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Henrique Bianchi Oliveira

INFLUÊNCIA DA INCLINAÇÃO POSITIVA E NEGATIVA SOBRE A FISIOMECÂNICA DA LOCOMOÇÃO DE ADULTOS COM OBESIDADE: RESPOSTAS RELACIONADAS AO GASTO ENERGÉTICO, TRABALHO MECÂNICO, VARIÁVEIS CARDÍACAS E FORÇA DE IMPACTO

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Tese de doutorado apresentada ao Programa de Pós-Graduação em Ciências do Movimento Humano da Escola de Educação Física, Fisioterapia e Dança da Universidade Federal do Rio Grande do Sul, como requisito parcial para obtenção do título de Doutor em Ciências do Movimento Humano.

Orientador: Prof. Dr. Luiz Fernando Martins Kruel

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RESUMO

Introdução: A locomoção em superfície inclinada promove alterações nos parâmetros energéticos e mecânicos, o que pode gerar vantagens para a prescrição do exercício para adultos com obesidade. Os objetivos deste estudo foram: i) desenvolver uma Revisão Sistemática relacionada aos desfechos mecânicos, energéticos e hemodinâmicos durante a locomoção em inclinação de pessoas com obesidade e sobrepeso ii) propor um método de avaliação integrativa entre os sistemas energéticos, mecânicos e hemodinâmicos durante a locomoção em inclinação; iii) comparar os efeitos da inclinação positiva (POS) e negativa (NEG) sobre os parâmetros máximos, limiares ventilatórios (LV) e percepção de esforço (PE) de adultos obesos; iv) comparar os efeitos POS e NEG nas respostas relacionadas ao gasto energético, trabalho mecânico, demanda cardiovascular e pico da força de reação vertical do solo (FRSv) em adultos com obesidade. **Métodos:** para o estudo dos parâmetros máximos, participaram 11 homens (idade = 24,32±2,32 anos) com obesidade (% massa gorda = 39,38±4,56%) que realizaram três testes máximos nas inclinações de -5, 0 e + 5% com, no mínimo, 72h de intervalo. Dados cardiorrespiratórios foram avaliados para determinar o primeiro LV (LV1), o segundo LV (LV2) e o VO_{2pico}. O protocolo para 0 e +5% iniciou em 3km.h^{-1} com aumento de 0,5 km.h^{-1}/min, e para -5% iniciou em 4km.h^{-1}, com aumento de 1km.h^{-1}/min. A análise estatística utilizou ANOVA de medidas repetidas com post-hoc de Bonferroni e α=0,05. Para o estudo dos parâmetros submáximos, participaram 4 homens (idade = 25,7±4,5 anos, % gordura = 36,9±1,7%, VO_{2pico} = 34,06±7,29 ml.kg^{-1}.min^{-1}). As variáveis foram coletadas em velocidade fixa (4,5 km.h^{-1}), velocidades de LV1 e LV2, nas inclinações -5%, 0%, + 5%. Utilizou-se um analisador de gases, um sistema cinemático 3D, uma esteira instrumentada e um dispositivo de impedância cardíaca. A análise dos dados foi feita com tamanho de efeito e intervalo de confiança. **Resultados:** No estudo dos testes máximos, o VO_{2pico} foi semelhante entre as inclinações. As velocidades de LV1, LV2 e máximo foram menores em POS (4,4, 6,5 e 7,3 km.h^{-1}), intermediárias no plano (5,3, 8,4 e 9,5 km.h^{-1}) e maiores em NEG (5,9, 10,5 e 11,5 km.h^{-1}). A PE foi menor em -5% em LV1 e semelhante nas três inclinações em LV2. O VO_2 em LV1 foi maior em POS e no LV2 foi semelhante entre as inclinações. No estudo dos parâmetros submáximos, as velocidades absolutas foram menores em POS e maiores NEG em relação ao plano. POS apresentou maior gasto energético nas três velocidades. O trabalho mecânico externo apresentou relação direta com a inclinação e trabalho mecânico interno com a velocidade absoluta. FRSv na maioria das condições foi menor em POS. Ainda, POS apresentou maiores valores de frequência cardíaca. **Conclusão:** A inclinação positiva promove demanda metabólica e percepção de esforço semelhante em teste máximo sob menores velocidades, sendo uma boa alternativa para adultos com obesidade. Em condições submáximas, a inclinação positiva é capaz de promover maior gasto calórico em menores velocidades, com redução do impacto e com carga cardiovascular semelhante.

Palavras-chave: inclinação, obesidade, locomoção, gasto calórico

ABSTRACT

Introduction: Locomotion on a sloping surface promotes changes in energetics and mechanical parameters, which can generate advantages for the prescription of exercise for adults with obesity. The objectives of this study were: i) to develop a Systematic Review related to mechanical, energetic, and hemodynamic outcomes during incline locomotion in people with obesity and overweight; ii) to propose an integrative assessment method between energetic, mechanical, and hemodynamic systems during incline locomotion; iii) to compare the effects of positive and negative inclination on maximum parameters, ventilatory thresholds (VT) and perceived exertion in obese adults; iv) to compare the effects of positive and negative inclination on responses related to energy expenditure, mechanical work, cardiovascular demand and peak vertical ground reaction force (GRFv) in adults with obesity. **Methods:** For the study of the maximum parameters, 11 men (age = 24.32 ± 2.32 years) with obesity (% fat mass = 39.38 ± 4.56%) participated, who underwent three maximum tests on the slopes of -5, 0, and + 5% with at least 72h interval. Cardiometabolic data were evaluated to determine the first VT (VT1), the second VT (VT2), and the VO_{2peak}. The protocol for 0 and + 5% started at $3km.h^{-1}$ with an increase of $0.5km.h^{-1}$/min, and for -5% it started at $4km.h^{-1}$, with an increase of 1.0km .h-1/min. Statistical analysis used repeated-measures ANOVA with Bonferroni post-hoc and $\alpha = 0.05$. For the study of submaximal parameters, 4 men participated (age = 25.7 ± 4.5 years, % fat = 36.9 ± 1.7%, VO_{2peak} = 34.06 ± 7.29 $ml.kg^{-1}.min^{-1}$). The variables were collected at fixed speed (4.5 $km.h^{-1}$), speeds of VT1 and VT2, on slopes -5%, 0%, + 5%. A gas analyzer, a 3D kinematic system, an instrumented treadmill, and a cardiac impedance device were used. Data analysis was performed with effect size and confidence interval. **Results:** In the study of maximum tests, VO_{2peak} was similar between the slopes. The speeds associated with VT1, VT2, and maximum were lower in the positive slope (4.4, 6.5, and $7.3km.h^{-1}$), intermediate in the level (5.3, 8.4, and $9.5km.h^{-1}$), and higher in the negative slope (5.9, 10.5, and 11.5 $km.h\text{-}^{1}$). The rate of perceived exertion was lower in -5% in VT1 and similar in the three slopes in VT2. In VT1, VO_2 was higher in the positive slope and in VT2 it was similar between the slopes. In the study of submaximal parameters, the absolute speeds were lower in the positive slope and higher in the negative slope concerning the flat. The positive slope showed higher energy expenditure. External mechanical work was directly related to the slope and Internal mechanical work to the absolute speed. GRFv in most conditions was lower in the positive slope. The positive slope showed higher heart rate values. **Conclusion:** The positive inclination promotes metabolic demand and perceived exertion similar in maximum test at lower speeds, being a good alternative for adults with obesity. In submaximal conditions, the positive slope promotes greater energy expenditure at lower speeds, with reduced impact, and with a similar cardiovascular load.

Keywords: gradient, obesity, locomotion, caloric expenditure, mechanical work

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LISTA DE ABREVIATURAS E SIGLAS

1LV: Primeiro Limiar Ventilatório

2LV: Segundo Limiar Ventilatório

ACSM: The American College of Sports Medicine

BMI: Body Mass Index

C: Cost of Transport

CM: Centro De Massa Corporal

CO: Cardiac Output

DC: Débito Cardíaco

E_C: Energia Cinética

E_P: Energia Potencial

ES: Effect Sizes

FC: Frequência Cardíaca

FC_{max}: Frequência Cardíaca máxima

FICF: Free and Informed Consent Form

FLAT: Level Ground Inclination (0%)

GRFv: Ground Reaction Force vertical

HAIT: High Intensity Interval

HR: Heart Rate

HR_{max}: Maximal Heart Rate

IEP: Índice de Esforço Percebido

IMC: Índice de Massa Corporal

MIT: Moderate Intensity Continuous

MOOSE: Meta-analyses of Observational Studies in Epidemiology

NEG: Inclinação Negativa (-5%)

NMM: Net Muscle Moment

NW: Nordic Walking

POS: Inclinação Positiva (+5%)

PROSPERO: International Prospective Register of Systematic Reviews

RER: Respiratory Exchange Rate

RPE: Rating of Perceived Exertion

SV: Stroke Volume

TB: Tibiofemoral

TESTEX: Tool for Assessment of Study Quality and Reporting in Exercise

UFRGS: Universidade Federal do Rio Grande do Sul

V1LV: Velocidade Relativa ao Primeiro Limiar Ventilatório

V2LV: Velocidade Relativa ao Segundo Limiar Ventilatório

VE: Ventilation

VO_2: Consumo de Oxigênio

VO_{2pico}: Consumo de Oxigênio de Pico

VS: Volume Sistólico

VT: Ventilatory Threshold

VT1: First Ventilatory Threshold

VT2: Second Ventilatory Threshold

W_{ext}: External Mechanical Work

WHO: World Health Organization

W_{int}: Internal Mechanical Work

W_{mec}: Mechanical Work

W_{tot}: Total Mechanical Work

SUMÁRIO

APRESENTAÇÃO DA TESE

Esta Tese foi elaborada de acordo com as orientações para a normalização de trabalhos acadêmicos da Escola de Educação Física, Fisioterapia e Dança da Universidade Federal do Rio Grande do Sul, a partir do regimento vigente do CEPE/UFRGS, com a inclusão de artigos científicos formatados para submissão nas respectivas revistas científicas. De acordo com a norma, este documento foi construído com a inclusão de quatro artigos na seguinte estrutura: introdução geral, materiais e métodos gerais, artigos (revisão sistemática (artigo 1), estudo de protocolo (artigo 2), estudo sobre os testes máximos (artigo 3), estudo sobre os testes submáximos (artigo 4)) e considerações finais.

O capítulo de revisão de literatura foi contemplado no formato de artigo de revisão sistemática (Artigo 1: *Mechanics, energetics, and hemodynamics outcomes of people with obesity and overweight during walking on a slope: a systematic review*), submetido na revista Obesity Reviews). O capítulo de materiais e métodos foi escrito também em formato de artigo de Protocolo (Artigo 2: *Obese locomotion on positive and negative slope at iso-intensity: outcomes related to energetics, mechanics, perceived exertion, and hemodynamics. A study protocol*.), submetido na revista Frontiers in Physiology – Methods. Os resultados referentes aos dados coletados nos testes máximos e submáximos estão divididos em dois artigos, sendo um deles com o N amostral completo (Artigo 3: *Influence of positive and negative inclination during maximal test on Vo_{2peak}, ventilatory thresholds and perceived exertion on adults with obesity*), formatado para submissão na revista Journal of Sports Science & Medicine, e o outro com o N amostral reduzido, devido à impossibilidade de conclusão da coleta de dados em função da situação de pandemia causada pela COVID-19 (Artigo 4: *Insights into an integrative point of view of the energetic, mechanical and hemodynamic systems on locomotion at different inclinations of individuals with obesity*), formatado para submissão na revista Journal of Physical Activity and Health – Brief Report.

1 INTRODUÇÃO GERAL

A quantidade de pessoas com obesidade triplicou em nível mundial em relação aos números registrados em 1975. Mais do que 1,9 bilhões de adultos apresentam sobrepeso e, destes, 650 milhões são classificados com algum grau de obesidade (WHO, 2017). No Brasil, aproximadamente 48% das mulheres e 54,5% dos homens estão com sobrepeso e, destes, 18,2% das mulheres e 16,5% dos homens adultos apresentam algum nível de obesidade (BRASIL, 2013). Fator preocupante relacionado a estes números é que o sobrepeso, a obesidade e seus fatores de risco relacionados apresentam uma forte relação com a incidência de morbidade e mortalidade (DI CESARE *et al.*, 2016).

A obesidade é tipicamente causada, entre outros fatores, por um crônico desequilíbrio energético, onde a energia consumida é maior do que a energia gasta (FOGELHOLM; KUKKONEN-HARJULA, 2000). Como resultado, indivíduos interessados em emagrecer, são orientados a modificar a dieta e realizar, no mínimo, 30-60 minutos de atividade física moderada/intensa (40-60% $VO_{2máx}$) na maioria dos dias da semana (HASKELL *et al.*, 2007). Neste contexto, a caminhada é a maneira mais popular de atividade física para indivíduos obesos, pois é relativamente de fácil execução, requer um gasto energético considerável e tipicamente atende ao critério da intensidade moderada/vigorosa, principalmente em altas velocidades (BROWNING *et al.*, 2006).

Apesar de ser considerada uma atividade motora complexa, a caminhada humana pode ser descrita como um modelo de pêndulo invertido simples, o qual conserva as energias mecânicas do centro de massa corporal (CM) pela reconversão de energia potencial gravitacional (E_P) em energia cinética (E_C) e vice-versa (MARGARIA, 1976). Contudo, a reconversão de energia advinda do mecanismo do pêndulo invertido não é de 100% (chega ao máximo de aproximadamente 70%). O restante da energia necessária para realizar a caminhada é advindo do trabalho mecânico das unidades músculo-tendão (CAVAGNA; SAIBENE; MARGARIA, 1963), relações que sofrem influência da inclinação do terreno (GOMEÑUKA *et al.*, 2016; MINETTI; ARDIGO; SAIBENE, 1993). O desenvolvimento do estudo da caminhada na inclinação tem demonstrado que a transferência energética entre E_P e E_C continua ocorrendo mesmo nas condições de inclinação positiva e inclinação negativa. Na comparação com a caminhada no plano, a caminhada em inclinação positiva apresenta redução na troca energética ente E_P e E_C (GOMEÑUKA *et al.*, 2014, 2016). Enquanto a caminhada em inclinação negativa parece promover um aumento nesta troca energética (DEWOLF *et al.*, 2017; GOTTSCHALL; KRAM, 2006). Situações de inclinação são desafios constantes na locomoção diária em ambiente livre, assim como a possibilidade de manipulação da inclinação da superfície em ambiente controlado, como em alguns modelos comerciais de esteira motorizada (LAY *et al.*, 2006).

A caminhada realizada em plano inclinado vem sendo investigada desde 1938, em um estudo clássico de Margaria, o qual demonstrou haver maior gasto energético na inclinação positiva, no plano e na inclinação negativa, respectivamente. O menor gasto energético é encontrado em inclinações entre -10 e -15% e, a partir desse percentual, o gasto energético aumenta em função da inclinação (MARGARIA, 1938). Caminhar em uma superfície com inclinação positiva requer ajustes na atividade muscular e maior demanda metabólica, comparando com a caminhada no plano sob mesma velocidade absoluta, principalmente em função do aumento da magnitude e da duração da atividade muscular, considerando que nesta condição há predominância de contrações concêntricas da musculatura propulsora, o que sugere que o padrão de ativação muscular pode ajudar a predizer o aumento do custo metabólico na inclinação (KIMEL-NAOR; GOTTLIEB; PLOTNIK, 2017; SILDER; BESIER; DELP, 2012). A caminhada em inclinação moderada positiva (5 – 15%) e em velocidades relativamente baixas (0,5 – 1,0 $m.s^{-1}$) pode atender aos requisitos recomendados para os níveis de atividade física, equivalendo, em termos metabólicos, à caminhada no plano em maiores velocidades. Por exemplo, adultos obesos caminhando a 0,75 $m.s^{-1}$ e em uma inclinação de 10% estão numa intensidade de aproximadamente 52% do VO_{2pico}, enquanto que, caminhando no plano a 1,50 $m.s^{-1}$, estão numa faixa de intensidade de aproximadamente 50% do VO_{2pico} (EHLEN; REISER; BROWNING, 2011).

Outra característica da caminhada em inclinação positiva moderada é que pode reduzir significativamente o risco de doenças musculoesqueléticas e articulares em adultos obesos, em função da diminuição das cargas e dos momentos articulares, quando comparada à caminhada no plano (ALEXANDER; SCHWAMEDER, 2016a). Portanto, a caminhada em inclinações positivas moderadas e em velocidades relativamente lentas pode ser uma forma de atividade física adequada em termos mecânicos e energéticos para adultos obesos atingirem o nível recomendado de gasto calórico (BROWNING *et al.*, 2013; EHLEN; REISER; BROWNING, 2011).

O estudo de Browning e col. (2013) foi, para nosso conhecimento, o pioneiro na pesquisa sobre a caminhada de adultos com obesidade tanto em inclinação positiva quanto em inclinação negativa, no qual os autores verificaram que, na inclinação negativa de -3º e na velocidade de 1,25 $m.s^{-1}$, indivíduos obesos conseguem atingir um nível de intensidade próxima a 40% do VO_{2pico}, sugerindo que essa condição de inclinação pode ser uma boa alternativa para intensidades moderadas de atividade física. Os autores sugerem que estudos futuros, com maior amostra, grupo controle, mensurações padronizadas e protocolos de caminhada são necessários para aprimorar os resultados encontrados. Uma das desvantagens do plano declinado é a possível maior carga articular, o que foi confirmado apenas em indivíduos eutróficos a partir de -10º (ALEXANDER; SCHWAMEDER, 2016b) e, em indivíduos com obesidade, apenas especulação de que mesmo com pouca inclinação negativa pode haver maiores impactos do que caminhar em superfície plana. (BROWNING *et al.*, 2013; STRUTZENBERGER; CLAUSSEN; SCHWAMEDER, 2021). Uma característica relativa à inclinação negativa é que existe um paradoxo entre índice de esforço percebido (IEP) e intensidade de exercício. Quando a caminhada é realizada em mesma velocidade absoluta, quando comparada com a caminhada no plano, o IEP é menor, devido principalmente à menor carga relativa (%$VO_{2máx}$) nesta condição (AGARWAL; SINGH; SHARMA; *et al.*, 2017). Contudo, em condições de mesma carga relativa, o que representa maiores velocidades absolutas na inclinação negativa, não foram encontrados estudos que confirmam ou rejeitam a hipótese de menor IEP nesta condição.

Outro sistema que apresenta respostas específicas ao tipo de contração muscular durante o exercício é o sistema cardiovascular, por meio da análise de variáveis como a frequência cardíaca (FC), o volume sistólico (VS) e o débito cardíaco (DC). Um estudo que comparou em método *crossover* uma sessão de treinamento de força realizado exclusivamente com contrações concêntricas e outra sessão com contrações exclusivamente excêntricas, demonstrou que o exercício excêntrico é capaz de gerar menores demandas cardiovasculares (menor FC para o mesmo DC) em comparação com os exercícios concêntricos. Os autores especulam que essa resposta pode ser atribuída à menor massa muscular utilizada, sob uma mesma carga absoluta, na atividade excêntrica, o que representa menor recrutamento e taxas de disparo das unidades motoras (AGARWAL; SINGH; NARAYAN; *et al.*, 2017). Contudo, não foram encontrados estudos que avaliaram as respostas cardiovasculares na caminhada em inclinação de adultos com obesidade. Se, por um lado, a caminhada em inclinação positiva pode favorecer o indivíduo com obesidade por diminuir o impacto articular e por poder ser realizada em velocidades absolutas menores para a mesma demanda metabólica, por outro lado, a caminhada em inclinação negativa pode ser favorável por permitir caminhar em maiores velocidades absolutas, com menor IEP e sob uma possível menor sobrecarga cardiovascular.

Diante deste contexto, justifica-se a importância de compreender, em situação de obesidade, a relação entre os fatores Fisiomecânicos da caminhada em plano inclinado positivo e negativo, tendo em vista o aumento significativo do desenvolvimento da obesidade na população mundial e a busca por alternativas de exercício físico que possam auxiliar na diminuição da obesidade e do sedentarismo. A partir dos resultados obtidos, pretende-se aprimorar a prescrição de exercício de caminhada/corrida com a utilização da inclinação, pois, estabelecendo o comportamento dos padrões biomecânicos e fisiológicos nestas condições, torna-se possível executar essa atividade com a melhor relação mecânica e energética, com o objetivo de realizar o exercício de maneira segura e eficiente.

