-max]	366.5 ± 95.7 [159-548]	395.7 ± 82 [214-540]
Walking distance in ISWT (in meters): mean ± SD; [min-max]	305.3 ± 176.8 [50-710]	292.0 ± 137.8 [100-660]

SD: standard deviation; Min: minimum; Max: maximum; 6MWT: Six-Minute Walking Test; ISWT: Incremental Shuttle Walking Test.

Table 2. Variables analyzed by the Cardiopulmonary Exercise Test (CPET)

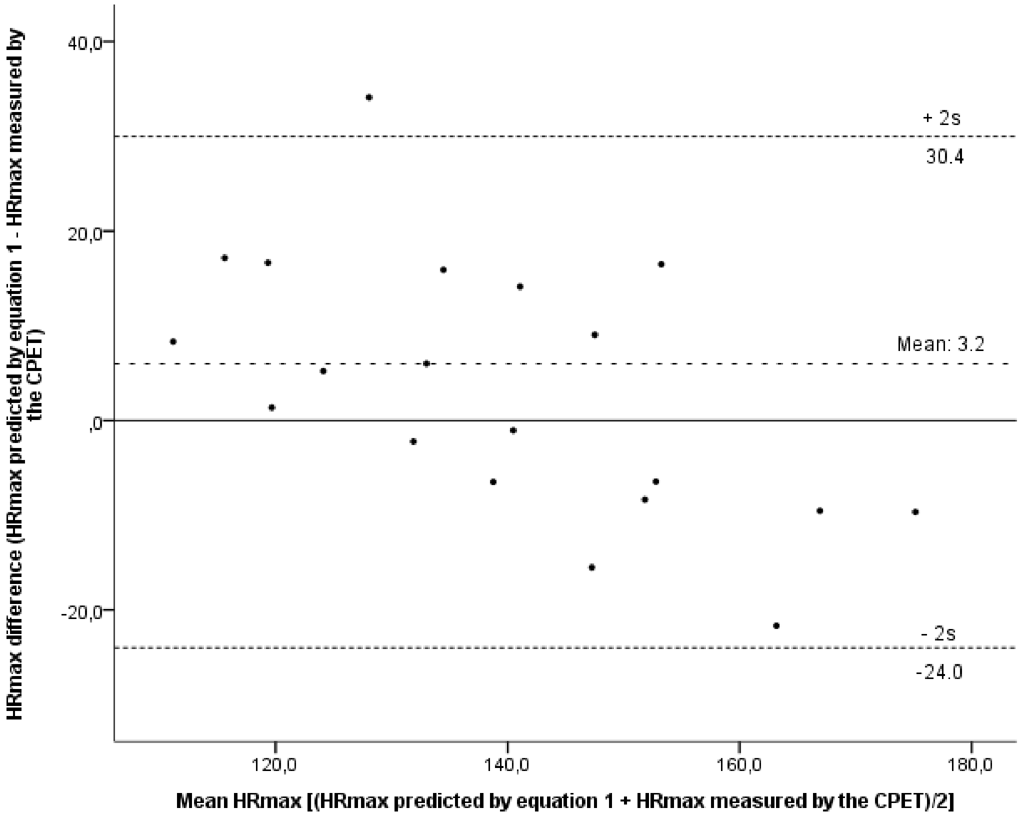
Variables	**Development group (*n*=60)**	**Cross-validation group (*n*=20)**
Test duration (minutes): mean ± SD; [min-max]	9.7 ± 2.9 [5.4-15.4]	12.2 ± 3.6 [7.4-19.5]
Peak speed (km/h): mean ± SD; [min-max]	4.6 ± 1.2 [2.2-7.7]	4.6 ± 1.2 [2.2-7.7]
Peak incline (%): mean ± SD; [min-max]	10.3 ± 3.4 [4.2-18.3]	10.3 ± 3.4 [4.2-18.3]
Peak RER: mean ± SD; [min-max]	1.2 ± 0.1 [1.0-1.5]	1.1 ± 0.1 [1.0-1.3]
VO_{2peak} ($ml.kg^{-1}.min^{-1}$): mean ± SD; [min-max]	20.7 ± 4.8 [11.9-40.9]	20.7 ± 4.8 [11.9-40.9]

SD: standard deviation; Min: minimum; Max: maximum; RER: respiratory exchange ratio;.