Dessa forma, configura-se o seguinte problema de pesquisa: Quais os efeitos da caminhada/corrida em plano inclinados positivo e negativo sobre as variáveis Fisiomecânicas máximas e submáximas, especialmente o gasto calórico, o trabalho mecânico, a força de reação do solo e a demanda cardiovascular em adultos com obesidade?

A hipótese central deste estudo foi de que há influência da inclinação sobre os parâmetros energéticos, mecânicos e hemodinâmicos da locomoção de adultos com obesidade. Especificamente, sob uma mesma condição de intensidade, a inclinação positiva deve promover maior gasto energético, maior trabalho mecânico total, menor força de impacto, enquanto a inclinação negativa deve possibilitar maiores velocidades absolutas, menor demanda cardiovascular e menor percepção de esforço.

1.1 OBJETIVOS

1.1.1 Objetivo geral

Comparar os efeitos da inclinação positiva e negativa em diferentes condições de velocidade sobre as respostas máximas e submáximas relacionadas especialmente ao gasto calórico, ao trabalho mecânico, ao impacto articular e à demanda cardiovascular durante a caminhada/corrida de adultos com obesidade.

1.1.2 Objetivos específicos

- Desenvolver uma revisão sistemática sobre os efeitos da inclinação em variáveis energéticas, mecânicas e hemodinâmicas de adultos com obesidade e sobrepeso (artigo 1);
- Desenvolver um novo protocolo integrativo de coleta de dados com variáveis energéticas, mecânicas e hemodinâmicas de adultos com obesidade (artigo 2);
- Comparar as respostas metabólicas e de percepção de esforço durante testes máximos em inclinação positiva e negativa de adultos com obesidade (artigo 3);
- Comparar os efeitos da inclinação positiva e negativa em diferentes velocidades sobre as variáveis metabólicas, mecânicas e hemodinâmicas da caminhada/corrida de adultos com obesidade (artigo 4).

2 MATERIAIS E MÉTODOS

Neste capítulo, será descrito de maneira simplificada o protocolo referente às coletas e análises dos dados que resultaram nos artigos 3 e 4. Este capítulo também foi escrito de forma detalhada e submetido no formato de artigo de Estudo de Protocolo (Artigo 2).

Este estudo foi aprovado pelo Comitê de Ética em Pesquisa da Universidade Federal do Rio Grande do Sul, sob protocolo número 2.660.010 (Apêndice 1).

2.1 DELINEAMENTO

Este estudo foi caracterizado como um estudo observacional transversal.

2.2 POPULAÇÃO DO ESTUDO

2.2.1 Critérios de Inclusão

Foram incluídos homens com idade entre 18 e 35 anos, classificados com obesidade grau 1 (Índice de Massa Corporal (IMC) entre 30 e 34,9 $kg.m^{-2}$)) ou grau 2 (IMC entre 35 e 39,9 $kg.m^{-2}$), isentos da prática regular de exercícios físicos há pelo menos três meses. A prática regular de exercício foi definida como realização de qualquer modalidade de treinamento físico por no mínimo 20 minutos em três ou mais dias da semana.

2.2.2 Critérios de Exclusão

Foram adotados como critérios de exclusão do estudo a presença de histórico de lesões músculo-tendíneas, articulares, doenças crônicas relacionadas a problemas cardíacos e respiratórios e qualquer outro comprometimento muscular ou articular que impedisse a realização de exercícios físicos com segurança.

2.2.3 Recrutamento e Elegibilidade

A seleção dos participantes ocorreu de forma não-probabilística, por voluntariedade. O recrutamento foi realizado por meios eletrônicos e redes sociais. Os participantes entraram em contato por telefone ou e-mail, quando foram convidados a agendar uma primeira visita à Escola de Educação Física, Fisioterapia e Dança (ESEFID) da Universidade Federal do Rio Grande do Sul (UFRGS). Nesta visita, um dos pesquisadores envolvidos no projeto informou aos participantes a respeito dos objetivos, riscos e procedimentos envolvidos na pesquisa. Após esta explicação detalhada, os participantes foram convidados a lerem um termo de consentimento livre e esclarecido (Apêndice 2) e o assinarem, quando em concordância com o mesmo.

2.2.4 Cálculo Amostral

O cálculo amostral foi realizado no software G*POWER 3.1.6 (Apêndice 3). Este cálculo foi desenvolvido a partir dos valores para gasto energético do estudo de Browning et al. (2013) considerando a comparação entre as inclinações de -3° e +3°, a qual apresentou tamanho de efeito de 1,3. Foi adotado um nível de significância de 0,05 e um poder de 80%, resultando na necessidade de pelo menos 11 participantes.

2.3 VARIÁVEIS INDEPENDENTES

Inclinação:

- Inclinação positiva: +5%
- Inclinação neutra: 0%
- Inclinação negativa: -5%

2.4 VARIÁVEIS DEPENDENTES

- Gasto Calórico;
- Custo de Transporte;
- Consumo de Oxigênio;

- Índice de Percepção de Esforço;
- Velocidade absoluta relativa ao Primeiro Limiar Ventilatório;
- Velocidade absoluta relativa ao Segundo Limiar Ventilatório;
- Trabalho Mecânico Total;
- Trabalho Mecânico Externo;
- Trabalho Mecânico Interno;
- Pico da Força de Reação do Solo vertical;
- Frequência Cardíaca;
- Volume Sistólico;
- Débito Cardíaco;

2.5 VARIÁVEIS DE CARACTERIZAÇÃO DA AMOSTRA

- Idade;
- Estatura;
- Massa Corporal;
- Índice de Massa Corporal;
- Massa Gorda Total;
- Percentual de Gordura Total.

2.6 DESCRIÇÃO DAS INTERVENÇÕES

As coletas de dados ocorreram no Laboratório de Pesquisa do Exercício, Setor de Biodinâmica, da Escola de Educação Física, Fisioterapia e Dança da UFRGS. Todas as avaliações de caminhada/corrida foram realizadas sobre a esteira rolante com capacidade de inclinação positiva e negativa. Cada avaliado compareceu ao laboratório em seis dias para realizar as avaliações, com intervalo mínimo de 72 horas entre cada dia (Figura 1).

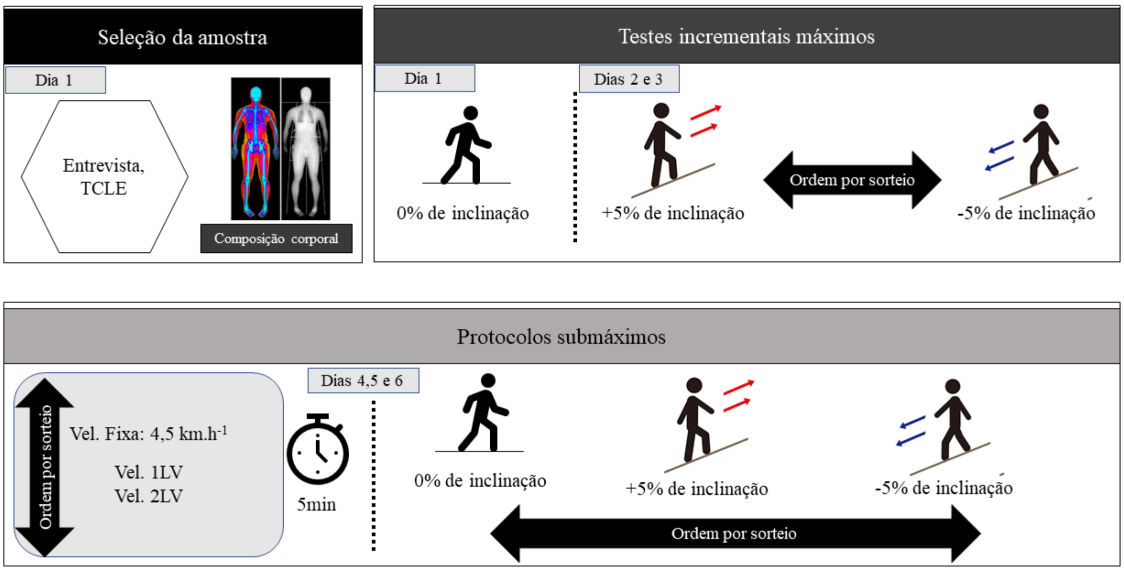

Figura 1: Desenho experimental do protocolo.

No primeiro dia foi realizada uma entrevista e a explicação e leitura do Termo de Consentimento Livre e Esclarecido (TCLE). Após a concordância sobre os procedimentos e a assinatura do TCLE, os indivíduos passaram por uma avaliação antropométrica (necessária para os parâmetros do sistema de cinemetria) e foram convidados a realizarem a familiarização com a esteira rolante e os equipamentos, além do teste incremental máximo na esteira na condição sem inclinação.

Nas próximas duas visitas, foram realizados os testes máximos em condição de inclinação. Em um dos dias em inclinação positiva e no outro inclinação negativa, com a ordem definida por sorteio.

Nos outros três dias de coleta (um dia para cada inclinação: plano, positiva e negativa), primeiramente foi realizada a colocação dos pontos refletivos necessários para o sistema de cinemetria, após foram colocados os eletrodos do sistema de cardioimpedância e a máscara de análise de gases respiratórios. Após, foi realizado o protocolo de testes nas seguintes condições nas três inclinações: velocidade referente ao 1º Limiar Ventilatório (V1LV); velocidade referente ao 2º limiar ventilatório (V2LV); e velocidade fixa (4,5 km.h^{-1}). A ordem foi randomizada e cada uma destas condições foi executada por cinco minutos, seguidos de, no mínimo, 15 minutos de descanso na posição sentado ou até que os valores de repouso (FC e VO_2 fossem reestabelecidos). Foi utilizado um sistema de cinemetria e um sistema de sensores de força sob a esteira para avaliação das forças de reação do solo para posterior cálculo das variáveis biomecânicas, um sistema de ergoespirometria para avaliação das variáveis bioenergéticas, um sistema de cardioimpedância para avaliação das variáveis cardiovasculares durante os testes. A marcação dos testes foi realizada na mesma faixa horária nos diferentes dias para cada indivíduo. Os dados de VO_2 e hemodinâmicos foram coletados durante os cinco minutos de teste, os registros cinéticos e cinemáticos ocorreram simultaneamente a partir de três minutos e trinta segundos, até quatro minutos e trinta segundos.

Os indivíduos foram orientados a seguir seus hábitos alimentares e de atividade física sem alterações durante o período de coletas. Para todas as avaliações, os indivíduos foram orientados também a utilizar roupas leves e confortáveis e um calçado habitualmente utilizado para prática de atividade física.

2.7 AFERIÇÃO DOS DESFECHOS: INSTRUMENTOS DE MEDIDA E PROTOCOLOS OPERACIONAIS

2.7.1 Composição Corporal

- Instrumento:
  1. Scanner DEXA: modelo Lunar Prodigy, General Electric (Company, Illinois, USA).
- Protocolo:

A composição corporal foi mensurada por meio de exames de dupla emissão de raios-X (DEXA), pois é um método não invasivo e de alta fidedignidade que avalia diretamente todos os componentes da composição corporal (massa óssea, massa muscular e líquidos e massa gordurosa). É um exame que não requer preparo do indivíduo, tem duração entre 10 e 15 minutos, a radiação é extremamente baixa e pode ser repetido quantas vezes for necessário. Para uma maior precisão nos resultados, os participantes receberam as seguintes orientações: não praticar exercícios físicos 12h antes do teste, estar em jejum de 4h antes do teste, não ingerir líquidos 1-2 horas antes do teste, não ingerir medicamentos à base de cálcio 24 horas antes da avaliação, não ter realizado exame de Medicina Nuclear (cintilografia) previamente (2 semanas), não ter realizado exame radiológico com uso de contraste em menos de 2 semanas, durante a avaliação usar roupa largas, sem metais tachas, zíper, botões, cintos, broches, brincos, pulseiras, anéis, etc.

2.7.2 Teste Incremental Máximo

- Instrumentos:
  1. Esteira ergométrica: modelo super-ATL da marca Inbramed (Porto Alegre, Brasil), com resolução de velocidade e inclinação de 0,1 $km.h^{-1}$ e 1%, respectivamente;
  2. Ergoespirômetro com monitor cardíaco: modelo K5 da marca Cosmed (Roma, Itália), com frequência de amostragem a cada respiração;
  3. Escala de Percepção de Esforço de Borg (6-20) (BORG, 1982).

- Protocolos:

Previamente a todos os testes máximos foi respeitado um período de 15 minutos de repouso. Os parâmetros de velocidade inicial, incremento de velocidade e tempo em cada estágio foram desenvolvidos a partir de testes pilotos. O protocolo utilizado para o teste máximo no plano consistiu em velocidade inicial de 3 $km.h^{-1}$ durante três minutos, com incrementos de 0,5 $km.h^{-1}$ a cada minuto, sem inclinação (0%). O protocolo para o teste máximo na inclinação positiva consistiu em uma velocidade inicial de 3 $km.h^{-1}$ durante três minutos, com incremento de velocidade de 0,5 $km.h^{-1}$ a cada minuto, com inclinação fixa de +5%. O protocolo para o teste máximo na inclinação negativa consistiu em uma velocidade inicial de 4 $km.h^{-1}$ durante três minutos, com incremento de velocidade de 1 $km.h^{-1}$ a cada minuto, com inclinação fixa de -5%.

A escolha dos percentuais de inclinação foi definida em função da capacidade do equipamento, pois a esteira utilizada tem capacidade de inclinação negativa máxima de -5%. Assim, buscamos uma comparação com inclinação positiva equivalente em +5%.

Os dados do consumo de oxigênio e a frequência cardíaca (FC) foram registrados de forma contínua e a percepção de esforço foi registrada no final de cada estágio. O teste foi interrompido quando o participante em teste sinalizou exaustão com gestos manuais. O teste foi considerado válido quando ao menos dois dos seguintes critérios fosse alcançado ao final do teste (HOWLEY *et al*. 1995): 1) obtenção da $FC_{máx}$ estimada (220 - idade); 2) obtenção de um RER maior que 1,1; 3) percepção de esforço maior que 17 (muito intenso – Escala RPE de Borg).

2.7.3 Protocolo Submáximo

- Instrumentos:
  1. Esteira ergométrica: modelo super-ATL da marca Inbramed (Porto Alegre, Brasil), com resolução de velocidade e inclinação de 0,1 $km.h^{-1}$ e 1%, respectivamente;
  2. Sistema com sensores de força acoplados à esteira para mensuração da força de reação do solo vertical, desenvolvido pela Instor (Porto Alegre, Brasil) e gerenciado pelo *software* LabView v.2014, com frequência de amostragem de 1000 Hz.
  3. Ergoespirômetro com monitor cardíaco: modelo K5 da marca Cosmed (Roma, Itália), com frequência de amostragem a cada respiração;
  4. Escala de Percepção de Esforço de Borg (6-20) (BORG, 1982).
  5. Monitor de cardioimpedância, modelo Enduro da marca PhysioFlow (Poissy, França), com registro dos dados médios a cada 15 segundos;
  6. Sistema de cinemetria 3D, VICON *Motion Capture System*, composto por seis câmeras de infravermelho (Oxford, UK), com frequência de amostragem de 100 Hz.

- Protocolo:

Os testes submáximos foram divididos em três dias, com intervalo mínimo de 72h entre eles. Em cada dia, foi utilizada uma das inclinações. Em cada inclinação, foram realizadas três velocidades, sendo as velocidades relativas ao primeiro (1LV) e segundo (2LV) limiar ventilatório, as quais foram obtidas com a análise dos testes máximos, e uma velocidade fixa de 4,5 $km.h^{-1}$. A inclinação relativa a cada dia de coleta e a ordem das velocidades foram previamente definidas por sorteio.

Inicialmente, foi realizado um período de repouso de 15 minutos. Após, foram colocados os eletrodos do sistema de cardioimpedância. Para isso, foram realizadas a tricotomia e a assepsia da pele (com gel abrasivo e álcool) nos locais de colocação dos eletrodos. Com a pele seca, os 6 eletrodos (FS-50, Skintact®, Áustria) foram fixados nos seguintes locais: região lateral esquerda do pescoço, fossa supraclavicular, centro do esterno, posições padronizadas V1 e V6 para eletrocardiograma e paralelo à coluna no nível do processo xifóide. O próximo passo foi a colocação dos 18 marcadores refletivos do sistema cinemático, aderidos à pele com fita dupla-face de silicone (3M®), seguindo o modelo proposto por Minetti et al. (1993) e recentemente descrito por Oliveira et al. (2020), bilateralmente posicionados nos seguintes pontos anatômicos: conduto auditivo, acrômio, epicôndilo lateral do úmero, ponto médio da articulação radioulnar distal, trocanter maior, epicôndilo femoral, maléolo lateral, calcâneo e quinto metatarso. A última etapa de preparação foi a colocação da máscara de análise de gases respiratórios.

Após a preparação completa, cada uma das velocidades foi realizada durante cinco minutos, com intervalo mínimo de 15 minutos entre cada velocidade. Os registros de consumo de oxigênio e de cardioimpedância foram realizados durante os cinco minutos de teste. Os registros cinéticos e cinemáticos ocorreram durante um minuto, entre o minuto 3:30 e o minuto 4:30.

2.8 ANÁLISE ESTATÍSTICA

Os procedimentos estatísticos foram realizados no *Software* SPSS v.19.

Para o artigo 3, referente aos testes máximos, foi realizada estatística descritiva com média e desvio padrão. A normalidade dos dados foi analisada com o teste de Shapiro-Wilk e a esfericidade foi avaliada com o teste de Mauchly. A fim de verificar a comparação entre as inclinações e considerando a normalidade dos dados, foi utilizada ANOVA de medidas repetidas, com post hoc de Bonferroni. O alfa adotado foi de 0,05. De forma complementar, foi calculado o tamanho de efeito, a partir do *g* de Hedges, com as seguintes classificações (HOPKINS, 2002): < 0,2 trivial, 0,2–0,59 pequeno, 0,6–1,29 moderado, 1,3–1,9 grande, 2,0–4,0 muito grande.

Para o artigo 4, foi realizada estatística descritiva com média e desvio padrão. De forma complementar, foi calculado o tamanho de efeito, a partir do *g* de Hedges, com as seguintes classificações (HOPKINS, 2002): < 0,2 trivial, 0,2–0,59 pequeno, 0,6–1,29 moderado, 1,3–1,9 grande, 2,0–4,0 muito grande.

ARTIGOS

ARTIGO 1: REVISÃO SISTEMÁTICA

Article type: Systematic Review

Title: Mechanics, energetics, and hemodynamics outcomes of people with obesity and overweight during walking on a slope: a systematic review

ABSTRACT

Objective: To conduct a systematic review related to mechanics, energetics, and hemodynamics outcomes during locomotion of people with obesity and overweight on a positive and/or negative slope.

Methods: The searches were carried out in PubMed, SCOPUS, SPORTDiscus, and Cochcrane Library. Cross-sectional studies and clinical trials which evaluated overweight (Body Mass Index $\geq$ 25 $kg.m^{-2}$) and/or obese (BMI $\geq$ 30 $kg.m^{-2}$) adults, performing walking/running on surfaces with positive and/or negative inclination, assessing kinematic, kinetic, cardiorespiratory, hemodynamics, or rating of perceived exertion (RPE) were considered.

Results: 15 studies (471 participants, male and female, age ranging from 20.8 to 59 years old) were included. Of them, 4 analyzed outcomes related to mechanics, 11 related to energetics, and 6 related to hemodynamics.

Conclusions: the use of positive inclination as an exercise strategy for individuals with obesity is still not found on a large scale. However, there is strong evidence that walking on a positive inclination may be favorable than walking in faster speed without inclination for increasing metabolic demand and energy expenditure, in addition to decreasing joint impacts during walking. Downhill and Nordic Walking seem to be good strategies for individuals with low exercise tolerance.

Key words: Inclination, Obesity, Locomotion, Gait, Physiomechanics.

INTRODUCTION

The number of overweight and obese people around the world is an alarming 2.1 billion, representing 39% of people over 18 years of age with overweight and 13% with obesity and the estimated increase is around 2 million to 2025.[1] According to data from the last decades, obesity is related to the cause of death of 3.4 million people per year,[2] and the increase in BMI is strongly associated with the high risk of cardiovascular disease, hypertension, metabolic syndrome, type 2 diabetes mellitus, apnea syndrome, hyperlipidemia, osteoarthritis, cancer, and death from all causes.[3,4]

Excess weight can originate, among other factors, from a chronic positive energy balance, that is, greater caloric consumption than expenditure.[5] Therefore, it is strongly related to the lack of sufficient physical activity.[6] Thus, aerobic training is directly associated with the reduction of these risk factors, in addition to improvement in physical and mental health.[7,8] Among the various aerobic exercise options, walking and running are the most popular forms of physical activity for obese individuals, as it is relatively easy to perform, requires considerable energy expenditure, and typically meets the criterion of moderate/vigorous intensity, especially in high speeds.[9,10] Recent systematic reviews and meta-analyses have analyzed and identified positive effects of interventions for weight loss and reduction of risk factors associated with obesity with the use of walking/running as a primary aerobic exercise.[11–13]

In this context, variations in the way of performing the walk are investigated, such as Nordic Walking, walking with loads and walking with a double task, aiming at a better understanding of the possible responses of mechanical parameters (e.g. mechanical work, spatiotemporal parameters, dynamic stability, impact forces), energetic (e.g. energy expenditure, cost of transport, and metabolic power) and hemodynamics (e.g. heart rate, stroke volume, cardiac output) of walking.[14–17] This set of variables related to terrestrial locomotion, conceptually known as Physiomechanics, is fundamentally dependent on factors such as speed, the force of gravity, the type of surface and the slope of the terrain.[18,19] Locomotion on an inclined surface is a constant challenge in the daily environment and promotes different demands on the neuromuscular and bioenergetic system.[20,21]

On positive inclinations, the magnitude and duration of muscle activity increases, which suggests that the pattern of muscle activation may help to predict the increase in the metabolic cost in the inclination, considering that in this condition there is a predominance of concentric contractions of the propulsive musculature.[22] Walking on a moderate positive slope (3 to 9°) and at relatively low speeds (0.5 to 1.0 $m.s^{-1}$) can meet the recommended requirements for physical activity levels, equivalent, in metabolic terms, to walking on a flat surface at higher speeds. For example, obese adults walking at 0.75 $m.s^{-1}$ and on a 6° positive slope are at an intensity of approximately 52% of VO_{2peak}, while, walking on the flat at 1.50 $m.s^{-1}$, they are in an intensity range of approximately 50% of VO_{2peak}.[23] Regarding the negative inclination, there is a paradox between the rating of perceived exertion (RPE) and exercise intensity. When walking is performed at the same absolute speed, when compared to walking on flat, the RPE is lower, mainly due to the lower relative load (%VO_{2max}), associated with a higher proportion of negative mechanical work in this condition.[24] However, under conditions of the same relative intensity, which represents higher absolute speeds in the negative slope, no studies have been found that have evaluated this relationship in patients with obesity. If, on the one hand, walking on a positive slope can favor the individual with obesity because it increases the metabolic demand, decreases the joint impact and can be performed at lower absolute speeds, on the other hand, walking on a negative slope can favor the individual with obesity for allowing walking at higher absolute speeds and with lower RPE, conditions that can favor individuals with low exercise tolerance.

Considering obesity as a health risk factor and physical exercise as one of the main alternatives for non-pharmacological treatment, the objective of this systematic review is to gather what exists in the literature related to mechanics, energetics, and hemodynamic outcomes during graded locomotion (positive and/or negative), of adults with overweight or obesity.

METHODS

The protocol of the present study was registered in the International Prospective Register of Systematic Reviews (PROSPERO, register number CRD42020160294, appendix 4). This systematic review was reported in accordance with the recommendations of the Meta-analyses of Observational Studies in Epidemiology (MOOSE): A Proposal for Reporting.[25]

Eligibility Criteria

We consider cross-sectional studies that have evaluated adult individuals with overweight (BMI ≥ 25 $kg.m^{-2}$) or obesity (BMI ≥ 30 $kg.m^{-2}$),[1] performing walking or running on a surface with a positive inclination (uphill walking/running) and/or negative inclination (downhill walking/running), reporting outcomes related to biomechanical, physiological and/or hemodynamic variables during the exercise. In addition, clinical trials that presented assessments of the target outcomes were included from the reference lists of the selected articles. We do not consider abstracts and unpublished studies. There was no publication date restriction. Only articles in English, Portuguese, or Spanish were accepted.

Search Strategy

The following databases were searched: PubMed, SCOPUS, SportDiscus, and Cochrane Library. The search was carried out jointly by three investigators (H.B.O., G.D.V., and J.C.Z.), in March 2020. In general, the following search strategy was used, adapted for each database: (("Obesity"[Mesh]) OR ("Obesity, Abdominal"[Mesh]) OR "Overweight"[Mesh] OR “Obese")) AND ("Locomotion" OR "Slope" OR "Inclined Gait" OR "Inclined Walking" OR "Gait" OR "Walking" OR "Downhill Walking" OR "Uphill Walking" OR "Downhill" OR "Uphill").

Study selection and data extraction

The studies found in the search had the titles and abstracts read by two independent researchers (G.D.V., and J.C.Z.). Articles that did not meet the eligibility criteria were excluded at this stage, the remaining articles were read in full and all the eligibility criteria were screened. The doubts were resolved by consensus between the two researchers. When there were disagreements, a third researcher was consulted (H.B.O.). For this procedure, a standardized form was adopted and the researchers (H.B.O., G.D.V., and J.C.Z.) examined each article in pairs (H.B.O./G.D.V., or G.D.V./J.C.Z., or H.B.O./J.C.Z.), independently, and the main information extracted was number of participants, age, type of intervention, type of slope used, intensity, among others. The doubts were resolved by consensus between the pair and, if necessary, the third researcher was requested.

Assessment of risk of bias

The methodological quality of the selected studies was assessed using the Tool for Assessment of Study Quality and Reporting in Exercise (TESTEX),[26] specifically developed for the evaluation of studies on physical exercise, based on the following items: elegibility criteria, randomization specification, allocation concealment, similarity of the groups at baseline, blinding of the assessor, outcomes measures assessed in 85% of patients, intention-to-treat analysis, between-group statistical comparison reported, point measures and measures of variability for all reported outcome measures, activity monitoring in control groups, relative exercise intensity remained constant, exercise volume and energy expenditure. The quality score of the papers was based on tertiles, where 0 to 5 points were considered low quality, 6 to 10 points were considered medium quality and 11 to 15 points were considered high quality.[27]

RESULTS

Studies included in this review

The electronic databases surveyed provided a total of 2654 articles. At the end of the identification processes, screening for eligibility, it was possible to select a total of 15 studies. The sum of the participants in these studies accumulated a total of 471 people analyzed, men and women (Figure 1).

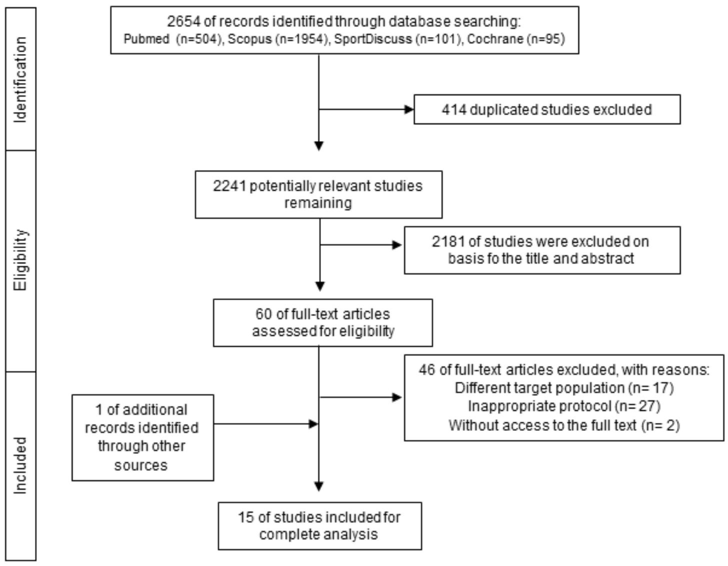

Figure 1: Flow chart of information through the different phases of the systematic review.

Regarding the gender of the study sample, 26% used only female sample, 8% used only male sample, and 66% used mixed sample. Regarding the classification of obesity, 8% assessed people with morbid obesity, 73% people with obesity, 26% people with overweight, and 26% used a control group for comparison. The average age of the participants was 42 years, with minimum age of 20.8 years and a maximum of 59. Concerning the slopes, 93% of the selected studies used a protocol with a positive inclination, while 26% used a protocol with a negative slope, and only three presented results in the positive and negative inclination. In relation to the outcomes, four presented results related to mechanical outcomes,[23,28–30] eleven to energetics outcomes,[23,28,30–39] and six to hemodyncamics outcomes[33,36–40] (Table 1).

Table 1: summary of the main information of the selected articles

Study	General characteristics of the participants	Study type	Inclination	Protocol summary	Main outcomes	Main considerations
Browning et al.[28]	Young men and women: obese (n=32); nonobese (n=19)	Cross-sectional study	11 speeds/grades combinations (0.50–1.75 m.s^{-1}, -5.2% to +15.9%)	3 sessions: 1st: physical examination, body composition and VO_{2max}; 2nd and 3rd: biomechanical and metabolic analysis protocol	VO_{2max}, GRF, and lower extremity kinematics	Obese adults can easily achieve recommended exercise intensities walking uphill slowly. Equivalent walking economy e W_{ext} between obese and nonobese.
Cho and Roh[41]	Obese young women with body fat% from 30.0 to 36.1 (n=8)	Crossover	Treadmill with negative inclination of 15%	2 sessions: one with and one without using NW poles. Both for 30 min at 50% of $HR_{reserve}$	Biochemical markers of injury and damage (muscle and cartilage): COMP, CK, LDH, plasma lactate	The use of poles when walking on a negative inclination can temporarily reduce muscle and cartilage damage after this exercise.
deJong et al.[33]	Morbidly Obese Men and women (n=43)	Cross-sectional study	During the maximal test: conventional or modified Bruce protocol	Only one session for the maximal test	VE/VCO_2 slope, VO_{2peak}, RPE	$\dot{V}E/VCO_2$ slope may serve to better reflect the cardiopulmonary response to exercise, as compared with peak VO_2.
Ehlen et al.[23]	Men and women obese adults (n=12)	Cross-sectional study	Various combinations of speeds (0.50–1.75 m.s^{-1}) and grade (0 – 15.8%)	3 sessions: 1st: physical examination, body composition and VO_{2max}; 2nd and 3rd: biomechanical and metabolic analysis protocol	VO_2, GRF, and three-dimensional lower-extremity kinematics	Walking slower uphill significantly reduced loading rates and lower-extremity NMM compared with faster level walking, and this condition can be a potential exercise strategy that may reduce the risk of musculoskeletal injury/pathological disease.
Evans et al.[35]	Men and women with OSA (n=16)	Cross-sectional study	During the maximal test, postive inclination (individually adjusted)	3 sessions: in a randomized order. The visits comprised either an ITMT, two 6MWTs, or two ISWTs.	VO_{2max} and cardiac parameters data from two field walking tests: 6MWT and ISWT	The ISWT can be used instead of an ITMT and in preference to the 6MWT to assess cardiorespiratory fitness for obese people with treated OSA.
Evans et al.[36]	Men and women with OSA (n=16)	Cross-sectional study	During the maximal test, positive inclination (individually adjusted)	6 sessions: The first two visits comprised an incremental treadmill (ITM) and cycle (ICE) test. From the third to the sixth visit: speed tests on a treadmill and two constant power tests on a cycle ergometer	EE and cardiorespiratory response	Walking might be the preferred training modality to achieve the combination of weight loss and increased cardiorespiratory fitness in adults with obesity and treated OSA.
Figard-Fabre et al.[30]	Obese middle-aged women (n=11)	Longitudinal (4 weeks)	Exercise trials (5 min each) at 1.11 m.s^{-1}, inclinations of -5, 0 and +5%, with and without poles	Learning period of NW Technique (12 sessions)	VE, VO_2, energy cost, HR, RPE and cycle length	NW poles increased physiological responses at a given speed but decreased RPE in comparison with noral walking during inclined level.
Figard-	Obese middle-aged	Longitudinal	During the maximal test, pre, pos-6	12-Weeks period, with 3	HR, resting blood	NW activity allows an increase in

Fabre et al.[37]	women (NW = 12; W=11)	(12 weeks)	and pos-12 weeks	programmed exercise sessions per week: 45 min.session^{-1}: warm up – 30 min training – cool down	pressure, VO_{2peak}, RPE, and adherence	exercise intensity and adherence without increasing the perception of effort leading to enhanced aerobic capacity.
Gallagher et al.[38]	Men and women morbidly obese patients (n=43)	Cross-sectional study	During the maximal test: conventional (37.2%) or modified Bruce protocol (60.5%)	Only one session for the maximal test	Systolic and diastolic blood pressure (rest and peak), HR_{peak}, $VO_{2máx}$	There is an inverse graded relationship between BMI and cardiorespiratory fitness. The impairment in VO_{2max} is related to BMI.
Haight et al.[29]	Moderate obese (n=9) and nonobese adults (n=10)	Cross-sectional study	0.75 m.s^{-1} at 10.5% and 1.50 m.s^{-1} at 0% as these conditions elicit similar metabolic rates	Only one session: all the experimental protocol	Joint kinematics, kinetics, muscle forces, and TF forces	Slow, uphill walking may be appropriate exercise for obese individuals at risk for musculoskeletal pathology or pain.
Justine et al.[39]	Obese (n=31), Overweight (n=30), and normal-weight (n=31) young men and women	Cross-sectional study	During the maximal test: Modified Bruce Protocol	Only one session: all the experimental protocol	EE, HRR, and the association between functional strength and EE	Similar HRR following a sub-maximal exercise between groups, however, the obesity group showed the highest EE.
Keller-Ross et al.[31]	Lean trained (n=7), overweight trained (n=7) and sedentary (n=26) Young women	Cross-sectional study	Overweight: Bruce protocol Lean subjects: modified Åstrand protocol	Only one session: all the experimental protocol (part of a larger clinical trial)	VO_{2peak}, Lean leg mass, $\dot{V}E/VCO_2$ slope	VE/VCO2 slope may not differentiate between low and high cardiorespiratory fitness in healthy individuals. Lean mass may play a role in determining the $\dot{V}E/VCO_2$ slope, independent of disease.
Kline et al.[32]	Overweight sedentary adults with OSA (n=43) and controls (n=9)	Longitudinal	During the maximal test: Bruce protocol	12-Weeks exercise training, 4 times per week: treadmill and elliptical exercise. Resistance exercise followed aerobic activity	VO_{2peak}, HRR	The exercise training, by increasing HRR and VO_{2peak}, may attenuate autonomic imbalance and improve functional capacity independent of OSA severity reduction.
Philippe et al.[42]	Pre-diabetic men (n=16)	Short term clinical trial (3 weeks)	The path had a relatively continuous slope of 10.2% and a length of 5000 m.	3-Weeks. Three times per week. Uphill or downhill walking sessions on a standardized path at low altitude	Glucose metabolism, blood lipids and energetics parameters	Both types of exercise (uphill or downhill walking) may be useful for the prevention of type 2 diabetes and disorders in lipid metabolism.
Støa et al.[40]	Sedentary overweight individuals with T2D (n=38)	Non-randomized clinical trial	The tests were conducted at an incline of 3%. Walking/running training was carried out uphill (without detailing the inclination)	12-Weeks. Both HAIT and MIT trained three times per week. The HAITand MIT training protocols were matched for total work	VO_{2max}, HbA1c	HAIT (85–95% HRmax) is an effective strategy to improve important risk factors associated with T2D, and more effective than moderate continuous exercise in improving VO_{2max} and lowering HbA1c.

Note: 6MWT: 6-min walk test; CK: serum creatine kinase; COMP: cartilage damage (serum cartilage oligomeric matrix protein [COMP] levels); EE: energy expenditure; GRF: ground reaction forces; HbA1c: glycated Hemoglobin type A1C; HRR: heart rate recovery; ISWT: incremental shuttle walk test; ITMT: incremental treadmill test; LDH: lactate dehydrogenase; NMM: net muscle moments; NW: Nordic Walking; OSA: obstructive sleep apnea; RPE: rating of perceived exertion; T2D: type 2 diabetes; TF: tibiofemoral; VE/VCO2 slope: minute ventilation/carbon dioxide production relation; VE: ventilation; Wext: external mechanical work.

Regarding the risk of bias, one article was classified as high quality,[32] 12 were classified as medium quality,[28,29,41,42,30,31,33,35–37,39,40] and two were classified as low quality[23,38] (Figure 2).

Studies	1. Elegibility criteria specified	2. Randomization specified	3. Allocation concealment	4. Groups similar at baseline	5. Blinding of assessor	6. Outcome measures	7. Intention-to-treat analysis	8. Between-group statistical	9. Point measures and measures of variability for all	10. Activity monitoring in	11. Relative exercise intensity remained	12. Exercise volume and energy expenditure	**Total / quality**
Browning et al.[28]	Y (1)	Na (0)	Na (0)	Na (0)	Ni (0)	Y (2)	Na (0)	Y (2)	Y (1)	Na (0)	Na (0)	Y (1)	7 / medium
Cho and Roh.[41]	Y (1)	Na (0)	Na (0)	Na (0)	Ni (0)	Y (2)	Na (0)	Y (2)	Y (1)	Na (0)	Na (0)	Y (1)	7 / medium
deJong et al.[33]	Y (1)	Na (0)	Na (0)	Na (0)	Ni(0)	Y (2)	Na (0)	Y (2)	Y (1)	N (0)	Na (0)	N (0)	6 / medium
Ehlen et al.[23]	Y (1)	Na (0)	Na (0)	Na (0)	Ni (0)	Ni (0)	Na (0)	N (1)	Y (1)	Na (0)	Na (0)	Y (1)	5 / low
Evans et al.[34]	Y (1)	Na (0)	Na (0)	Na (0)	Ni (0)	Y (3)	Na (0)	N (1)	Y (1)	Na (0)	Na (0)	Only volume (0)	6 / medium
Evans et al.[35]	Y (1)	Na (0)	Na (0)	Na (0)	Ni (0)	Y (3)	Na (0)	N (1)	Y (1)	Na (0)	Na (0)	Y (1)	7 / medium
Figard-Fabre et al.[30]	Y (1)	Na (0)	Na (0)	Na (0)	Ni (0)	Y (2)	Na (0)	N (1)	Y (1)	Na (0)	Na (0)	Y (1)	6 / medium
Figard-Fabre et al.[36]	Y (1)	Na (0)	Na (0)	Y (1)	Y (1)	Y (2)	Na (0)	N (1)	Y (1)	N (0)	Y (1)	Y (1)	9 / medium
Gallagher et al.[37]	Y (1)	Na (0)	Na (0)	Na (0)	Ni (0)	N (0)	Na (0)	Y (2)	Y (1)	N (0)	Na (0)	Ni (0)	4 / low
Haight et al.[29]	Y (1)	Na (0)	Na (0)	Na (0)	Ni (0	Y (2)	Na (0)	Y (2)	Y (1)	Na (0)	Na (0)	Only volume (0)	6 / medium
Justine et al.[38]	Y (1)	Na (0)	Na (0)	Na (0)	Ni (0)	Y (2)	Na (0)	Y (2)	Y (1)	Na (0)	Na (0)	Y (1)	7 / medium
Keller-Ross et al.[31]	Y (1)	Na (0)	Na (0)	Na (0)	Ni (0)	Y (2)	Na (0)	Y (2)	Y (1)	Na (0)	Na (0)	N (0)	6 / medium
Kline et al.[52]	Y (1)	Y (1)	Y (1)	Y (1)	Y (1)	Y (1)	Y (1)	Y (2)	Y (1)	Y (1)	Y (1)	Y (1)	13 / high
Philippe et al.[40]	Y (1)	Y (1)	Na (0)	Y (1)	Ni (0)	Y (2)	Na (0)	Y (2)	Y (1)	N (0)	Na (0)	Y (1)	9 / medium
Støa et al.[39]	Y (1)	N (0)	N (0)	N (0)	Ni (0)	Y (2)	Na (0)	Y (2)	Y (1)	N (0)	N (0)	Y (1)	7 / medium

Figure 2: Individual risk of bias of selected studies. Y=yes, N=no, NA= not applicable, Ni- uninformed

DISCUSSION

The objective of this systematic review is to gather what exists in the literature related to mechanics, energetics, and hemodynamic outcomes during graded locomotion (positive and/or negative), of adults with overweight or obesity. In general, it was possible to perceive a principally mechanical and energetic advantage of locomotion in the positive inclination over the negative and without inclination. The influence of slope on hemodynamic factors still needs further investigation. In an innovative way, we try to bring an integrative view of the results obtained, considering some of the main outcomes related to the locomotion of obese adults, as shown below.