Table 3. Mean values of the maximum heart rate (HR_{max}) and Intraclass correlation coefficient (ICC) with 95% confidence interval (CI) between the HR_{max} prediction equations and the HR_{max} obtained by the cardiopulmonary exercise test (CPET).

Method of obtaining the HR_{max}	***N***	**Mean HR_{max} (bpm) ± SD**	**Mean HR_{max} (bpm) ± SD of the difference**	**ICC**	**95% CI**
CPET	20	138 ± 22	Not applicable	Not applicable	Not applicable
Equation 1 (6MWT)	20	141 ± 15	3.2 ± 13.6	0.85	0.63 - 0.94
Equation 2 (ISWT)	20	137 ± 13	-1.3 ± 17.3	0.72	0.29 - 0.89

SD: standard deviation; ICC: intraclass correlation coefficient; CI: confidence interval; HR_{max}: maximum heart rate; bpm: beats per minute; 6MWT: Six-Minute Walking Test; ISWT: Incremental Shuttle Walking Test. $p < 0.05$ for both ICC values


HRmax difference (HRmax predicted by equation 1 - HRmax measured by the CPET)
40,0
20,0
,0
-20,0
+ 2s
30.4
Mean: 3.2
- 2s
-24.0
120,0
140,0
160,0
180,0
Mean HRmax [(HRmax predicted by equation 1 + HRmax measured by the CPET)/2]

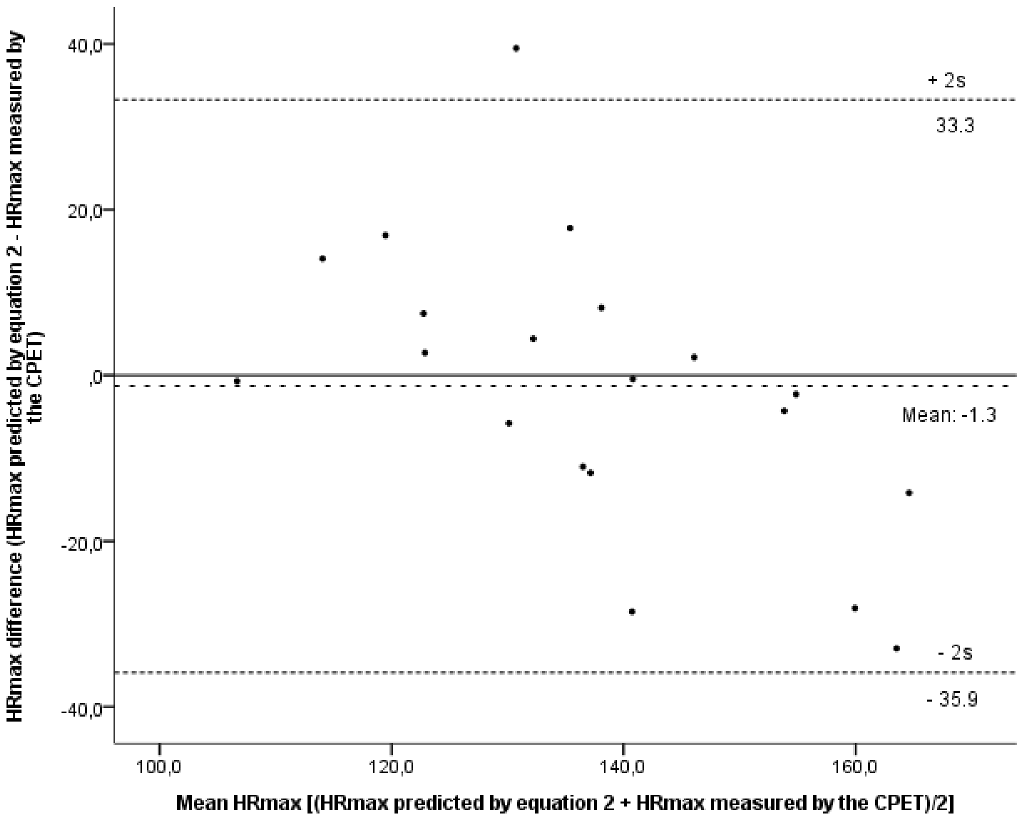

HRmax difference (HRmax predicted by equation 2 - HRmax measured by the CPET)
40,0
20,0
,0
-20,0
-40,0
+ 2s
33.3
Mean: -1.3
- 2s
- 35.9
100,0
120,0
140,0
160,0
Mean HRmax [(HRmax predicted by equation 2 + HRmax measured by the CPET)/2]

Figure 1. Bland-Altman plot comparing maximum heart rate (HR_{max}) predicted by equation 1 (6MWT) and measured by the Cardiopulmonary Exercise Test (CPET) (*n*=20).