Mechanics

Walking on an inclined plane requires adjustments in activity and muscle activation pattern, compared to walking on flat surface, which results in differences in metabolic cost depending on the type of inclination (positive or negative). On positive inclinations, the magnitude and duration of muscle activity increases, which suggests that the pattern of muscle activation may help to predict the increase in the metabolic cost in the inclination, considering that in this condition there is a predominance of concentric contractions of the propulsive musculature.[22] On the other hand, the negative inclination generates a stimulus of eccentric predominance of the locomotive muscles, generating less metabolic demand under the same external load (e.g. walking speed).[24,42]

One of the main mechanical concerns during locomotion of people with obesity is the joint load of the lower limbs. It is known that there is a strong positive relationship between walking speed in the flat surface and joint load of the lower limbs [estimated by liquid muscle moments (NMM), joint reaction forces and joint load rates].[43] To our knowledge, the first study to evaluate the kinematics of people with obesity walking on an inclined plane was that of Ehlen et al.[23] in which it was found that walking at lower speeds (<0.75 $m.s^{-1}$) and moderate positive inclinations (6 to 9°) resulted in less NMM in the lower limb joints than walking in the flat at the same speed in moderately obese adults. The peak of NMM of hip and knee extension are decreased by approximately 3.5 times in positive slope when compared to walking in the flat.[23] Additionally, rate of force development (inclination of GRFv at the beginning of the contact phase) are reduced at lower speeds, regardless of inclination, because of the lower peak values of GRFv and longer initial contact time.[44] The combination of adequate stimulation and reduction in hip and knee NMM (extension and abduction) and low rates of force development suggest that walking at lower speeds and at a positive incline is relatively safe form of exercise for obese adults.

Agreeing with the findings of Ehlen et al.[23], Haight et al.[29] when analyzing other biomechanical outcomes from the combination of different speeds and inclinations (in this case only positive), they found that obese individuals had knee extensor NMMs similar to non-obese, but greater muscle strength estimated, in particular, the tibiofemoral (TB) strength. However, in conditions of inclination, the peak of the TB force at the beginning of the contact phase was reduced, which makes the authors also conclude that the slower walk and on moderate positive inclinations can be an efficient exercise alternative for obese individuals.

If, on the one hand, studies agree that walking on a positive inclination can decrease the mechanical load on the lower limbs,[23,29] on the other hand, little has been studied about the behavior of these variables in negative inclination. No studies have been found that have assessed the joint impacts of walking on negative inclination, but only speculations that this type of exercise should promote greater joint impacts than level walking.[28] However, it was possible to verify that walking in a negative inclination, when performed with the use of poles (Nordic walking), is able to reduce the level of damage to muscles and cartilage in women with obesity, when compared to downhill walking without the use of poles. These findings indicate that Nordic walking may be able to reduce the amount of impact and muscle demand, especially of lower limbs of obese young women.[41]

To our knowledge, the first study to assess in an integrative way the mechanics and the energetics of locomotion of individuals with obesity in the positive inclination and in the negative inclination was that of Browning et al.[28] walking through a range of speeds and inclinations in nonobese and people with obesity. For this, 11 combinations of speed (0.5 - 1.75 $m.s^{-1}$, with an increase of 0.25, total of 6 speeds) and inclination (-5.2, 0, 5.2, 10.5, and 15.8%) were used. In short, for both groups, stride length and stride frequency decreased as walking speed decreased, while double support time and duty factor increased. Individuals with obesity walked with similar stride length/frequency across all speed/grade combinations that nonobese, however with longer double support time, greater duty factor, wider steps, and greater lateral leg swing. Corroborating these findings, when analyzing the influence of slope

(-5, 0, +5%), at 4 $km.h^{-1}$, stride length was similar between the different slopes, however it was higher with the use of poles (Nordic Walking) than in the free walk on all slopes.[30]

Still from an integrative point of view, the analysis of muscular mechanical work (W_{tot}) is of fundamental importance for understanding the mechanical and energetic relationships of locomotion.[16] During walking, the mechanism for minimizing energy expenditure, known as an inverted pendulum, is related to the conversion of the mechanical energies of the Center of Mass (CM) and the rest of the energy required for movement comes from the elements of the W_{tot}, composed of the sum the external mechanical work (W_{ext} = mechanical work required to raise and accelerate the Center of Mass (CM) in relation to the environment) and the internal mechanical work (W_{int} = mechanical work required to move the segments in relation to the CM).[19,45,46] Despite being considered the primary determinant of metabolic cost, W_{ext} was not affected by the obesity factor in the different combinations of speed and incline.[47] This result can suggest that obesity, by itself, does not worsen the walking economy. Among the selected studies, none evaluated the internal mechanical work (W_{int}) during locomotion of people with obesity on the inclination. It may be a limitation of the understanding of the integrative mechanisms related to the higher metabolic cost people with obesity, mainly due to the greater segmental masses and greater moments of inertia that may reflect in greater W_{int} in this population, a relationship that was recently observed in obese children at walking speeds above 3 $km.h^{-1}$.[16]

Energetics

Classically, one of the most commonly evaluated parameters in exercise physiology is maximum oxygen consumption (VO_{2max} or VO_{2peak}).[48–50] From a clinical point of view, the decrease in VO_{2max} or aerobic capacity is commonly associated with increased mortality due to cardiovascular reasons or all causes.[51] A modest increase in aerobic capacity is capable of decreasing mortality rates (for every 1min increase in the maximum test on the treadmill, equivalent to 1MET, corresponds to approximately 8% reduction in mortality).[38,52] Individuals with obesity who have a moderate or high level of cardiorespiratory fitness have a reduction in the mortality rate that reaches 71% when compared to obese with low fitness.[51]

The choice of the maximum test protocol appropriate to the sample studied is important for the validation criteria to be met. Of the studies included in this review, considering the groups of individuals with obesity, four used the modified Bruce or the traditional Bruce Protocol,[31–33,38] two used the modified Balke protocol,[23,28] and six used their own protocols.[30,35–37,40,42] Therefore, there seems to be no consensus on an ideal protocol for assessing the maximum aerobic capacity of obese individuals. Commonly in practically all articles, except for Philippe et al.[42], we found positive inclination as a strategy of increasing intensity during the performance test on a treadmill. Interestingly, we observed that alternatives protocols are being developed and tested to obtain more precise maximum values, especially considering that the Bruce Protocol seems very intense for individuals with higher levels of obesity.[31,38] Therefore, it is possible to observe a trend towards the development of specific protocols, considering the specific sample of the study and seeking optimal answers to the test, based on the values of each subject (e.g. perception of effort or self-selected speed), as well as the pilot studies to determine initial parameters and test increments.[35,36,40]

Moreover, the exercise modality can influence the maximum and submaximal energetics responses. It was found that the physiological responses to the test on the cycle-ergometer were significantly lower than on the treadmill (VO_{2peak} approximately 22% lower), as well as ventilation and heart rate parameters, however without difference on the RER in the different modalities.[36] Other factors such as the classification of the level of obesity (considering the BMI values) and the level of training may be correlated to the values of VO_{2max}. It was found that the higher the BMI (divided by quintile), the lower the expected VO_{2max}, and, under comparison between people with obesity and morbid obesity, VO_{2max} was 16% lower in the group with morbid obesity (17.8 vs 21.3 $ml.kg^{-1}.min^{-1}$).[38] Also, in overweight individuals, VO_{2peak} was 34% lower in the untrained than trained group (25.3 vs 38.1 $ml.kg^{-1}.min^{-1}$).[31]

The use of positive inclination is a practical strategy for increasing the exercise intensity without the need to increase walking/running speed, while negative inclination can be used as a form of eccentric training for lower limb muscles, or as a strategy for individuals with low exercise tolerance.[42] In a study that sought a better combination of speed and inclination to obtain greater energy expenditure and less joint impact (described in the mechanics chapter) of adults with moderate obesity, Ehlen et al.[23] found that the net metabolic rate was similar (approximately 3.8 $W.kg^{-1}$) in the condition without inclination at 1.50 $m.s^{-1}$ and in the moderate positive inclination (15.8 and 10.5%), however in considerably lower speeds (0.50 and 0.75 $m.s^{-1}$, respectively). Besides, when comparing the results with those proposed by the ACSM predictive metabolic rate equations, it was identified that the results of the equation overestimated the energy expenditure approximately 10% at slow speed/positive inclination condition and underestimated in the fast speed/flat condition by approximately 28%. Interestingly and practically, the study by Browning et al.[28] developed an equation[1] to estimate VO_2 from inclination, velocity, and body mass data, proposing a correction to the ACSM equation.

One way to analyze and compare the influence of the slope is to fix the speed and change only the slope. Using this strategy with fixed speed (4.3 $km.h^{-1}$) and on slopes of -5%, 0% and + 5%, significant differences between these slopes, with values of 40±1, 47±1 and 58±1% $\%VO_{2peak}$, respectively. Corroborating these results, Figard-Fabre et al.[30] proposed a protocol of submaximal intensity for obese middle-aged women, with a fixed speed of 4.0 $km.h^{-1}$ on positive slope (+ 5%), negative slope (-5%) and on the flat, with and without the use of Nordic Walking poles. In general, the values of VO_2 ($ml.min^{-1}$), HR (bpm) and energy cost ($J.kg^{-1}.m^{-1}$) increased as the slope increased and were higher in all conditions with the use of poles. Considering the $\%VO_{2max}$ of each condition, the following values were verified: Downhill (NW = 43±14%; Walking (W) = 35±15%, flat (NW = 53±15%, W = 51±15%), Uphill (NW = 78,18±18%, W = 74±18%). In other words, it is expected that there will be a difference between 18 and 39% with the manipulation of only the inclination and under the same speed, comparing downhill (-5%) with uphill (+5%) in the walk of individuals with obesity.

Interestingly, the behavior of perceived exertion went in the opposite direction to the physiological variables about the use of poles, as the perception was lower in NW condition, even with higher values of physiological intensity. Therefore, in a practical way, it is possible to understand the NW modality as an alternative to increase the physiological demand under the same external load demand (speed x inclination), which is essential for people with obesity, aiming to improve the energy balance. We can still add important information about the perception of effort and inclination, because another advantage of walking on the slope at lower speeds is that it can also reduce the perception of effort, which can result in a longer duration of exercise and greater adherence to training when compared to walking on the flat.[23,53]

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[1] $VO_2/kg = 1.40 + 0.42(G) + 3.68(V) – 0.01(M) – 0.03$, where G is slope in degrees, V is the velocity in $m.s^{-1}$ and M is the body mass in kg.

This set of information allows us to view walking on a positive inclination as an interesting strategy for increasing energy demand, without increase in perception of exercise effort. In addition, the use of poles, as occurs in Nordic Walking, seems to optimize these results also without generating greater perception of exercise effort, which may even increase adherence to training for obese individuals.

Hemodynamics

One of the clinical concerns of physical exercise for obese people is the load exerted on the cardiovascular system, assessed by the hemodynamic parameters of locomotion. We seek here to bring the main information found on the hemodynamic responses of the locomotion of people with obesity during exercise on inclination. We will consider hemodynamics as the set of physical components that constitute the pumping of blood in the cardiovascular system related to exercise. In this sense, the main variables are blood pressure, heart rate, stroke volume and cardiac output.

The study by Evans et al.[36] evaluated outcomes such as systolic and diastolic blood pressure under two modes of exercise (inclined treadmill vs cycle ergometer) in two intensities (60 and 80% of VO_{2peak}). Although the authors do not present a discussion about the mechanisms, it was found that the exercise performed on an ergometer cycle had higher values for systolic and diastolic blood pressure than on the inclined treadmill, both for the condition 60 and 80% of VO_{2peak}. In the maximum incremental tests, only the diastolic pressure showed a difference between the exercise modes, being lower in the cycle ergometer. It is important to note the duration of the exercises in these submaximal tests: 80% of VO_{2peak} lasted 13:34 and 03:25min, while 60% of VO_{2peak} lasted 40:00 and 13:23min for treadmill and cycle ergometer, respectively. Even with this considerable difference in duration, the authors state that the central cardiovascular stimulus was significantly greater at 80% of the VO_{2peak} on the treadmill than on the cycle ergometer and similar between the modes at 60% since the HR at the end of the test was 136 ± 31 bpm on the treadmill and 126 ± 21 bpm on the cycle ergometer.

In the study by Gallagher et al.[38] the ECG and blood pressure were continuously monitored during the performance of maximum tests (modified Bruce or Bruce protocol). HR_{peak} was higher in patients with obesity compared to the control group (159 ± 22 vs 152 ±

25 bpm, respectively, p = 0.007), as well as the maximum values obtained for systolic blood pressure (190 ± 24 vs 176 ± 28 mmHg, respectively, p = 0.002). In addition, 23% of patients with obesity had some chronotropic impairment (defined as the inability to reach 85% of the predicted HR_{max}). The authors argue that these results corroborate the concept of "cardiomyopathy of obesity", as it may be one of the explanations for the signs and symptoms of heart failure which are commonly assessed in people with morbid obesity attributed to lipotoxicity in the myocardium.[54]

The study by Støa et al.[40] compared two types of training, a moderate intensity continuous (MIT) and a high intensity interval (HAIT) in overweight and diabetic patients. Blood pressure measurements at rest before and after training were measured. The MIT group significantly reduced the values of systolic blood pressure (from 160 ± 20 to 148 ± 26 mmHg), diastolic (from 86±12 to 78±11), while the HAIT group significantly decreased only diastolic blood pressure (from 87±9 to 81±8 mmHg). It was not possible to find the inclination conditions during the training, only that it was performed in an external environment and maintaining the same circuit, making it difficult to understand the relationship between the characteristics of the inclination (the type of inclination and the degrees/percentage of inclination).

The results of the selected articles regarding exercise hemodynamics demonstrate the importance of clinically evaluating everyone in detail. The concept of "cardiomyopathy of obesity" was highlighted because it can be one of the explanations for the signs and symptoms of heart failure commonly assessed in people with morbid obesity attributed to lipotoxicity in the myocardium. It has not yet been possible to find more robustly the effects of inclination on hemodynamic outcomes of exercise for individuals with obesity. However, it is possible to consider that training with greater volume may be more efficient in reducing blood pressure at rest than training with greater intensity.

We observed a series of limitations in this article, such as the great difference between the protocols used, making specific comparisons difficult and the performance of a meta-analysis on the analyzed outcomes in relation to the different inclinations. In addition, few studies with negative inclination could be included, demonstrating the need for further studies that directly compare acute and chronic effects of exercises in positive and negative inclination. One of the strengths of this review was to be able to select a good number of articles that used the positive inclination in at least one of the outcomes, allowing to agree with the hypothesis that it may be a good exercise strategy for individuals with obesity. The main novelty was the integrative view between three of the main groups of variables related to the locomotion of people with obesity, considering the mechanical, energetic, and hemodynamics aspects.

CONCLUSIONS

The use of inclination as an exercise strategy for individuals with obesity is still not found on a large scale. However, there is strong evidence that walking on positive inclination may be favorable for increasing metabolic demand and energy expenditure, in addition to decreasing joint impacts during walking, hemodynamic and RPE benefits. Little evidence was found about the downhill condition, but it seems to be a good alternative for individuals with low tolerance to exercise, very frequent for individuals with obesity, despite requiring less energy demand. Interestingly, the Nordic Walking training method also appears as an interesting alternative for obese individuals, due to the greater distribution of joint loads and lower RPE. We suggest future studies that compare the influence of different types of inclination in iso-intensity, on mechanical, energetic, and mainly hemodynamic outcomes, for a better understanding of the influence of inclination, and not based on an external load.

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CONFLICT OF INTEREST

The authors have no conflict of interest.

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ARTIGO 2: ESTUDO DE PROTOCOLO

Journal: Frontiers in Physiology

Article type: Methods

Title: Obese locomotion on positive and negative slope at iso-intensity: outcomes related to energetics, mechanics, perceived exertion, and hemodynamics. A study protocol.

Abstract

The main objective of this study is to propose a form of walking/running protocol that is capable of evaluating energy expenditure at different types of slopes, considering the same relative intensities (iso-intensity conditions), as well as to assess biomechanical and hemodynamic factors that may be associated. 11 obese adult men (BMI between 30 $kg.m^{-2}$ and 39.9 $kg.m^{-2}$) aged between 18 and 35 years, physically inactive. Assessments will be carried out on six different days. On the first day, body composition, familiarization with the equipment, and a maximum incremental test without slope. In the next two days, the maximums tests in positive and negative slope will be performed. In the other three days, biomechanical, energetics, and cardiac variables will be collected in the following conditions: fixed speed (4.5 $km.h^{-1}$), speed relative to the first, and the second ventilatory threshold, being one day for tests on the positive slope, one on the negative slope and one without slope. From the second day, the tests will be distributed in random order and with an interval of, at least, 72 hours between tests. Metabolic data will be obtained using a gas analyzer, biomechanical data will be obtained through a kinematics system, with six infrared cameras, data Ground Reaction Forces (GRF) are obtained through force sensors installed on the treadmill, and hemodynamic parameters using a Signal-Morphology impedance device. The primary outcome is energy expenditure concerning slopes and speeds and the secondary outcomes are the mechanical work, mean GRF, and hemodynamic aspects. The data will be described by the mean and standard error values. The interactions between slopes and speeds will be tested with Generalized Estimating Equations (GEE) and Bonferroni post-hoc, adopting a significance level (α) of 0.05. Also, effect sizes (ES) will be calculated. The energy expenditure should be greater on the positive slope at all speeds. Higher production of positive mechanical work is expected on the positive slope and the impact peaks should be less in this condition. The negative slope should enable higher speeds relative to the thresholds, as well as lower cardiovascular load.

1 Introduction

Obesity is considered one of the most important public health problems, making both treatment and prevention a priority (Di Cesare et al., 2016; Menéndez et al., 2019). Over 1.9 billion adults are overweight, of these, 650 million are characterized as obese. A concerning factor regarding these numbers is that overweight, obesity, and associated risk factors present a strong association with the incidence of morbidity and mortality. The main strategies to reduce the incidence of obesity and overweight include adequate dietary intake and engagement in regular physical activity, at least 150 minutes spread over most days of the week, seeking negative energy balance (WHO, 2017).

Systematic reviews with meta-analyses have demonstrated the benefits of walking, as predominantly aerobic activity, considering the sum of daily steps or especially in the form of periodized exercise. Walking/running benefits occur at the level of physical fitness with the prevention of cardiovascular disease risk (Hamer and Chida, 2008), weight control and loss (Richardson et al., 2008), as well as decrease of resting blood pressure and body fat (Murphy et al., 2007). Daily locomotion in an uncontrolled environment presents several challenges regarding the slope of the terrain, as well as the possibilities of increasing the slope of the surface in a controlled environment, such as on the treadmill (Lay et al., 2006).

Walking/running on a sloped surface requires adjustments in muscular recruitment and activation when compared to situations on level ground surfaces, which can result in differences in metabolic cost and biomechanical parameters (Kimel-Naor et al., 2017). In positive slopes, there is an increase in the magnitude and duration of the activity, which suggests that the muscular activation pattern may help to predict the increased metabolic cost, considering that in this condition there is a predominance of concentric contractions of propulsive muscles (Silder et al., 2012). On moderate positive slopes (3 – 9°) and at relatively slow walking speeds (0.5 – 1.0 $m.s^{-1}$) obese individuals can meet the recommended requirements for physical activity levels, which, in metabolic terms, is equivalent to walking on level terrain at higher speeds. For example, obese adults walking at 0.75 $m.s^{-1}$ and 6° slope are at an intensity of approximately 52% of VO_{2peak}, whereas walking on level terrain at 1.50 $m.s^{-1}$, the intensity is approximately 50% of VO_{2peak} (Ehlen et al., 2011).

Walking on a moderate positive slope can significantly reduce the risk of musculoskeletal and joint diseases in obese adults, due to the decrease of loads and joint movements when compared to walking on level terrain. Therefore, walking on moderate positive slopes and at relatively slow speeds can be a suitable form of physical activity in mechanical and energetic terms for obese adults to reach the recommended level of energy expenditure (Ehlen et al., 2011; Browning et al., 2013). Previous studies demonstrated that a positive slope favors the decrease of joint impact in eutrophic and obese individuals (Browning, 2012; Strutzenberger et al., 2017). However, no studies were found evaluating the joint impact of walking on a negative slope in obese people, but only speculations that this type of exercise may promote greater joint impact than walking on level terrain (Browning et al., 2013). There is a relationship between negative inclination, rating of perceived exertion (RPE) and walking speed, in which at the same absolute speed compared to walking on level ground, the rating of RPE is lower, mainly due to the lower relative load (%VO_{2max}) (Agarwal et al., 2017b), due to a higher proportion of negative W_{mec} and its high efficiency (~100%) (Minetti et al., 1993). However, under the same relative load, which represents greater absolute speeds in the negative slope, no studies were found confirming or rejecting the hypothesis of lower RPE in this condition. Unlike the positive slope, in the negative slope, there is a predominance of eccentric contractions (Minetti et al., 1993), which are used as a strategy in clinical practice for eccentric activities (Geremia et al., 2019).

Another system presenting specific responses to the type of muscular contraction during exercise is the cardiovascular. Through a non-invasive Signal-Morphology impedance device, hemodynamic parameters such as heart rate (HR), stroke volume (SV), and cardiac output (CO) can be accurately measured. It is speculated that in predominantly eccentric activities, such as walking on a negative slope, there is less overload on this system. This response can be attributed to the smaller amount of muscle mass used, under the same relative load, when compared to a predominantly concentric muscular activity, which represents lower recruitment and firing rates of motor units (Agarwal et al., 2017a).

To our knowledge, the study of Browning et al. (2013) was the pioneer in the research on walking on negative slope of obese adults, in which the authors verified that, at a 3° negative slope and at a speed of 1.25 $m.s^{-1}$, obese individuals can reach an intensity level close to 40% of VO_{2peak}, suggesting that this slope condition can be a good alternative for moderate intensities of physical exercise. The authors suggest that future studies with greater samples, control group, standardized measurements, and walking protocols are needed to improve the results found. Besides, speed is one of the critical points of the comparison analysis between different slopes, because if the absolute speed is the same at different inclinations, the relative intensity will be different. No studies were found developing a robust methodology to compare mechanical and energetic outcomes in different slopes, but in the same relative intensity, that is, iso-intensity (for example, speeds referring to the first ventilatory threshold (VT1), and second ventilatory threshold (VT2)).

To answer some of these questions, it is necessary to conduct an integrative analysis between biomechanics and physiology of locomotion, named Locomotion Physiomechanics (Peyré-Tartaruga and Coertjens, 2018). According to a classic study, a better understanding of the metabolic outcomes' behavior must be accompanied by biomechanical analysis. Muscle mechanical work (W_{mec}) can be estimated through kinematic analysis and is basically divided into two parts: 1) external Wmec (W_{ext}) which considers the work performed to elevate and accelerate the center of mass (CM) concerning the environment and 2) internal Wmec (W_{int}), which considers the work performed to accelerate the body segments in relation to the CM. These variables, when analyzed together, can provide important information on how the locomotor machinery and the pendulum system are working to generate the energy needed to perform the task, including at different types of slope, which helps us to understand the main mechanisms associated with energy expenditure. To our knowledge, no studies have yet been conducted seeking a comparison of iso-intensity at different slopes measuring the locomotion physiomechanics, especially energy expenditure, to verify if there are differences caused by the type of slope.

The objective of the present study is to propose a form of walking/running protocol that is capable of evaluating energy expenditure at different types of slopes (-5, 0, +5%), considering the same relative intensities (iso-intensity conditions, at VT1 and VT2 relative speeds), as well as to assess biomechanical and hemodynamic factors that may be associated.

2 Materials and Equipment

- Instrumented treadmill (super ATL model, Inbramed - Porto Alegre, Brazil) with four three-dimensional load cells will be used for data collection. The sensor had a low-pass and second-order filter with a cut-off frequency of 30Hz. Data were collected at 1000Hz per channel with Instor software (Porto Alegre, Brasil) and a custom LabVIEW system (National Instruments, Austin, USA), as previously described by Da Rosa et al. (2019).

- Dual-Energy X-Ray absorptiometry (DXA) (Lunar Prodigy model, General Electric Company, Illinois, USA).

- Portable metabolic system plus heart rate monitor, (K5 model, Cosmed - Rome, Italy), breath by breath, calibrated and validated as previously described by Guidetti et al. (2018).
- Kinematics system (VICON Motion Capture System, Oxford, UK), composed by six infrared cameras, accompanied by Nexus software (v. 1.8.2).
- Signal Morphology Impedance device (Enduro model, PhysioFlow - Poissy, France).

3 Methods

Objectives and method validation

The main objective of this method is to propose a way of comparing walking/running in isso isso-intensity condition at different slopes. Considering that physiological, biomechanical, and hemodynamic responses have to be specific according to the slope type (level, positive or negative), we realized that there was no validated/published protocol that could make it possible to compare this set of variables at speeds relative to the specific VT of each slope.

Step-by-step procedures

Study Population

The sample size was obtained through the calculation performed in the G*POWER 3.1.6 software, wherein a significance level of 0.05 and a power of 80% were adopted, based on effect size values for energy expenditure from the study of Browning et al. (2013), considering -3° and +3° slopes. Therefore, the calculation demonstrated a need for at least 11 participants.

Besides, men aged 18-35 years, grade 1 (Body mass index (BMI) between 30 and 34.9 $kg.m^{-2}$) and grade 2 obese (BMI between 35 and 39.9 $kg.m^{-2}$) will be included, who were not practicing regular physical exercise for at least three months, and non-smoking. Regular physical exercise practice was defined as the performance of any physical training modality for at least 20 minutes in three or more days of the week. The exclusion criteria of the study will include the presence of a history of musculoskeletal and joint injuries, chronic diseases associated with cardiovascular and respiratory problems, and any other muscular or joint impairment that prevents physical exercise performance safely.

Flow diagram of the study protocol

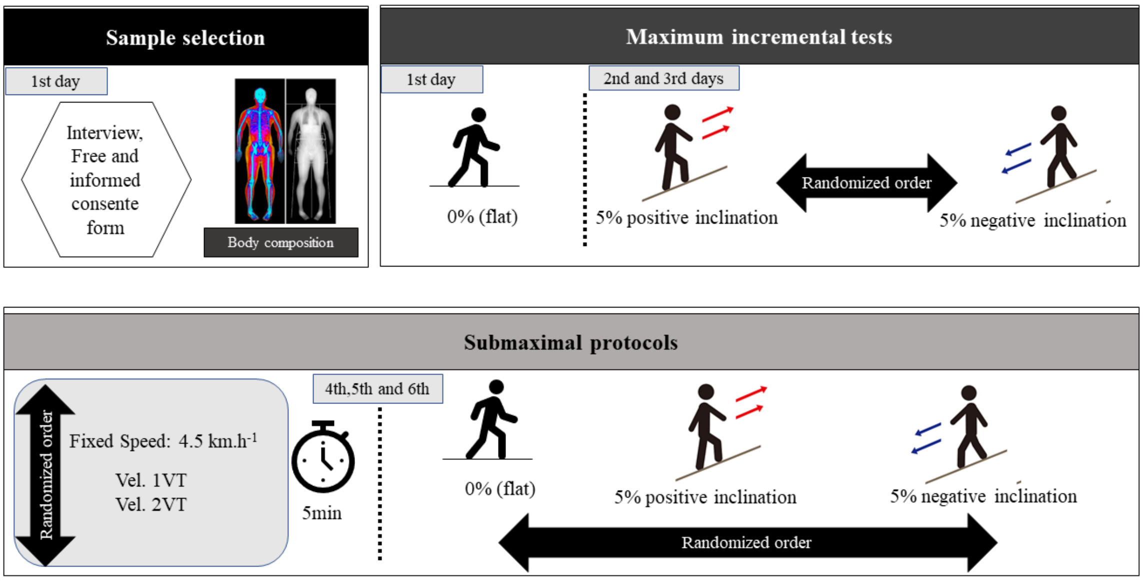

Figure 1: Flow diagram of the six days of evaluation.

General aspects of the tests

Collections will be performed at the Laboratory of Exercise Research, Biodynamics Sector, at the School of Physical Education, Physiotherapy and Dance of UFRGS. Each participant will have to attend the laboratory in six days to carry out the assessments (Figure 1). Individuals will be instructed to keep their eating and physical activity habits unchanged during the collection period. All walking/running tests will be performed on the treadmill.

On the first day, reading and explanation of the Free and Informed Consent Form (FICF) will be held, indicating the risks and benefits of participating in the research, and the entire testing protocol will be explained. After agreeing on the procedures and signing the FICF, the individuals will undergo a body composition assessment via dual-energy x-ray, having followed the preparation recommendations informed by the equipment manual and using the appropriate clothing. The evaluation is conducted with the individual in the supine position, with the hands along the body, without moving, using the full-body protocol

After the body composition assessment, the individuals will be familiarized with the treadmill and other equipment. Thereafter, the maximal incremental test on the treadmill will be performed on the level condition, using the portable gas analyzer along with the cardiac monitor. In the next two visits, maximal tests in positive and negative slope conditions will be carried out, in a randomized order. The data obtained in the three maximal tests will be analyzed by two experienced physiologists, in an independent and blinded manner, for the determination of VT1 and VT2 and thus, the ideal speeds for the submaximal protocols will be determined.

On the other three days of collection, submaximal protocols will be performed at the speeds referring to the thresholds determined in the maximal tests, wherein each day a slope condition (positive, negative, and level) will be carried out. First, the placement of the reflective points required for the three-dimensional reconstruction in the kinematics system will be performed. After that, the electrodes for hemodynamic monitoring, and the silicone mask of the respiratory gas analyzer will be placed.

Thereafter, test protocols in the following conditions will be performed: speed referring to the VT1; speed referring to the VT2; and fixed speed (4.5 $km.h^{-1}$). The order will be randomized, and each condition will be executed for five minutes, followed by at least 15 minutes of rest or until the resting values (HR and VO_2) are re-established. VO_2 data and kinematic and kinetic records will simultaneously occur after three minutes and 30 seconds of walking, until four minutes and thirty seconds, considering that in this period it is already possible to obtain steady-state values. Tests will be scheduled in the same time range on different days for everyone, to eliminate possible differences arising from the circadian rhythm. Individuals will be oriented to keep their eating and physical activity habits unchanged during the collection period.

Maximal tests protocols

Before starting all protocols, the gas analyzer equipment will be calibrated for air volume (with a 3L calibration syringe), humidity (with a specific device), and gas concentrations (by using a cylinder with a standard concentration of mixed gas with 16% of O_2, 5% of CO_2 and nitrogen for balance).

Individuals will be initially positioned sitting in a chair on the treadmill, where the silicone mask of the gas analyzer will be placed. Gases collections will start with the individual at rest for 15 minutes and the median for every 10 points during the last 3 minutes will be considered as resting values. At the end of the 15 minutes of rest, resting blood pressure will be measured for control and release for testing.

Considering the specific fixed slopes of each of the three tests (-5%, 0% e +5%) and to adjust the protocol of maximal voluntary exhaustion test (duration between 7 and 12 min) for the study sample, a series of pilot tests were carried out and the following protocols for maximal tests were developed:

- Level Ground (0%) and positive inclination (5%): initial speed of 3.0 $km.h^{-1}$, for 3 minutes, with an increase of 0.5 $km.h^{-1}$ every 1 min.
- Negative Slope (-5%): initial speed of 4.0 $km.h^{-1}$, for 3 minutes, with an increase of 1.0 $km.h^{-1}$ every 1 min.

Heart rate will be continuously registered and the perceived effort (Borg Rating of Perceived Exertion 6-20) (Borg, 1982) will be registered at the end of each stage. The test will be interrupted when the participant signals through manual gestures, being instructed to signal only when they reach a state of exhaustion. The assessment will be considered valid when at least two of the following criteria is reached at the end of the test (Mclaughlin et al., 2010): 1) obtainment of the estimated HR_{max} (220 - age); 2) obtainment of a respiratory exchange ratio (RER) greater than 1.1; 3) perceived exertion greater than 17.

Submaximal tests protocols

From the results of the analyzed maximal tests, the three last collection days will be carried out, one day for each condition: level ground, positive and negative slopes. Initially, the period of 15 minutes of rest will be repeated, and at the end, resting blood pressure will be measured for control and release for testing.

In these protocols, after the initial resting period, the electrodes of the hemodynamic monitoring system will be placed. For that, trichotomy and asepsis of the skin will be carried out (with abrasive gel and alcohol) at the electrode placement sites. With the dry skin, 6 electrodes will be fixed for hemodynamic monitoring (FS- 50, Skintact®, Austria) in the following sites: left lateral region of the neck, supraclavicular fossa, the center of the sternum, V1 and V6 standardized positions for electrocardiogram and parallel to the spine at the xiphoid process level. Using the specific software of the device, paired via Bluetooth, the equipment calibration will be performed.

The next step will be the placement of reflective points of the kinematics system, adhered to the skin with double-sided silicone tape (3M®), following the model proposed by (Minetti et al., 1993) and recently described by Oliveira et al. (2020), on the following anatomical points: ear canal, acromion, lateral epicondyle of the humerus, midpoint of the distal radioulnar joint, greater trochanter, femoral epicondyle, lateral malleolus, calcaneus, and fifth metatarsal. The last preparation step will be the placement of the respiratory gas analysis mask.

Data analysis

Energetics

Maximal tests

The energetic variables of the maximum test will be collected throughout the test. The ventilatory method will be used to determine VT1 and VT2, from VO_2, Ventilation (VE), and carbon dioxide production (VCO_2) curves, independently by two experienced physiologists, according to the methodology previously described (Binder et al., 2008; Cassirame et al., 2015):

- VT1: from the break in linearity of the VE/VO_2 ratio;
- VT2: from the break in the linearity of the VE/VCO_2 ratio;
- VO_{2peak}: the second highest VO_2 value in the last stage of the test.

In a complementary way, the Ventilation/time curve will be analyzed for possible checking of the determination of thresholds. For submaximal tests, the relative speeds of each slope in which the VT1 and VT2 were found.

Submaximal tests

The collection of energy variables occurs during the five-minute test. For the analysis, we will consider the values obtained in 1min, between 3min30s from the beginning to 4min30s, to evaluate the steady-state in the conditions of inclines and speeds (Ferretti et al., 2017).

- Caloric expenditure: in kcal.min-1, obtained by multiplying VO_2 (L/min) and the metabolic equivalent of RER (eqRER);
- Cost of Transport: in $J.kg^{-1}.m^{-1}$, obtained for VO_{2net} multiplied by 60 and eqRER and divided by speed;
- VO_2: in $ml.kg^{-1}.min^{-1}$, were considered as the average values during the walk/run during the steady-state period.

Mechanics

Mechanical Work

The kinematic model will be performed as described by (Minetti et al., 1993), with bilateral placement of nine anatomical markers (14 mm in diameter). The motion capture system is composed of six infrared cameras with a sampling frequency of 100Hz. The calibration procedure will be carried out according to the supplier's manual. After placing the markers, the static calibration will be conducted with the participant in an upright standing position, with the shoulders abducted and flexed elbow, both 90°, for 5s, to construct the model, and the data from 15 consecutive strides will be considered to analysis.

Kinematic data will be filtered through a fourth-order Butterworth low-pass digital filter using a cut-off frequency defined by residual analysis technique (limited at 6–12 Hz). The mechanical work will be calculated according to previously described methodologies (Cavagna and Kaneko, 1977; Willems et al., 1995). From the three-dimensional positions of the 18 anatomical markers, will build a spatial model of 11 rigid segments: head–neck–trunk, upper arms, lower arms, thighs, lower legs, and feet (Minetti et al., 1993; Nardello et al., 2011). The characteristics of each body segment (CM and radius of gyration) will be determined according to results of Dexa exam, as suggested by (Browning, 2012) and detailed described by (Matrangola et al., 2008). Based on these characteristics, the three-dimensional trajectory of the CM will be calculated. The kinematic collection will be performed only in submaximal tests.

Finally, based on the CM data, the time course of potential (Ep) and kinetic (Ek) energies (using three-dimensional coordinates: z, vertical; x, anteroposterior; and y, mediolateral) will be computed to determine W_{tot}, W_{ext}, and W_{int}, as recently described by Oliveira et al. (2020), and briefly described below:

- W_{tot}: summation of the W_{ext} and W_{int} modules

- W_{ext}: The summation of all increases over the E_{ext} time course resulted in the positive external mechanical work, W_{ext}. The Wext corresponds to the work necessary to lift and accelerate the Body CM within the environment.

- W_{int}: The work necessary to rotate and accelerate the limbs concerning the CM. It was calculated through the summation of the positive increments of rotational energy from the body segments and the translational energy from the body segments relative to the CM.

Kinetic: impact force

We will also calculate the impact peak magnitude. Values will be expressed as total load (N), and normalized to body weight (%) (Wallace et al., 2018). The average of the same 15 strides of kinematic analysis will be considered for each inclination and speed condition.

Cardiac Hemodynamics

We will analyze the following parameters regarding hemodynamics. Data gathering will be carried out throughout the submaximal test. We will use for this analysis only the data from the 1min steady-state period for each speed.

- Heart Rate (HR), in bpm, will be considered as the average HR during this 1min period;

- Stroke Volume (SV), in ml, will be considered as the average of the estimated amount of blood ejected from the left ventricle by beating during this 1min period;

- Cardiac Output (CO), in $L.min^{-1}$, will be considered as the product average between HR and VS during this 1min period.

Statistical analysis

Statistical Package for the Social Sciences version 17.0 (SPSS Inc., Chicago, DE, USA) will be used. Descriptive analyses will be presented as the mean and standard error. Comparisons between the variables of submaximal protocols will be analyzed with Generalized Estimating Equations (GEE) with two factors (slope and speed) and Bonferroni post hoc test. Also, effect sizes (ES) will be calculated through Cohen's d value with the following classifications (Hopkins, 2002): trivial ($d \leq 0.2$), small ($d < 0.2$), moderate ($d > 0.6$), large ($d > 1.2$), or very large ($d \geq 2.0$), to compare the main differences between the slopes. A significance level of $\alpha = 0.05$ will be adopted.

The expected outcomes

A potential strategy for obese adults to achieve higher levels of energy expenditure can be walking/running on inclined surfaces. In positive slope conditions, lower limb muscles perform a greater proportion of positive mechanical work for increasing gravitational potential energy in each step and most of this work is performed by hips and knees muscles and joints when compared to level walking (Sawicki and Ferris, 2009). The combination of lower speeds at positive slope versus walking on level ground at higher speeds will result in similar metabolic cost between the conditions (Ehlen et al., 2011; Dewolf et al., 2017), which can mean the advantage of locomotion on an inclined level. On the other hand, the negative slope may favor the development of higher speeds with less perceived effort, and generally require less load on the cardiovascular system, a favorable condition for individuals with low exercise tolerance.

Advantages

The protocol aims to define iso-intensity conditions for comparing the mechanical and energetic factors of locomotion. aims to enable a better understanding of the relationship of these variables and the possible advantages found depending on the type of inclination, thus increasing the possibilities of exercise prescription safely and efficiently.