The middle solid line represents the mean difference between the measures. The bias is represented by the gap between the X axis, corresponding to a zero difference, and the parallel line to the X axis. The 2 outside dashed lines indicate the 95% limits of agreement.

Figure 2. Bland-Altman plot comparing maximum heart rate (HR_{max}) predicted by equation 2 (ISWT) and measured by the Cardiopulmonary Exercise Test (CPET) (*n*=20).

The middle solid line represents the mean difference between the measures. The bias is represented by the gap between the X axis, corresponding to a zero difference, and the parallel line to the X axis. The 2 outside dashed lines indicate the 95% limits of agreement.

4 CONSIDERAÇÕES FINAIS

O presente estudo está de acordo com a linha de pesquisa “Estudos em reabilitação neurológica no adulto” do Programa de Pós-graduação em Ciências da Reabilitação da UFMG, que visa o estudo das relações entre as deficiências, limitações de atividades e restrições de participação, e a influência dos fatores contextuais (pessoais e ambientais), em indivíduos adultos com condições de saúde que acometem o sistema nervoso, conforme preconizado pela Classificação Internacional de Funcionalidade, Incapacidade e Saúde (CIF) da Organização Mundial de Saúde (OMS). O presente estudo apresenta características de um estudo metodológico, envolvendo a investigação da validade de equações de predição da $FC_{max,}$ além da criação de duas novas equações, com o mesmo propósito, mas considerando variáveis específicas para indivíduos pós-AVE, com a investigação de sua validade. A frequência cardíaca faz parte das funções cardíacas, que pertence ao domínio funções do aparelho cardiovascular na CIF. Além disso, também faz parte das funções do corpo a capacidade aeróbica, que é um desfecho intimamente ligado à realização do exercício aeróbio. Os programas de exercício físico também estão incluídos na parte de recreação e lazer, do domínio de participação social. Para a devida prescrição destes exercícios físicos é necessária a obtenção do valor da $FC_{max,}$ para que seja calculada a faixa de treinamento da FC, para monitoramento da intensidade do exercício aeróbio. A FC_{max} só pode ser obtida por meio da realização do TECP ou por meio de equações de predição. Neste sentido, os resultados do presente estudo contribuirão positivamente para a saúde e funcionalidade dos indivíduos pós-AVE e, portanto, estão de acordo com a proposta do Programa de Pós-graduação em Ciências da Reabilitação da UFMG.

Um dos estudos da presente dissertação envolveu a investigação da validade de seis equações de predição da FC_{max} baseadas na idade que foram desenvolvidas previamente para indivíduos saudáveis e para indivíduos com DAC, para serem utilizadas em indivíduos pós-AVE na fase crônica. Essas equações não se mostraram adequadas para serem utilizadas. Apenas uma delas, que foi desenvolvida para indivíduos com DAC, apresentou resultados adequados, porém moderados, o que justifica a sua utilização com cautela. Sendo assim, no outro estudo desta dissertação foram desenvolvidas duas equações específicas para indivíduos pós-AVE e com aplicabilidade clínica para predição da FC_{max}, que obtiveram validade adequada. Essas equações tiveram como base dois testes clínicos amplamente utilizados como alternativas na impossibilidade de realização do TECP.

De acordo com o nosso conhecimento, esse foi o primeiro estudo que investigou a validade de equações prévias de predição da FC_{max} e que tenha desenvolvido equações específicas para indivíduos pós-AVE e que sejam aplicáveis à prática clínica. Portanto, os resultados desse estudo apresentam adequada e direta aplicabilidade clínica, além de potencial para modificar os guias clínicos para prescrição de exercício aeróbio pós-AVE. O uso corriqueiro das equações desenvolvidas previamente para indivíduos saudáveis deve ser desencorajado e as novas equações desenvolvidas por um dos estudos desta dissertação devem fazer parte das recomendações futuras para prescrição da intensidade do exercício dessa população.