Limitations

Despite the possible benefits of this method, we observe some limitations: i) only one level of inclination for each condition (positive and negative); ii) the speeds determined by the iso-intensities of VT1 and VT2 can happen while some individuals are running and others are walking; iii) there is no comparator group.

Discussion

Considering the expressive increase of obesity worldwide and the several associated risk factors, this work aims to propose a new method of performing primarily aerobic exercise capable of improving many health-related aspects, especially an increase in energy expenditure, reduction of joint impact, and cardiovascular demand during the activity. Physical exercise performed in a regular and oriented manner is currently highly recommended for most people since its general benefits are established and consolidated in the international literature. In this context, walking is considered a great alternative to the exercise method, because it is a functional activity and simple to perform.

The present study seeks to elaborate a proposal for locomotion methodology on an incline, to compare, under iso-intensity conditions, biomechanical, physiological, and hemodynamic responses related to the different types of slopes (positive and negative) and to verify the possible advantages and disadvantages of their results in the obese population.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

Conception or design of the work: H.B.O., G.D.V, R.G.R., L.T.F., R.S., and L.F.M.K. Writing, proofreading and organization: H.B.O., G.D.V., R.G.R. E.B.F., C.G.B., B.M.B, L.T.F., R.S, L.F.M.K. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work. All persons designated as authors qualify for authorship, and all those who qualify for authorship are listed.

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ARTIGO 3: RESULTADOS DOS TESTES MÁXIMOS

Journal for submission: Journal of Sports Science and Medicine

Title: Influence of positive and negative inclination during maximal test on VO_{2peak}, ventilatory thresholds and perceived exertion in adults with obesity

Running Head: Maximal tests at different inclinations

ABSTRACT

Objective: The present study aimed to compare the effects of positive and negative inclination on maximal parameters, ventilatory thresholds (VT), and the perceived exertion of adults with obesity. **Methods:** 11 obese men (% fat mass = 39.38 ± 4.56%), young adults (age = 24.32 ± 2.32 years old) performed three maximum tests on different types of inclination (-5, 0 e +5%). Cardiometabolic and effort perception data were collected during all tests and independently assessed by two experienced physiologists to determine the first and second ventilatory thresholds and VO_{2peak}. The protocol for 0 and +5% was the same, starting at 3 $km.h^{-1}$ with an increase of 0.5 $km.h^{-1}$ per min, and for -5% it started at 4 $km.h^{-1}$ with an increase of 1.0 $km.h^{-1}$ per min. The statistical analysis was performed with a repeated-measures ANOVA with Bonferroni post-hoc and the alpha adopted was 0.05. **Results:** The three protocols were performed in an adequate time for the population and VO_{2peak} was similar between the slopes. The speed for analyzed points VT1, VT2, and the maximum was lower in the positive slope (4.4, 6.5, and 7.3 $km.h^{-1}$, respectively), intermediate in the flat (5.3, 8.4, and 9.5 $km.h^{-1}$, respectively), and higher in the negative slope (5.9, 10.5, and 11.5 $km.h^{-1}$, respectively). The perception of effort was similar in the three inclinations. In VT1 the VO_2 was higher in the positive inclination, and in VT2 it was similar between the inclinations. **Conclusions:** Positive inclination can promote the same metabolic demands and perceived exertion of a maximum test at much slower speeds than flat and negative inclination in obese adults. The positive slope seems to be the best alternative for maximum testing in obese adults, as it generates the necessary metabolic demand with a lower absolute speed.

KEY WORDS: Locomotion, obesity, exercise test, slope, treadmill, aerobic threshold

INTRODUCTION

Obesity has been considered a worldwide epidemic disease since 1999 (Dietz, 2015), and it is currently estimated that more than 1.9 billion people are overweight (WHO, 2017). Several risk factors for mortality are associated with the disease, such as dyslipidemia, arterial hypertension, cancer, cardiovascular diseases, type 2 diabetes mellitus (Anari et al., 2017; Blond et al., 2019), among others. International guidelines recommend engaging in regular physical activity (150 minutes spread through the week for adults) (WHO, 2017). In this context, walking is an easily accessible, safe, efficient, and low-cost alternative, capable of reducing these risk factors (Browning, 2012).

From a clinical point of view, one of the parameters most commonly assessed concerning cardiorespiratory fitness and health condition is the maximum oxygen consumption (VO_{2max} or VO_{2peak}) (Cotes and Reed, 2007; Albouaini et al., 2007; Kaminsky et al., 2014). A small improvement in aerobic capacity can decrease the risk of mortality, considering that every 1min increase in the maximum test on the treadmill, equivalent to 1MET, corresponds to approximately an 8% reduction in mortality (Blair et al., 1995; Gallagher et al., 2005). When obese individuals have a moderate or high level of cardiorespiratory fitness, the reduction in the mortality rate reaches 71% when compared to obese with low fitness (McAuley and Beavers, 2014).

There are several pre-established protocols for the maximum test, as well as minimum and maximum limits for the development of new protocols, according to the population studied (Delevatti et al., 2015; Mezzani, 2017). One of the most frequent strategies in the maximum test of obese adults is the use of the positive inclination of the treadmill to increase the intensity, commonly with the use of the Bruce Protocol (Bruce, Kusumi and Hosmer, 1973). During locomotion on positive slopes, the magnitude and duration of muscle activity increase, suggesting that the pattern of muscle activation may help to predict the increase in metabolic cost compared to level walking (Silder, Besier and Delp, 2012). This happens in an advantageous mechanical condition since it can occur at lower speeds in the inclination, decreasing the joint impact (Ehlen, Reiser and Browning, 2011).

In contrast, the use of negative inclination as an alternative training method applied to people with low exercise tolerance has been investigated (Browning et al., 2013; Philippe et al., 2017). In this condition, there is a paradox between the rating of perceived exertion (RPE) and exercise intensity. When walking is performed at the same absolute speed, when compared to level walking, the RPE is lower, mainly due to the lower relative load (%VO_{2max}) (Agarwal et al., 2017).

Graded walking can be interesting to assess the effects of exercise with a predominance of concentric (positive inclination) and eccentric (negative inclination) activities. If, on the one hand, walking on a positive inclination can favor the obese individual because it reduces joint impact and can be performed at lower absolute speeds, on the other hand, walking on a negative inclination can favor the obese individual because it allows walking at greater absolute speeds, with lower RPE. Nevertheless, no studies have been found that have evaluated the behavior of cardiorespiratory, especially the relationship between the threshold points and perceived exertion variables in a maximum test on the different slopes. The results can be used to choose the evaluation protocol and training strategy for people with obesity, due to the possible mechanical and energetic advantages generated by the different inclinations. Thereby, the present study aimed to compare the effects of positive and negative inclination on maximal parameters, ventilatory thresholds, and the perceived exertion of obese adults.

METHODS

The study was performed under the latest revision of the Declaration of Helsinki (October 2013) and approved by the Research Ethics Committee of the Federal University of Rio Grande do Sul (UFRGS) under protocol number 2.660.010.

Subjects

Eleven obese men (% fat mass = 39.38 ± 4.56%) young adults (age = 24.32 ± 2.32 years old) participated in the study. Subjects were considered sedentary (i.e. < 60 min/Week of structured exercise), non-smoking, and free of cardiovascular disease. Subjects were excluded if they presented a history of musculoskeletal and joint injuries, chronic diseases associated with cardiovascular and respiratory problems, and any other muscular or joint impairment that prevents physical exercise performance safely.

Experimental Design

The complete protocol was developed in three days, with a minimum interval of 72h. Individuals were instructed to keep their eating and physical activity habits unchanged during the collection period.

On the first day, reading and explanation of the Free and Informed Consent Form (FICF) were performed, indicating the risks and benefits of participating in the research, and the entire testing protocol was explained. After agreeing on the procedures and signing the FICF, the individuals underwent a body composition assessment via dual-energy x-ray (Lunar Prodigy model, General Electric Company, Illinois, USA), having followed the preparation recommendations informed by the equipment manual and using the appropriate clothing. The evaluation is conducted with the individual in supine position, with the hands along the body, without moving, using the full-body protocol. After the body composition assessment, the individuals were familiarized with the Instrumented treadmill (super ATL model, Inbramed - Porto Alegre, Brazil), the portable metabolic system plus heart rate monitor (K5 model, Cosmed - Rome, Italy - breath by breath), calibrated and validated as previously described by Guidetti et al. (2018), and the Borg's Scale (6-20) (Borg, 1982). Thereafter, the maximal incremental test on the treadmill was performed on the flat condition, using the portable gas analyzer along with the cardiac monitor. In the next two visits, maximal tests in positive and negative slope conditions were carried out, in a randomized order. The data obtained in the three maximal tests were analyzed by two experienced physiologists, in an independent and blinded manner, for the determination of first (VT1) and second (VT2) ventilatory thresholds, and VO_{2peak}.

Protocols for maximum testing

Before starting all protocols, the gas analyzer equipment was calibrated for air volume (with a 3L calibration syringe), humidity (with a specific device), and gas concentrations (by using a cylinder with a standard concentration of mixed gas with 16% of O_2, 5% of CO_2 and nitrogen for balance). The temperature was maintained between 18 and 22°C and humidity less than 60%.

Gases collections started with the individual at rest for 15 minutes and the median for every 10 points during the last 3 minutes was considered as resting values. At the end of the 15 minutes of rest.

Considering the specific fixed slopes of each of the three tests (-5%, 0% e +5%) and to adjust the protocol of maximal voluntary exhaustion test (duration between 7 and 15 min) for the study sample, pilot tests were carried out and the following protocols for maximal tests were developed: level ground (0%) and positive inclination (5%): initial speed of 3.0 km.h^{-1}, for 3 minutes, with an increase of 0.5 km.h^{-1} every 1 min; negative slope (-5%): initial speed of 4.0 km.h^{-1}, for 3 minutes, with an increase of 1.0 km.h^{-1} every 1 min.

Heart rate (HR) was continuously registered, and the perceived effort registered at the end of each stage. The test was interrupted when the participant signals through manual gestures, being instructed to signal only when they reach a state of exhaustion. The assessment was considered valid when any of the following criteria is reached at the end of the test (Mclaughlin et al., 2010): 1) obtainment of the estimated HR_{max} (220 - age); 2) obtainment of a respiratory exchange ratio (RER) greater than 1.1; 3) perceived exertion greater than 17.

Data analyses

The ventilatory method was used to determine VT1 and VT2, from VO_2, Ventilation (VE), and carbon dioxide production (VCO_2) curves, independently by two experienced physiologists, according to the methodology previously described (Wasserman et al., 1973; Cassirame et al., 2015): VT1: from the break in linearity (decrease) of the $VE.VO_2^{-1}$ ratio; VT2: from the break in the linearity (increase) of the $VE.VCO_2^{-1}$ ratio; VO_{2peak}: the second-highest VO_2 value in the last stage of the test. In a complementary way, the Ventilation/time curve was analyzed for possible checking of the determination of thresholds.

The values of VO_2 (ml.kg^{-1}.min^{-1}) and HR (bpm) were obtained directly by the equipment. As the collection was carried out in breath-by-breath mode, we smoothed the data considering the median every five points.

Statistical analysis

Descriptive statistics were performed using means and standard deviations. The normality of data was tested with the Shapiro-Wilk test and sphericity with the Mauchly test.

Considering that the data were parametric, the comparison between the slopes was performed with a repeated-measures ANOVA with Bonferroni's post-hoc. The adopted alpha was 0.05. Hedges' *g* was used to determine the effect size (ES) between the inclinations. The interpretation of ES's magnitude was based on Hopkins' criteria (Hopkins, 2002): 0.2 is trivial, 0.2–0.6 is small, 0.6–1.2 is moderate, 1.2–1.9 is large, and 2.0–4.0 is very large. The data were processed using the SPSS software v.19.

RESULTS

The characteristics of participants are shown in Table 1.

Table 1: Characteristics of participants

	Mean	**± SD**
Age (years)	24.32	2.32
Height (m)	1.78	0.07
Weight (kg)	119.70	17.23
BMI ($kg.m^{-2}$)	37.50	3.10
Fat percentage (%)	39.38	4.56
Total fat mass (kg)	48.10	14.00
Fat free mass (kg)	72.34	8.13
$VO2_{rest}$ ($ml.kg^{-1}.min^{-1}$)	4.66	1.29
HR_{rest}	84.80	10.86

Note: $VO2_{rest}$: mean VO_2 at rest period for the three test days. HR_{rest}: mean HR at rest period for the three test days.

Test time

The average test time between the three inclines was 11min40s. There was no significant difference between the positive slope and the flat condition ($p = 0.22$), as well as between the positive and the negative slope ($p = 0.55$). The average test time in the flat was longer than in the negative slope ($p = 0.007$) (Table 2).

HR at VT1 and VT2

The HR at VT1 and VT2 showed no difference between the slopes ($p>0,05$) (Table 2).

VO2 at VT1, VT2, VO2peak, and Ratio VO2peak/VO2 VT2

VO_2 in VT1 was higher in the positive slope than in flat ($p = 0.003$) and in the negative slope ($p = 0.001$). There was no significant difference between flat and the negative slope ($p> 0.05$). VO_2 at VT2 was similar between the three slopes ($p> 0.05$). VO_{2peak} and Ratio VO_{2peak}/VO_2 VT2 showed no significant difference between the slopes (Table 2).

Table 2: Values in mean ± standard deviation at different slopes: positive slope (POS), flat (FLAT) and negative slope (NEG)

Variable	POS	FLAT	NEG	ES	
				Numeric	**Classification**
Test time (min)	11.4±0.4^{AB}	13.2±0.5^{B}	10.7±0.6^{A}	POS*PLA = 3.32 POS*NEG = 1.18 PLA*NEG = 3.86	Very large Moderate Very large
HR VT1 (bpm)	124±12^{A}	119±9^{A}	113±11^{A}	POS*PLA = 0.08 POS*NEG = 0.88 PLA*NEG = 0.55	Trivial Moderate Small
HR VT2 (bpm)	159±16^{A}	163±16^{A}	166±13^{A}	POS*PLA = 0.23 POS*NEG = 0.44 PLA*NEG = 0.19	Small Small Trivial
VO_2 VT1 ($ml.kg^{-1}.min^{-1}$)	19.26±3.33^{B}	14.73±3.48^{A}	12.73±2.27^{A}	POS*PLA = 1.23 POS*NEG = 2.11 PLA*NEG = 0.63	Large Very large Moderate
VO_2 VT2 ($ml.kg^{-1}.min^{-1}$)	29.03±6.63^{A}	26.70±7.94^{A}	25.47±5.74^{A}	POS*PLA = 0.29 POS*NEG = 0.53 PLA*NEG = 0.16	Small Small Trivial
VO_{2peak} ($ml.kg^{-1}.min^{-1}$)	33.99±7.90^{A}	33.95±6.27^{A}	31.60±6.68^{A}	POS*PLA = 0.01 POS*NEG = 0.30 PLA*NEG = 0.33	Trivial Small Small
Ratio VO_{2peak}/VO_2 VT2 (%)	84.90±3.91^{A}	87.10±6.60^{A}	84.17±6.65^{A}	POS*PLA = 0.37 POS*NEG = 0.12 PLA*NEG = 0.41	Small Trivial Small

Note: ES = Effect Size; Different letters represent significant differences ($p<0.05$) between the slopes.

Speeds relative to VT1 and VT2, and maximum speed

The speed was significantly different in the comparisons of the three inclinations for VT1, VT2, and $VO2_{peak}$. In the VT1, the positive slope had lower values (4.4 $km.h^{-1}$) than the flat (5.3 $km.h^{-1}$, $p = 0.004$), and then the negative slope (5.9 $km.h^{-1}$, $p = 0.001$), just as the flat had lower values than the negative slope ($p = 0.008$). In the VT2, the same behavior was found, the positive slope showed lower values (6.5 $km.h^{-1}$) than the flat (8.4 $km.h^{-1}$, $p = 0.002$) and the negative slope (10.5 $km.h^{-1}$, $p <0.001$), just as the flat was smaller than the negative slope ($p <0.001$). In the VO_{2peak} stage, the maximum speed found in the negative slope (11.5 $km.h^{-1}$) was higher than in the flat (9.5 $km.h^{-1}$, $p <0.001$) and in the positive slope

(7.36 $km.h^{-1}$, $p < 0.001$), as well as in the flat test it was higher than in the positive slope ($p = 0.001$) (Figure 1).

Rating of perceived exertion (RPE)

RPE showed a significant difference only in the VT1 comparison between flat and the negative slope, being lower in the negative slope ($p = 0.004$). No significant differences were identified between the slopes in the remaining comparisons. Interestingly, in the three slopes, the RPE of the second threshold showed the same values (16.0 ± 1.0) (Figure 1).

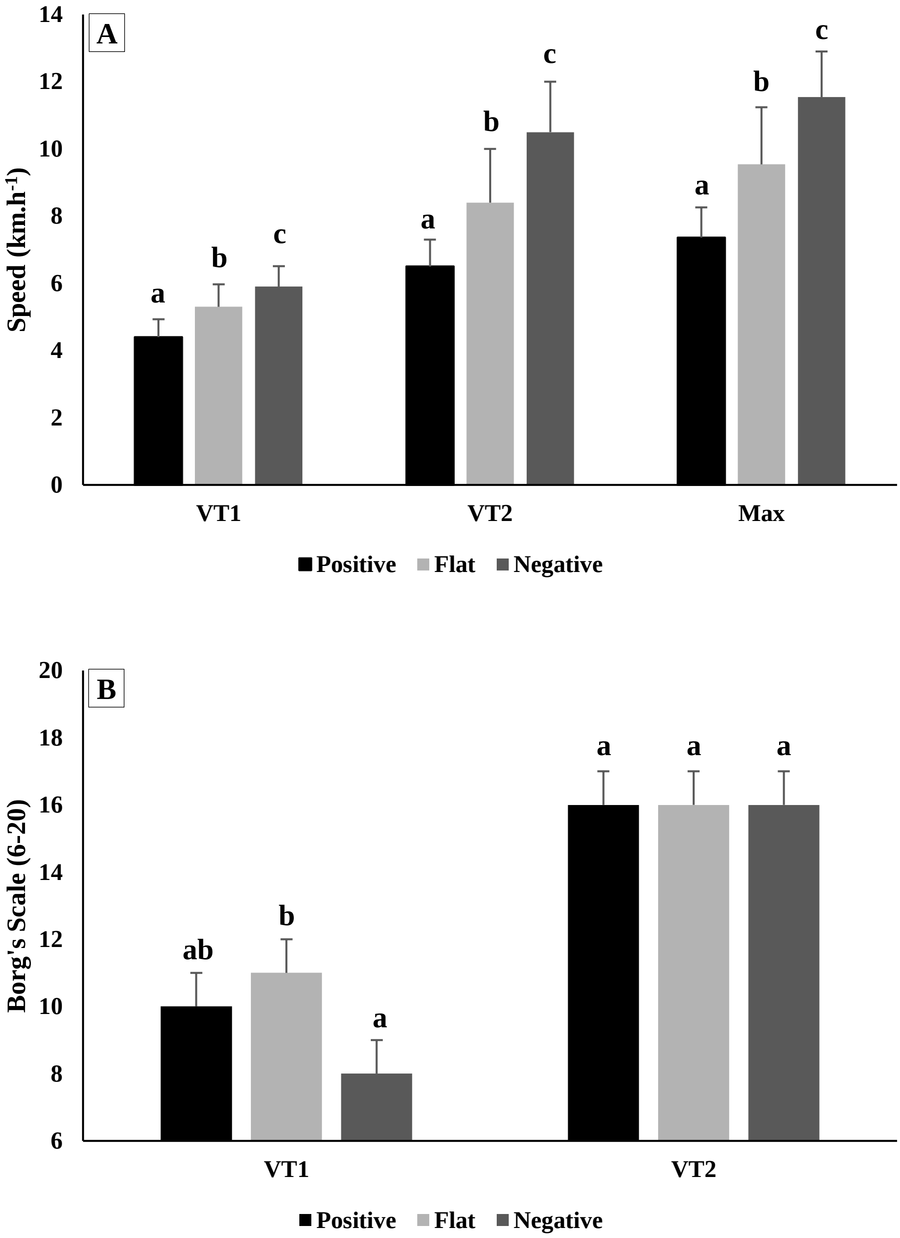

Figure 2: In panel A, the average speed values in positive (black bar), flat (light gray bar), and negative slope (dark gray bar), at the first (VT1), second (VT2) ventilatory thresholds, and at maximal speed. In panel B, Average Borg Scale values in positive (black bar), flat (light gray bar), and negative slope (dark gray bar), at the first (VT1) and second (VT2) ventilatory thresholds. Different letters represent significant differences ($p<0.05$) between the slopes at same the intensity.