O presente estudo também contribui para o direcionamento de estudos futuros. Para ambas as etapas do estudo (investigação da validade das equações prévias e desenvolvimento das novas equações), foram incluídos somente indivíduos na fase crônica do AVE. Ainda faz-se necessário investigar a validade dessas equações em indivíduos que estejam nas fases aguda e subaguda, além do desenvolvimento de equações específicas para indivíduos que não deambulem de forma independente. Além disso, os modelos de regressão das equações propostas foram capazes de explicar 53% da variabilidade da FC_{max} de indivíduos pós-AVE, o que indica que outras variáveis, não incluídas no presente estudo, também tem o potencial de predizer esse desfecho. A validade das equações desenvolvidas foi realizada em uma amostra de 20 indivíduos. Estudos futuros devem realizar a validação dessas equações em amostras maiores.

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ANEXO A - APROVAÇÃO PELO COMITÊ DE ÉTICA E PESQUISA DA UFMG

UNIVERSIDADE FEDERAL DE MINAS GERAIS
COMITÊ DE ÉTICA EM PESQUISA - COEP

Projeto: CAAE – 51454115.6.0000.5149

Interessado(a): Profa. Christina Danielli Coelho de Morais Faria
Departamento de Fisioterapia
EEFFTO- UFMG

DECISÃO

O Comitê de Ética em Pesquisa da UFMG – COEP aprovou, no dia 09 de março de 2016, o projeto de pesquisa intitulado " **Eficácia do treino aeróbio no nível de atividade física de indivíduos acometidos pelo acidente vascular encefálico: um ensaio clínico aleatorizado"** bem como o Termo de Consentimento Livre e Esclarecido.

O relatório final ou parcial deverá ser encaminhado ao COEP um ano após o início do projeto através da Plataforma Brasil.

Telma Campos Medeiros Lorentz

Profa. Dra. Telma Campos Medeiros Lorentz
Coordenadora do COEP-UFMG

Av. Pres. Antonio Carlos, 6627 – Unidade Administrativa II - 2° andar – Sala 2005 – Cep:31270-901 – BH-MG
Telefax: (031) 3409-4592 - e-mail: coep@prpq.ufmg.br

ANEXO B – TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO Nº_______

TÍTULO DO PROJETO DE PESQUISA: "Eficácia do treino aeróbico no nível de atividade física de indivíduos acometidos pelo Acidente Vascular Encefálico: um ensaio clínico aleatorizado"

INVESTIGADORAS:
- Prof.ª Christina Danielli Coelho de Morais Faria, fisioterapeuta, Ph.D. Professora do Departamento de Fisioterapia da Universidade Federal de Minas Gerais (UFMG). Telefone: (31) 3409-7448; (31) 3409-4783; cdcmf@ufmg.br
- Prof.ª Raquel Rodrigues Britto, fisioterapeuta, Ph.D. Professora do Departamento de Fisioterapia da UFMG. Telefone: (31) 3409-4793; rbrito@ufmg.br
- Prof.ª Paula Luciana Scalzo, fisioterapeuta, Ph.D. Professora do Departamento de Morfologia da UFMG. Telefone: (31) 3409-2796; paula.scalzo@ig.com.br
- Larissa Tavares Aguiar, fisioterapeuta, aluna do Programa de Pós-Graduação em Ciências da Reabilitação da UFMG. Telefone: (31) 993132076; larissatavaresaguiar@gmail.com
- Júlia Caetano Martins, fisioterapeuta, aluna do Programa de Pós-Graduação em Ciências da Reabilitação da UFMG. Telefone: (31) 983099334; julia_caetano@yahoo.com.br

INFORMAÇÕES
Você está sendo convidado a participar de uma pesquisa a ser desenvolvida no Departamento de Fisioterapia da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da UFMG, que tem como objetivo avaliar os efeitos do treino aeróbio em pessoas que sofreram derrame (acidente vascular cerebral - AVC).

DETALHES DO ESTUDO
Várias estratégias de reabilitação de indivíduos que sofreram AVC demonstram melhora da capacidade funcional. Contudo, não se sabe qual estratégia de tratamento determina melhores resultados relacionados ao nível de atividade física e ao condicionamento cardiorrespiratório. A partir das informações obtidas neste estudo, será possível indicar o melhor tipo de treinamento para melhora do nível de atividade física e do condicionamento cardiorrespiratório.

DESCRIÇÃO DOS TESTES E DAS INTERVENÇÕES A SEREM REALIZADOS

Avaliação inicial
A avaliação para começar o programa de exercícios será uma coleta de dados pessoais e exame físico, a ser realizada por um examinador treinado. Caso você participe, será necessário responder alguns questionários acerca da sua saúde e da sua funcionalidade. Serão realizados alguns testes e medidas, simples e facilmente realizados para se obter informações sobre as estruturas e funções do seu corpo, as atividades que você realiza com e sem dificuldades e aquelas que você não realiza, assim como sobre o seu nível de participação, comumente empregados na prática clínica dos profissionais da área da saúde. Um dos testes a ser realizado é o teste ergoespirométrico, que tem como finalidade principal avaliar as respostas cardiovasculares frente à aplicação de esforço físico progressivo. Existe a possibilidade do aparecimento de sintomas como cansaço, falta de ar e dor no peito, entretanto, são mínimas as chances de ocorrerem complicações de difícil controle clínico. O teste ergoespirométrico será realizado sob acompanhamento médico. Também será realizada uma coleta de 30ml de sangue e um pouco de saliva, por um enfermeiro com capacidade técnica, seguindo os procedimentos recomendados.

Grupos do estudo
Será realizado um sorteio para saber em qual dos grupos do estudo você fará parte. Durante os meses de participação no estudo, nenhum voluntário poderá participar de outros exercícios, como os que envolvem o fortalecimento muscular ou o treino aeróbico (por exemplo, hidroginástica e musculação).

Procedimentos
Inicialmente, será realizada uma avaliação inicial, em que algumas medidas serão realizadas, como o seu peso e altura, você responderá alguns questionários e desempenhará testes que envolvem atividades rotineiras e que comumente são utilizados na prática clínica do fisioterapeuta. Além disso, você realizará um teste ergoespirométrico sobre a esteira, que será acompanhando por um médico. Finalmente, será realizada a coleta de 30 ml de sangue e um pouco de saliva por um enfermeiro. Em seguida você irá realizar as 36 sessões de exercícios, em grupos de três a quatro participantes, supervisionados por um fisioterapeuta. As sessões serão realizadas três vezes por semana por 12 semanas. Os mesmos procedimentos da avaliação inicial, ou seja, todos os testes e medidas empregados, serão realizados novamente após 12 semanas de intervenção e 4, 12 e 24 semanas após o término da intervenção. Todos procedimentos, testes, medidas e intervenções a serem

realizados no presente estudo são padronizados e comumente adotados na prática clínica ou em estudos científicos já realizados anteriormente. Durante todos os procedimentos, serão considerados a sua segurança e o seu conforto.

Riscos
Os riscos associados com estes testes e com o programa de intervenção são mínimos e similares aos que você está exposto no seu dia a dia. Durante as sessões de treinamento você pode vir a sentir-se cansado. Caso isto aconteça, períodos de repouso serão permitidos. Há um risco de você sentir dor, mal-estar, ou apresentar hematoma no local da punção venosa durante a coleta de amostra de sangue por um técnico de Enfermagem, o qual recebeu o devido treinamento para realizar este procedimento. Qualquer tipo de desconforto vivenciado durante os testes ou treinamento deve ser revelado para que os pesquisadores tomem as devidas providências com o objetivo de minimizá-lo. Caso durante os testes ou treinamento você sofra alguma complicação, como queda ou evento cardiovascular, os pesquisadores irão fornecer o auxílio necessário ou o encaminharão para outros profissionais da saúde, caso seja necessário. Alguns voluntários poderão ser fotografados durante a participação no estudo, para fins de apresentações em eventos científicos. Antes de fotografar, será solicitada a permissão individual para o uso da imagem, através da assinatura de um termo de autorização. A identidade dos voluntários não será revelada.

Benefícios
Você e futuros pacientes poderão se beneficiar com os resultados desse estudo, principalmente porque o objetivo principal do mesmo é determinar a melhor abordagem de tratamento fisioterápico para indivíduos após o AVC. Se após a conclusão do estudo for observado maior benefício alcançado em um grupo em relação aos demais, a intervenção de maior benefício será ofertada para os participantes do grupo controle.

Confidencialidade
Você não será reconhecido pelo nome e recebera um código que será utilizado em todos os seus testes para preservar sua identidade. Se as informações originadas deste estudo forem publicadas em revista ou evento científico, você não será reconhecido individualmente, pois será representado pelo número.

Natureza voluntária do estudo e pagamento
Sua participação neste estudo é voluntária e você é livre para concordar ou não em participar. Caso deseje, você pode abandonar o estudo a qualquer momento, sem que isto lhe traga qualquer prejuízo pessoal. Você não receberá nenhuma forma de pagamento pela participação. Caso seja necessário gastos adicionais serão de responsabilidade dos pesquisadores.