DISCUSSION

The main finding of this study was that the physiological responses, including HR, VO_2 at VT2, VO_{2peak}, and perceived exertion, regardless of the type of inclination (positive, negative, or flat), show similar behavior during the performance of a maximum test of obese young adults. However, the relationship between the type of slope and speed must be considered, since to achieve the same physiological intensities, lower speeds in the positive slope and higher speeds in the negative slope were necessary.

The three proposed protocols were able to take all 11 individuals, during the three tests, to reach the criteria established for the test to be valid as maximum, considering the first three minutes of each test as a warm-up. In the positive slope and in flat condition, the protocol's sequence of speed increases was similar, which may justify the very large effect size (d = 3.32) between these conditions, with longer time in flat, as well as the higher VO_{2peak} speed on the flat (7.36 ± 0.9 *vs* 9.54 ± 1.7 $km.h^{-1}$). The test time on the negative slope was shorter than in flat, probably because the speed increments were 1 $km.h^{-1}$ every minute, while in flat it was 0.5 $km.h^{-1}$ every minute, generating a compensation intensity in the negative slope. In general, the tests must include an interval between 8 and 12 minutes, up to a maximum of 15 minutes considering the heating, regardless of the protocol and equipment used (Lear et al., 1999), which demonstrates that the test time for the three protocols was suitable.

HR showed no significant difference between the slopes, which indicates that a relative intensity was detected for the thresholds, considering the difference in speed between the slopes. Mainly at higher intensities, there is likely an adjustment of stroke volume so that cardiac output is adequate for metabolic demand (Vella et al., 2009; Moore et al., 2016). This relationship can be reinforced by the trivial/small effect size values between all comparisons at VT1 and VT2, even considering the significant difference between the speeds. HR is commonly used as a practical way of prescribing and monitoring exercise at specific intensities, due to its linear relationship with intensity and greater ease of access and control (Byrne and Hills, 2002), according to the results found it is also possible to use in exercises performed on different types of inclination. The results for HR are following the literature, as it is expected, under the same external load (absolute speed), lower cardiovascular load in an exercise condition with a predominance of eccentric contractions (i.e. downhill), compared to an exercise with a predominance of concentric contractions (i.e. uphill) (Agarwal et al., 2017). A potential explanation may be attributable to the difference in active muscle mass utilized in these two modes of muscle contraction. Moreover, the recruitment and discharge rate of motor units is known to be less during an eccentric contraction than during a concentric contraction (Duchateau and Enoka, 2008).

One of the main research questions of this study was to verify whether, even on positive and negative slopes with little angulation, there would be significant differences in speed at the points of VT1, VT2, and maximum speed. The results confirmed the hypothesis of lower speeds on the positive slope and higher on the negative slope for the three points analyzed significantly, finding that corroborates with previous studies that found mechanical and safety advantages of positive inclination for the development of aerobic activities for individuals with obesity, however under higher degrees of inclination (Ehlen et al., 2011; Browning et al., 2013; Philippe et al., 2017). Importantly, we highlight that the average speed of VT2 on the + 5% incline corresponds to a walking condition, while at 0 and -5% corresponds to running conditions. Instead, the negative inclination can be an interesting training strategy for individuals with low exercise tolerance, as in some cases of obesity (Figard-Fabre et al., 2009; Philippe et al., 2016) even considering the speed differences of each type of incline for an optimal intensity prescription.

Perception of effort is a low-cost method validated for controlling exercise intensity (Tiggemann et al., 2016; Pageaux, 2016). Our results demonstrated that, in the VT1, the perception of effort was lower ($p = 0.004$) in the negative slope (8±1) than in flat (11±1), which may have occurred because the average speed of this condition is still walking, representing a mechanical advantage of the negative slope (Minetti, Ardigò and Saibene, 1994; Browning et al., 2013). These values are slightly below those reported in the literature, with averages between 12-13 of the Borg Scale for VT1, according to %VO_{2max} (Alberton et al., 2016), probably explained because low-intensity walking is one of the most performed tasks in daily activities, representing lower perceptions of effort in this condition (Pageaux, 2016). Interestingly, in VT2 the perception was considered “very intense” (average of 16 of the Borg’s Scale) in the three inclinations, despite the significant difference in speed, which agrees with previous studies that reported perceptions between 16-17 in the condition of VT2, even in different environments and types of exercises (Alberton et al., 2013, 2016). These responses suggest that the perception of effort is sensitive to different types of inclination and capable of being interpreted by individuals in different conditions.

VO_{2peak} was considerably similar between the three inclinations, which again confirms that the individuals reached a level considered to be a maximum effort. It seems that in the condition of VT1, wherein the three inclines the individuals were walking, the inclination has a greater influence than the speed, as it was significantly higher in the positive inclination. An answer that agrees with previous studies that analyzed submaximal conditions at different slopes (Reynolds et al., 2010; Haight et al., 2013). Differently, in the condition of VT2 it seems that the speed can compensate for a difference relative to the type of slope because, despite the higher speed in the negative slope and in flat, there was no significant difference in VO_2. Curiously, the percentage ratio between VO_{2peak} and VT2 was higher than expected for the studied sample, because typically corresponds to 47 to 76% of the VO_{2max} in untrained individuals with and without cardiovascular disease (Gallagher et al., 2005), and our results on average were 84.9 ± 3.9, 87.1 ± 6.6 and 84.1 ± 6.6% on the positive slope, on flat and on the negative slope, respectively. Probably, this higher percentage in our study may be due to the young age and the high homogeneity of the sample, a characteristic that tends to demonstrate higher values of aerobic capacity, like values found with young eutrophic adults (Silva, Deresz and Lima, 2008; Alberton et al., 2013).

This study has limitations that should be discussed. The main limitation was not to measure the ground reaction forces at different slopes, which does not allow us to infer that on the positive slope the locomotion is performed with less impact on the joints. However, as observed in the literature, it is known that there is a direct relationship between speed and peak ground reaction force in the touch-down moment, so it is suggested that the lower speed performed on the positive slope may have less impact for the same intensity relative.

Therefore, as a practical application of these findings, the positive inclination made it possible to achieve similar results of the metabolic outcomes of flat and negative inclinations at lower speeds, therefore an evaluation strategy for a population with obesity in which there is a high risk of musculoskeletal injuries. Besides, the results can also be applied to training strategies, since between points VT1 and VT2 individuals can reach this zone of intensity while walking on the positive slope and, on the other hand, on flat and the negative slope is necessary to run. Finally, the perception of effort can be an easily accessible applicable tool to be used in the prescription of training intensity, regardless of the terrain slope.

CONCLUSION

The three proposed protocols were able to achieve the general recommendations for maximum testing criteria. The positive inclination can promote the same metabolic demands and perceived exertion of a maximum test at much slower speeds than flat and negative inclination in adults with obesity. The positive slope seems to be the best alternative for maximum testing in adults with obesity, as it generates the necessary metabolic demand with a lower absolute speed, and the perception of effort is applicable in all the inclination conditions analyzed, even considering the different absolute speeds.

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The experiments comply with the current laws of Brazil.

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ARTIGO 4: RESULTADOS DOS PROTOCOLOS SUBMÁXIMOS

Journal for submission: Journal of Physical Activity and Health

Section: Brief Report

Article title: Insights into an integrative point of view of the energetic, mechanical and hemodynamic systems on locomotion at different inclinations of individuals with obesity

Running Head: Locomotion at different inclinations of individuals with obesity

Abstract

Background: Sloped surfaces on locomotion may reflect advantages for the exercise prescription for obese adults. This study aimed to compare the effects of positive and negative slopes at different speeds on responses related to energy expenditure, mechanical work, the peak of vertical ground reaction force, and cardiovascular demand in adults with obesity.

Methods: 4 adult men participated (age = 25.7±4.5 years, body mass = 110.7±19.8 kg, height = 1.73±0.09 m, BMI = 36.7±3.56 $kg.m^{-2}$, % fat = 36.9 ± 1.7 %, VO_{2peak} = 34.06±7.29 $ml.kg^{-1}.min^{-1}$). Energetics, biomechanics, and cardiac variables were measured at a fixed speed (4.5 $km.h^{-1}$), speed relative to the first (VT1) and the second ventilatory threshold (VT2), previously determined, at 3 different slopes (-5%, 0%, +5%). Metabolic data were obtained using a gas analyzer, biomechanical data through a kinematics 3D system and force sensors installed on the treadmill, and hemodynamic parameters using a Signal-Morphology impedance device.

Results: The absolute speeds between the metabolic iso-intensities were slower on the positive slope (VT1 = 4.37±0.48 $km.h^{-1}$, VT2 = 6.62±0.85 $km.h^{-1}$) and higher on the negative slope (VT1 = 5.62±0.75 $km.h^{-1}$, VT2 = 10.25±0.75 $km.h^{-1}$) in relation to the flat (VT1 = 5.00±0.71 $km.h^{-1}$, VT2 = 8.50±2.34 $km.h^{-1}$). Metabolic parameters were higher in the positive slope, except VO_2 in VT2. External mechanical work had a direct relationship with the slope and internal mechanical work with absolute speed. GRFv in most conditions was lower in the positive slope. The positive slope showed higher heart rate values, however, the cardiac output showed little variation between the slopes.

Conclusion: Positive slope can be an alternative with benefits for people with obesity aerobic exercise, especially because of the greater metabolic demand, lower absolute speeds, which reduce the impact during locomotion. Importantly, walking at slower speeds also reduces the perceived exertion of the exercise, which may result in increased activity time and adherence even when walking uphill.

Keywords: Slope, Walking, mechanical work, caloric expenditure, cardiac output

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Introduction

Obesity has been considered since 1999 as a disease with proportions of a global epidemic,[1] and can be classified historically as the first non-infectious epidemic.[2,3] The chronic energy imbalance, where the energy consumed is greater than the energy spent is typically one of the main causes of obesity.[4] A large effect size is found in the decrease in mortality levels with regular levels of physical activity, reaching approximately 33% reductions in deaths from all causes compared to physically active and sedentary individuals.[5] In this context, physical activity is one of the main strategies for reducing the risk factors associated with obesity and physical inactivity, being the basis of most weight loss programs.[6,7]

Exercises with a predominance of aerobic metabolism remain the most effective strategy for improving anthropometric and fitness measures.[3,8] Weight loss interventions have used walking as a primary aerobic exercise, as it is easily adjustable in volume, intensity, and duration to the capacity of each individual.[9,10] For an optimal training prescription, an integrative view of the systems involved in locomotion of the individual with obesity is important, including the bioenergetic system,[11,12] the mechanical system, [9,13,14] the impact on the skeletal muscle system,[15,16] and the hemodynamic system,[17,18] seeking the best effectiveness of the activity combined with a lower risk of injuries and adverse events.

The manipulation of aerobic exercise intensity has been investigated, since a simple increase in walking speed can generate greater joint loads and indices of osteoarticular injuries, and the use of positive inclination seems to be an efficient alternative, whereas at lower speeds it is possible to reach ideal levels of intensity with lesser impacts.[19] On positive inclinations, the magnitude, and duration of muscle activity increase, which suggests that the pattern of muscle activation may help to predict the increase in metabolic cost, considering that in this condition there is a predominance of concentric contractions of the propulsive musculature.[20] For example, obese adults walking at 0.75 $m.s^{-1}$ and on a 6° slope are at an intensity of approximately 52% of VO_{2peak}, whereas, walking on flat surface at 1.50 $m.s^{-1}$, they are in an intensity range of approximately 50% of VO_{2peak}.[19] However, the studies found used the same absolute speed for the comparison between the slopes, which limits the understanding of the conduct of these variables in conditions of metabolic iso-intensity, such as the points of first (VT1) and second ventilatory threshold (VT2), important for the prescription of inclined walking.

Another way of manipulating the intensity of locomotion is the negative inclination. As a characteristic, there is a predominance of eccentric contractions which can result in a decrease in metabolic demand, mainly due to the efficiency of its contraction and the optimization of the pendular system,[21,22] favoring the development of higher speeds with lower rates of perceived exertion (RPE).[23] One of the disadvantages of the negative inclination is the possible greater joint load, which was confirmed only with eutrophic individuals from -10º [16] and, in individuals with obesity, just speculation that even with little negative inclination there may be greater impacts than walking on the flat surface.[15,24]

Another system that presents specific responses to the type of muscle contraction during exercise is the hemodynamic system. Eccentric exercise is capable of generating lower cardiovascular demands (lower heart rate for the same cardiac output) compared to concentric exercises, possibly due to the lower muscle mass used, under the same absolute load, which represents less recruitment and firing rates of motor units.[25] However, the relationship between these parameters in locomotion at different inclinations of adults with obesity is not yet clear. Therefore, this study aimed to compare the effects of positive and negative inclined locomotion in iso-intensity on responses related to energy expenditure, mechanical work, the peak of vertical ground reaction force, and cardiovascular demand in adults with obesity.

Methods

The ethics committee of the Federal University of Rio Grande do Sul approved this project under application number 2.660.010.

Participants

Four men with obesity (% fat mass = 36.9±1.7 %) young adults (age = 25.7±4.5 years old) participated in the study. Subjects were considered sedentary (i.e. < 60 min/Week of structured exercise), non-smoking, and free of cardiovascular disease. Subjects were excluded if they presented a history of musculoskeletal and joint injuries, chronic diseases associated with cardiovascular and respiratory problems, and any other muscular or joint impairment that prevents physical exercise performance safely.

Procedure

Each participant has to attend the laboratory in six days to carry out the assessments with an interval of, at least, 72 hours between tests. Individuals were instructed to keep their eating and physical activity habits unchanged during the collection period. All walking/running tests were performed on the treadmill (super ATL model, Inbramed - Porto Alegre, Brazil).

On the first day, the individuals underwent a body composition assessment via dual-energy x-ray (Lunar Prodigy model, General Electric Company, Illinois, USA), followed the preparation recommendations informed by the equipment manual, and using the appropriate clothing. After the body composition assessment, the individuals were familiarized with the treadmill and other equipment used during the tests. Thereafter, the maximal incremental test on the treadmill was performed on the flat condition, using the portable gas analyzer along with the cardiac monitor (K5 model, Cosmed - Rome, Italy) with sampling frequency breath by breath. In the next two visits, maximal tests in positive and negative slope conditions were carried out, in a randomized order. The data obtained in the three maximal tests were analyzed by two experienced physiologists, in an independent and blinded manner, for the determination of VT1 and VT2 and thus, the ideal speeds for the submaximal protocols were determined. On the other three days of tests, submaximal protocols were performed at the speeds referring to the thresholds determined in the maximal tests, wherein each day a slope condition (positive, negative, or flat) was carried out. First, the placement of the reflective points required for the three-dimensional reconstruction in the kinematics system was performed. After that, the placement of the electrodes used for hemodynamic monitoring, and the silicone mask of the respiratory gas analyzer was placed.

Thereafter, test protocols in the following conditions were performed: speed referring to the VT1; speed referring to the VT2; and fixed speed (4.5 $km.h^{-1}$). The order was randomized, and each condition was executed for five minutes, followed by at least 15 minutes of rest or until the resting values (HR and VO_2) are re-established. VO_2, kinematic, and kinetic records simultaneously occurred after three minutes and 30 seconds of walking, until four minutes and thirty seconds, considering that in this period it is already possible to obtain steady-state values.[26]

Maximal tests protocols

Before starting all protocols, the gas analyzer equipment was calibrated for air volume (with a 3L calibration syringe), humidity (with a specific device), and gas concentrations (by using a cylinder with a standard concentration of mixed gas with 16% of O_2, 5% of CO_2 and nitrogen for balance). Participants were initially positioned sitting in a chair on the treadmill, where the silicone mask of the gas analyzer was placed. Considering the specific fixed slopes of each of the three tests (-5%, 0%, and +5%) and to adjust the protocol of maximal voluntary exhaustion test (duration between 7 and 12 min) for the study sample, pilot tests were carried out and the following protocols for maximal tests were developed: i) level ground (0%) and positive inclination (5%): initial speed of 3.0 $km.h^{-1}$, for 3 minutes, with an increase of 0.5 $km.h^{-1}$ every 1 min; ii) negative slope (-5%): initial speed of 4.0 $km.h^{-1}$, for 3 minutes, with an increase of 1.0 $km.h^{-1}$ every 1 min.

Heart rate was continuously registered and the perceived effort (Borg Rating of Perceived Exertion 6-20)[27] was registered at the end of each stage. The test was interrupted when the participant signals through manual gestures, were instructed to signal only when they reach a state of exhaustion. The assessment was considered valid when any of the following criteria was reached at the end of the test:[28] 1) obtainment of the estimated HR_{max} (220 - age); 2) obtainment of a respiratory exchange ratio (RER) greater than 1.1; 3) perceived exertion greater than 17.

Submaximal tests protocols

From the results of the analyzed maximal tests, the three last collection days were carried out, one day for each of these conditions: level ground, positive and negative slopes, in randomized order. In these protocols, first, the electrodes of the hemodynamic monitoring (Enduro model, PhysioFlow - Poissy, France) system were placed. For that, trichotomy and asepsis of the skin were carried out (with abrasive gel and alcohol) at the electrode placement sites. With the dry skin, six electrodes were fixed (FS- 50, Skintact®, Austria) in the following positions: left lateral region of the neck, supraclavicular fossa, the center of the sternum, V1 and V6 standardized positions for electrocardiogram and parallel to the spine at the xiphoid process level. Using the specific software of the device, paired via Bluetooth, the equipment calibration was performed. The next step was the placement of reflective points of the kinematics system, adhered to the skin with double-sided silicone tape (3M®), following the model proposed by Minetti et al. 1993[21] and recently described by Oliveira et al. (2020),[9] on the following anatomical points: ear canal, acromion, lateral epicondyle of the humerus, midpoint of the distal radioulnar joint, greater trochanter, femoral epicondyle, lateral malleolus, calcaneus, and fifth metatarsal. The last preparation step was the placement of the respiratory gas analysis mask.

Measures and Data Analyses

Maximal tests

The energetic variables of the maximum test were collected throughout the test. The ventilatory method was used to determine VT1 and VT2, from VO_2, Ventilation (VE), and carbon dioxide production (VCO_2) curves, independently by two experienced physiologists, according to the methodology previously described.[29,30] The VT1 was determined from the break-in linearity (decrease) of the VE/VO_2 ratio, the VT2 from the break-in linearity (increase) of the VE/VCO_2 ratio, and the VO_{2peak} from the second-highest VO_2 value in the last stage of the test. In a complementary way, the Ventilation/time curve was analyzed for possible checking of the determination of thresholds. For submaximal tests, the relative speeds of each slope in which the VT1 and VT2 points were determined.

Submaximal tests

The collection of energy variables occurs during the five-minute test. For the analysis, were considered the values obtained in 1min, between 3min30s from the beginning to 4min30s, to evaluate the steady-state in the conditions of inclines and speeds.[26]

Energy expenditure parameters

The following parameters were considered: i) Caloric expenditure: in kcal.min^{-1}, obtained by multiplying VO_2 (L/min) and the metabolic equivalent of RER (eqRER); ii) Cost of Transport: in J.kg^{-1}.m^{-1}, obtained for VO_{2net} multiplied by 60 and eqRER,and divided by speed; iii) VO_2: in ml.kg^{-1}.min^{-1}, were considered as the average values during the walk/run during the steady-state period.

Mechanical Work

The kinematic model was performed as described by Minetti et al. 1993[21], with the bilateral placement of nine anatomical markers (14 mm in diameter). The motion capture system is composed of six infrared cameras with a sampling frequency of 100Hz (VICON Motion Capture System, Oxford, UK). The total volume calibration procedure was carried out according to the supplier’s manual. After placing the markers, the static calibration was conducted with the participant in an upright standing position, with the shoulders abducted and flexed elbow, both 90°, for 5s, to construct the model, and the data from 15 consecutive strides were considered for analysis (Nexus Software, v.2.11).