Após ter lido as informações acima, se desejar participar, por favor, preencha e assine a declaração abaixo.

DECLARAÇÃO E ASSINATURA

Eu, ____li e entendi toda a informação repassada sobre o estudo, sendo que os objetivos, procedimentos e linguagem técnica foram satisfatoriamente explicados. Tive tempo suficiente para considerar as informações acima e tive a oportunidade de tirar todas as minhas dúvidas. Estou assinando este termo voluntariamente e tenho direito de agora, ou mais tarde, discutir qualquer dúvida ética que venha a ter com relação à pesquisa com:
- Comitê de Ética em Pesquisa da UFMG: (31) 3409-4592

Av. Antônio Carlos, 6627 Unidade Administrativa II, sala 2005. Campus Pampulha, BH/MG. CEP 31270-901

Tenho direito de agora, ou mais tarde, discutir demais dúvidas que venha a ter com relação à pesquisa com:
- Prof. Christina Danielli Coelho de Morais Faria: (31) 3409-7448; (31) 3409-4783; cdcmf@ufmg.br
  Av. Antônio Carlos, 6627, Escola de Educação Física, Fisioterapia e Terapia Ocupacional, Departamento de Fisioterapia, Sala 3109. Campus Pampulha, BH/MG. CEP: 31270-901.
- Larissa Tavares Aguiar: (31) 93132076; larissatavaresaguiar@gmail.com
- Júlia Caetano Martins: (31) 83099334; julia_caetano@yahoo.com.br

Assinando esse termo de consentimento, estou indicando que concordo em participar deste estudo.

______________________________________ ______________________

Assinatura do Participante Data

RG:___________________________ CPF:_________________________

End.: ____

______________________________________ ______________________

Assinatura da Investigadora Responsável Data

Christina DCM Faria/ Raquel R Britto/ Paula L Scalzo/Larissa T Aguiar/Júlia C Martins

APÊNDICE II - MINI CURRÍCULO (2019-2021)

ARTIGOS PUBLICADOS EM PERIÓDICOS CIENTÍFICOS

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4. Peniche PC, Aguiar LT, Reis MTF, Oliveira DMG, Scalzo PL, Faria CDCM. The distance covered in field tests is more explained by walking capacity than by cardiorespiratory fitness after stroke. J Stroke Cerebrovasc Dis. 2021;30(9):105995.
5. Peniche PC, Aguiar LT, Reis MTF, Faria CDCM. Investigation into the validity of four equations to predict the maximum oxygen comsumption of individuals after stroke. Ann Phys Rehabil Med. 65(2021)101584.

ARTIGOS SUBMETIDOS PARA PUBLICAÇÃO

1. Reis MTF, Garcia LN, Bernardino LHN, Martins JC, Aguiar LT, Faria CDCM. Exercise capacity of individuals after stroke is most strongly explained by which dimension of physical activity: duration, frequency, or intensity? Neurological Sciences.
2. Reis MTF, Aguiar LT, Garcia LN, Brito SAF, Benfica PA, Faria CDCM. Knee extensor muscle strength indicates global lower limb strength in community-dwelling older adults. Physiotherapy Theory and Practice.
3. Reis MTF, Aguiar LT, Peniche PC, Faria CDCM. Age-predicted equations are not valid in predicting maximum heart rate in individuals after stroke. Annals of Physical and Rehabilitation Medicine.

OUTRAS PRODUÇÕES

1. Faria CDCM, Rodrigues AL, Silva FG, et al. Guia de aula prática da disciplina medidas clínicas e observacionais. In: Faria CDCM, Peniche PC, Brito SAF. AVALIAÇÃO DA POTÊNCIA MUSCULAR. Belo Horizonte: Universidade Federal de Minas Gerais, 2020.

FINANCIAMENTO

1. Bolsa de mestrado da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) (Agosto, 2019).

EXPERIÊNCIA DOCENTE

1. Estágio em docência. Disciplina: Fisioterapia Neurológica II. Instituição: Universidade Federal de Minas Gerais. Duração: 2019/2, nos meses de agosto a novembro de 2019.
2. Estágio em docência. Disciplina: Medidas Clínicas e Observacionais. Instituição: Universidade Federal de Minas Gerais. Duração: 2020/1 (Ensino Remoto Emergencial), nos meses de março a junho de 2020.
3. Participação como professora convidada na disciplina: Medidas Clínicas e Observacionais para os alunos do curso de graduação em Fisioterapia da UFMG, no segundo período de 2020.

FORMAÇÃO COMPLEMENTAR

1. Avaliação Fisioterapêutica Neurofuncional da Criança e do Adolescente. (Carga horária: 10h). Fisioconsult, Brasil.
2. Atualizações em Fisioterapia na Doença de Parkinson. (Carga horária: 4h). Associação dos Parkinsonianos de Minas Gerais, ASPARMIG, Brasil.
3. Lesão medular e complicações associadas. (Carga horária: 3h). Acreditando, Brasil.
4. Mendeley para a UFMG. (Carga horária: 1h). Elsevier B.V., Holanda.
5. Prescrição de exercícios em populações com lesões neurológicas. (Carga horária: 24h). Acreditando, Brasil.
6. e-AEROBICS for Stroke Training Program. Canadian Partnership for Stroke Recovery, CPSR, Canadá.
7. PROTOCOLOS DE MANEJO CLÍNICO DO CORONAVÍRUS (COVID-19). Ministério da Saúde, Brasil.
8. Minicurso: Gaiola de habilidades como recurso terapêutico. (Carga horária: 3h). Instituto Prado, Brasil.

PARTICIPAÇÃO EM EVENTOS CIENTÍFICOS

1. IV Evidence - Fórum de prerrogativas e práticas científicas do CREFITO 4. 2019.
2. IV Encontro Científico da ABRAFIN/MG. 2019.
3. Simpósio de Fisioterapia Neurofuncional Online. 2020.
4. I Simpósio Brasileiro de Atualização em Neurofuncional. 2020.
5. III Simpósio Online de Fisioterapia Neurofuncional. 2020.
6. I Fórum de Assistência Domiciliar. 2020.
7. EVIDENCE - V Fórum de Prerrogativas e Práticas Científicas: Neurofuncional. 2020.
8. Congresso online de avaliação e tratamento das disfunções neurológicas (NEUROADVANCE). 2020.
9. Congresso internacional de fisioterapia e envelhecimento humano. 2020.
10. Simpósio Internacional Online em Ciências da Reabilitação. 2021.

APRESENTAÇÃO DE TRABALHO EM EVENTOS CIENTÍFICOS

1. Reis MTF, Aguiar LT, Peniche PC, Faria CDCM. Equações de predição da frequência cardíaca máxima para indivíduos pós-acidente vascular encefálico. #VisualizaUFMG2020: Tecnologia, Ciência e Arte. Diretoria de Divulgação Científica, Universidade Federal de Minas Gerais. 2020.
2. Reis MTF, Aguiar LT, Peniche PC, Faria CDCM. Predição da frequência cardíaca máxima de indivíduos pós-acidente vascular encefálico: validade de equações prévias baseadas na idade. VI COBRAFIN.
3. Reis MTF, Aguiar LT, Peniche PC, Faria CDCM. Desenvolvimento e investigação da validade de equações de predição da frequência cardíaca máxima específicas para indivíduos pós-acidente vascular encefálico. VI COBRAFIN.

TRABALHOS PREMIADOS

1. Reis MTF, Aguiar LT, Peniche PC, Faria CDCM. Desenvolvimento e investigação da validade de equações de predição da frequência cardíaca máxima específicas para indivíduos pós-acidente vascular encefálico. Melhor trabalho científico apresentado no VI COBRAFIN.

PARTICIPAÇÃO EM BANCA EXAMINADORA

1. Banca de defesa de trabalho de conclusão de curso. Rosângela Alves Rocha. Quais protocolos de treino de marcha para indivíduos pós-Acidente Vascular Encefálico na fase crônica são viáveis de serem orientados nos diferentes níveis de atenção do Sistema Único de Saúde?: uma revisão narrativa de literatura. Curso de Especialização em Avanços Clínicos em Fisioterapia. Universidade Federal de Minas Gerais. 2021.

ORGANIZAÇÃO DE EVENTOS

1. Encontro com a Pesquisa e a Extensão na EEFFTO. Universidade Federal de Minas Gerais. 2019.

EXPERIÊNCIA COMO REVISOR

1. Periódico: Journal of Bodywork and Movement Therapies (Agosto, 2020; Março, 2021).