Kinematic data were filtered through a fourth-order Butterworth low-pass digital filter using a cut-off frequency defined by residual analysis technique (limited at 6–12 Hz). The mechanical work was calculated according to previously described methodologies.[31,32] From the three-dimensional positions of the 18 anatomical markers to build a spatial model of 11 rigid segments: head–neck–trunk, upper arms, lower arms, thighs, lower legs and feet.[21,33] Each body segment mass was determined according to the results of DEXA exam, as suggested by Browning (2012)[34] and detailed described by Matrangola et al. (2008).[35] The segmental center of mass position and the segmental radius of gyration were estimated from the anthropometric tables of Zatsiorsky (1998).[36] Based on these characteristics, the three-dimensional trajectory of the body Center of Mass (CM) was calculated. The kinematic collection was performed only in submaximal tests. Finally, based on the CM data, the time course of potential (E_P) and kinetic (E_K) energies (using three-dimensional coordinates: z, vertical; x, anteroposterior; and y, mediolateral) were computed to determine total mechanical work (W_{tot}), external mechanical work (W_{ext}), and internal mechanical wort (W_{int}), as recently described by Oliveira et al. (2020),[9] and briefly described here. The routine of mathematical calculations was built in the Matlab software (v. 2013) W_{tot}: summation of the W_{ext} and W_{int} modules; W_{ext}: The W_{ext} corresponds to the work necessary to lift and accelerate the CM within the environment, and is a result of the summation of all increases over the External Energies time course resulted in the positive external mechanical work; W_{int}: corresponds to the work necessary to rotate and accelerate the limbs concerning the CM. It was calculated through the summation of the positive increments of rotational energy from the body segments and the translational energy from the body segments relative to the CM.

Ground Reaction Force

The magnitude of the vertical component peak of the ground reaction forces was computed from four load cells. The sensor had a low-pass and second-order filter with a cut-off frequency of 30Hz. Data were collected at 1000Hz per channel with Instor software (Porto Alegre, Brasil) and a custom LabVIEW system (National Instruments, Austin, USA), as previously described by Da Rosa et al. (2019). The average of the same 15 strides of kinematic analysis was considered for each inclination and speed condition. Values are present in absolute form (N) and normalized to body weight (%).

Hemodynamics Parameters

Data gathering was carried out throughout the submaximal test using a Signal Morphology Impedance device (Enduro model, PhysioFlow - Poissy, France), obtained real-time determinations every 15 seconds.[38] For this analysis, only the data from the 1 min steady-state period for each speed: i) Heart Rate (HR), in bpm, was considered as the average HR during this 1min period; ii) Stroke Volume (SV), in ml, was considered as the average of the estimated amount of blood ejected from the left ventricle by beating during this 1min period; iii) Cardiac Output (CO), in $L.min^{-1}$, was considered as the product average between HR and VS during this 1min period.

Statistical analysis

Descriptive analyses were presented as the mean and standard deviation. To compare the main differences between the slopes, the effect size (ES) calculation was used, with Cohen's d value with the following classifications:[39] trivial ($d \leq 0.2$), small ($d > 0.2$ and < 0.6), moderate ($d \geq 0.6$ and < 1.2), large ($d \geq 1.2$ and < 2.0), or very large ($d \geq 2.0$).

Results

The characteristics of participants are shown in Table 1.

Table 1: characterization of each participant and the sample mean of anthropometric and aerobic fitness parameters.

Participant	Age (years)	Body mass (kg)	Height (m)	BMI ($kg.m^{-2}$)	Fat mass (%)	VO_{2peak} ($ml.kg^{-1}.min^{-1}$)
1	27	119	1.74	39.31	35.8	30.29
2	20	95.2	1.72	32.18	35.4	35.26
3	25	134.7	1.84	39.79	39.2	43.75
4	31	93.3	1.62	35.55	37.4	26.97
Mean ± SD	**25.7±4.5**	**110.7±19.8**	**1.73±0.09**	**36.70±3.56**	**36.9±1.7**	**34.06±7.29**

Note: Body Mass Index (BMI), Standard Deviation (SD)

The results of Caloric Expenditure, Cost of Transport, VO_2, and Rates of Perceived Exertion are presented in table 2. In general, regardless of the intensity analyzed and the difference in absolute speeds in VT1 and VT2 between the three slopes, the positive slope was able to generate higher mean values in the energy expenditure parameters, while the negative inclination showed the lowest values. This pattern was similar in the analysis of the Cost of Transport, because in the effect size comparisons, at the fixed speed and at VT1, all slope comparisons showed very large effect size, with higher mean values for POS. At VT2 intensity, the mean values followed the order (POS > FLAT > NEG), with effect sizes moderate (POS*FLAT) or large (FLAT*NEG and POS*NEG). In the analysis of VO_2, at fixed speed, the POS presented the highest average value and NEG the smallest, with effect size very large on POS*FLAT and POS*NEG comparisons, while in FLAT*NEG comparison, the effect size large. At VT1 intensity, the mean values followed the order (POS > FLAT > NEG), with effect sizes moderate (POS*FLAT and POS*NEG) or small (FLAT*NEG). At VT2 intensity, the difference in the mean values was smaller, but with a lower value in NEG, with a small effect size in NEG*POS and NEG*FLAT, and POS*FLAT the effect size was trivial. The RPE at the fixed speed and VT1 was higher in the positive slope, with a large effect size in POS*FLAT and POS*NEG in both intensities. At VT2 the RPE was similar between the three conditions.

Table 2: Outcomes related to physiological parameters.

		POS		FLAT		NEG			
		Mean	**±SD**	**Mean**	**±SD**	**Mean**	**±SD**	**ES**	**95% CI**
CE ($kcal.min^{-1}$)	**Fixed Speed (4.5 $km.h^{-1}$)**	8.84	2.32	5.95	1.04	4.35	1.45	POS*FLAT = 1.39 FLAT*NEG = 1.10 POS*NEG = 2.01	(-0.15; 2.94) (-0.39; 2.58) (0.31; 3.71)
	VT1	9.31	2.88	6.80	1.88	5.78	2.43	POS*FLAT = 0.89 FLAT*NEG = 0.41 POS*NEG = 1.15	(-0.56; 2.35) (-0.99; 1.81) (-0.35; 2.64)
	VT2	15.68	4.37	13.54	3.84	11.85	4.73	POS*FLAT = 0.45 FLAT*NEG = 0.34 POS*NEG = 0.73	(-0.95; 1.86) (-1.06; 1.74) (-0.70; 2.16)
C **($J.kg^{-1}.m^{-1}$)**	**Fixed Speed (4.5 $km.h^{-1}$)**	4.42	0.70	3.21	0.24	2.15	0.42	POS*FLAT = 2.01 FLAT*NEG = 2.69 POS*NEG = 3.42	(0.31; 3.71) (0.78; 4.60) (1.24; 5.59)
	VT1	4.74	0.55	3.13	0.22	2.25	0.58	POS*FLAT = 3.34 FLAT*NEG = 1.74 POS*NEG = 3.83	(1.19; 5.48) (0.11; 3.37) (1.50; 6.16)
	VT2	4.47	1.20	3.57	0.81	2.61	0.81	POS*FLAT = 0.76 FLAT*NEG = 1.03 POS*NEG = 1.58	(-0.67; 2.20) (-0.45; 2.50) (0.10; 3.17)
VO_2 ($ml.kg^{-1}.min^{-1}$)	**Fixed Speed (4.5 $km.h^{-1}$)**	16.83	2.76	11.18	1.34	8.20	1.81	POS*FLAT = 2.26 FLAT*NEG = 1.62 POS*NEG = 3.21	(0.49; 4.04) (0.03; 3.22) (1.11; 5.31)
	VT1	17.62	3.54	13.10	2.53	11.14	4.43	POS*FLAT = 0.82 FLAT*NEG = 0.22 POS*NEG = 0.84	(-0.63; 2.26) (-1.17; 1.61) (-0.61; 2.28)
	VT2	25.38	9.21	25.33	6.67	21.71	8.89	POS*FLAT = 0.01 FLAT*NEG = 0.40 POS*NEG = 0.35	(-1.38; 1.39) (-1.00; 1.80) (-1.04; 1.75)
RPE	**Fixed Speed (4.5 $km.h^{-1}$)**	11.50	2.38	7.75	0.95	7.25	1.25	POS*FLAT = 1.80 FLAT*NEG = 0.39 POS*NEG = 1.94	(0.16; 3.44) (-1.01; 1.79) (0.26; 3.62)
	VT1	11.25	1.50	8.50	1.73	8.75	0.50	POS*FLAT = 1.48 FLAT*NEG = 0.17 POS*NEG = 1.94	(-0.09; 3.04) (-1.22; 1.56) (0.26; 3.62)
	VT2	16.00	1.82	16.25	1.50	16.25	1.50	POS*FLAT = 0.13 FLAT*NEG = 0.00 POS*NEG = 0.13	(-1.26; 1.52) (-1.39; 1.39) (-1.26; 1.52)

Note: Mean, standard deviation (SD), effect size (ES), and 95% of confidence interval values of Caloric Expendture (CE), Cost of Transport (*C*), Oxygen Consumption (VO_2), and Rates of Perceived Exertion (RPE) at fixed speed (4.5 $km.h^{-1}$), first (VT1) and second (VT2) ventilatory thresholds in the positive slope (POS), flat (FLAT), and in the negative slope (NEG).

The results of Absolute Speeds, Mechanical Work (external, internal, and total), and Ground Reaction Forces are presented in table 3. It is possible to observe that there was an influence of the inclination on the average of the speeds relative to the metabolic points, being lower velocities in the POS, intermediate in FLAT, and higher in NEG, with a large effect size in POS*NEG, moderate in POS*FLAT and FLAT*NEG at VT1 and VT2. About Mechanical Work, it is possible to observe a trend of higher values for POS in comparison with FLAT and NEG in the W_{ext} in all intensities. At the fixed speed, W_{int} was higher in POS, in FLAT, and NEG, respectively. However, in the other intensities, it showed the opposite way, being greater in NEG, in FLAT, and in NEG, respectively. W_{tot} at fixed speed was higher in POS, at VT1 intensity it was lower in POS and in VT2 it was higher NEG. For the other mechanical variable, GRFv, it is possible to observe a trend of lower values for POS at the fixed speed and the VT2 intensity for both average GRF and normalized GRF. At VT1 intensity, the results were similar between the slopes.

Table 3: Outcomes related to mechanical parameters.

		POS		FLAT		NEG			
		Mean	±SD	Mean	±SD	Mean	±SD	ES	95% CI
Absolute Speeds ($km.h^{-1}$)	Fixed Speed ($4.5\ km.h^{-1}$)	4.50	-	4.50	-	4.50	-	-	-
	VT1	4.37	0.48	5.00	0.71	5.62	0.75	POS*FLAT = 0.92 FLAT*NEG = 0.74 POS*NEG = 1.73	(-0.54; 2.37) (-0.69; 2.18) (0.11; 3.36)
	VT2	6.62	0.85	8.50	2.34	10.25	2.98	POS*FLAT = 0.93 FLAT*NEG = 0.57 POS*NEG = 1.44	(-0.53; 2.39) (-0.85; 1.98) (-0.12; 2.99)
W_{ext} ($J.kg^{-1}.m^{-1}$)	Fixed Speed ($4.5\ km.h^{-1}$)	0.48	0.06	0.44	0.04	0.42	0.02	POS*FLAT = 0.56 FLAT*NEG = 0.53 POS*NEG = 1.08	(-0.85; 1.98) (-0.88; 1.94) (-0.41; 2.56)
	VT1	0.46	0.03	0.45	0.05	0.42	0.02	POS*FLAT = 0.21 FLAT*NEG = 0.57 POS*NEG = 1.23	(-1.18; 1.60) (-0.84; 1.99) (-0.28; 2.75)
	VT2	1.13	0.48	0.99	0.37	0.69	0.29	POS*FLAT = 0.29 FLAT*NEG = 0.78 POS*NEG = 0.97	(-1.10; 1.68) (-0.66; 2.22) (-0.49; 2.44)
W_{int} ($J.kg^{-1}.m^{-1}$)	Fixed Speed ($4.5\ km.h^{-1}$)	0.48	0.05	0.42	0.04	0.39	0.04	POS*FLAT = 1.15 FLAT*NEG = 0.65 POS*NEG = 1.73	(-0.35; 2.65) (-0.77; 2.07) (0.10; 3.35)
	VT1	0.37	0.08	0.45	0.09	0.48	0.14	POS* FLAT = 0.82 FLAT*NEG = 0.22 POS*NEG = 0.84	(-0.63; 2.26) (-1.17; 1.61) (-0.61; 2.28)
	VT2	0.46	0.05	0.53	0.09	1.22	0.99	POS*FLAT = 0.84 FLAT*NEG = 0.85 POS*NEG = 0.94	(-0.61; 2.28) (-0.59; 2.30) (-0.52; 2.40)
W_{tot} ($J.kg^{-1}.m^{-1}$)	Fixed Speed ($4.5\ km.h^{-1}$)	0.96	0.09	0.87	0.04	0.82	0.03	POS* FLAT = 1.12 FLAT*NEG = 1.23 POS*NEG = 1.81	(-0.37; 2.61) (-0.28; 2.74) (0.17; 3.46)
	VT1	0.84	0.07	0.91	0.08	0.90	0.12	POS*FLAT = 0.81 FLAT*NEG = 0.09 POS*NEG = 0.53	(-0.63; 2.25) (-1.30; 1.47) (-0.88; 1.94)
	VT2	1.67	0.39	1.53	0.19	1.91	0.76	POS*FLAT = 0.40 FLAT*NEG = 0.60 POS*NEG = 0.35	(-1.00; 1.80) (-0.82; 2.01) (-1.05; 1.74)
Mean GRFv (kg)	Fixed Speed ($4.5\ km.h^{-1}$)	102.34	4.23	124.03	27.54	115.29	27.38	POS*FLAT = 0.96 FLAT*NEG = 0.28 POS*NEG = 0.57	(-0.51; 2.42) (-1.12; 1.67) (-0.84; 1.99)
	VT1	125.02	26.56	127.13	27.83	122.88	36.38	POS*FLAT = 0.07 FLAT*NEG = 0.11 POS*NEG = 0.06	(-1.32; 1.45) (-1.27; 1.50) (-1.33; 1.44)
	VT2	170.50	53.37	200.79	46.76	197.66	47.73	POS*FLAT = 0.52 FLAT*NEG = 0.06 POS*NEG = 0.47	(-0.89; 1.93) (-1.33; 1.44) (-0.94; 1.87)

Mean GRFv (%BM)	**Fixed Speed (4.5 km.h^{-1})**	100.00	12.10	111.00	5.20	103.00	6.00	POS*FLAT = 1.02 FLAT*NEG = 1.24 POS*NEG = 0.27	(-0.45; 2.50) (-0.28; 2.75) (-1.12; 1.67)
	VT1	112.50	4.3	114.00	6.00	112.00	8.70	POS*FLAT = 0.25 FLAT*NEG = 0.23 POS*NEG = 0.06	(-1.14; 1.64) (-1.16; 1.62) (-1.32; 1.45)
	VT2	154.00	30.3	180.00	12.10	177.00	18.20	POS*FLAT = 0.98 FLAT*NEG = 0.17 POS*NEG = 0.80	(-0.49; 2.45) (-1.22; 1.56) (-0.64; 2.24)

Note: Mean, standard deviation (SD), effect size (ES), and 95% of confidence interval values of absolute speeds, External (Wext), Internal (Wint), and Total Mechanical Work (Wtot), absolute (kg), and Relative (% Body Mass) Mean Ground Reaction Force vertical (GRFv) at fixed speed (4.5 km.h^{-1}), first (VT1) and second (VT2) ventilatory thresholds in the positive slope (POS), flat (FLAT), and in the negative slope (NEG).

The results of Heart Rate, Stroke Volume, and Cardiac Output are presented in table 4. The analysis of Heart Rate values demonstrates a trend of lower values for the NEG, and higher values for POS at the fixed speed. At VT1 intensity, the Heart Rate values were higher at POS than in other conditions. At VT2 intensity, the results were similar between the slopes. The Stroke Volume shows similar values between the slopes at the fixed speed and at VT1 intensity. At VT2 intensity, it is possible to verify a trend of lower values in POS. The Cardiac Output (CO) demonstrated higher values for POS at the fixed speed and at VT1 intensity. At VT2 intensity, little variation between the different conditions was observed.

Table 4: Outcomes related to hemodynamic parameters.

		POS		FLAT		NEG			
		Mean	**±SD**	**Mean**	**±SD**	**Mean**	**±SD**	**ES**	**95% CI**
HR (bpm)	**Fixed Speed (4.5 km.h^{-1})**	124.0	5.0	105.75	14.03	100.0	11.14	POS*FLAT = 1.51 FLAT*NEG = 0.39 POS*NEG = 2.41	(-0.06; 3.08) (-1.01; 1.79) (0.59; 4.24)
	VT1	124.66	14.36	108.0	12.22	112.25	6.66	POS*FLAT = 1.09 FLAT*NEG = 0.38 POS*NEG = 0.96	(-0.40; 2.57) (-1.77; 1.02) (-0.50; 2.43)
	VT2	157.5	15.63	157.25	19.09	153.25	20.55	POS*FLAT = 0.01 FLAT*NEG = 0.18 POS*NEG = 0.20	(-1.37; 1.40) (-1.21; 1.56) (-1.19; 1.59)
SV (ml)	**Fixed Speed (4.5 km.h^{-1})**	125.63	14.43	120.08	12.05	121.02	20.45	POS*FLAT = 0.36 FLAT*NEG = 0.05 POS*NEG = 0.23	(-1.03; 1.76) (-1.34; 1.43) (-1.16; 1.62)
	VT1	125.65	14.76	123.21	5.03	128.98	16.77	POS*FLAT = 0.19 FLAT*NEG = 0.40 POS*NEG = 0.18	(-1.20; 1.58) (-1.00; 1.80) (-1.21; 1.57)
	VT2	137.25	15.56	154.71	11.48	151.53	12.37	POS*FLAT = 1.11 FLAT*NEG = 0.23 POS*NEG = 0.88	(-0.38; 2.60) (-1.16; 1.62) (-0.57; 2.33)
CO (L.min^{-1})	**Fixed Speed (4.5 km.h^{-1})**	15.74	1.94	12.75	2.33	12.29	2.98	POS*FLAT = 1.21 FLAT*NEG = 0.15 POS*NEG = 1.19	(-0.30; 2.72) (-1.24; 1.54) (-0.31; 2.70)
	VT1	15.48	0.42	13.40	2.63	14.46	2.70	POS*FLAT = 0.96 FLAT*NEG = 0.35 POS*NEG = 0.46	(-0.50; 2.42) (-1.05; 1.74) (-0.95; 1.86)
	VT2	22.17	1.32	24.25	2.04	23.23	5.06	POS*FLAT = 1.05 FLAT*NEG = 0.23 POS*NEG = 0.25	(-0.43; 2.53) (-1.16; 1.62) (-1.14; 1.64)

Note: Mean, standard deviation (SD), effect size (ES), and 95% of confidence interval values of Heart Rate (HR), Stroke Volume (SV), and Cardiac Output (CO) at fixed speed (4.5 km.h^{-1}), first (VT1) and second (VT2) ventilatory thresholds in the positive slope (POS), flat (FLAT), and in the negative slope (NEG).

Discussion

The present study aimed to compare the effects of positive (POS) and negative (NEG) slope at iso-intensity on responses related to energy expenditure, mechanical work, hemodynamic demand, and the peak of vertical GRF in obese adults. The main findings were that the positive slope can promote, at a considerably lower absolute speed than the flat (FLAT) and NEG, greater metabolic demand, greater total mechanical work, lower GRFv, greater HR and VS similar to that in the flat and in the negative slope associated with a higher CO in the fixed speed and VT1 intensity.

The manipulation of the inclination during locomotion requires several adjustments in the physiological and biomechanical systems.[21] In our study, it was possible to observe that even with a slight inclination, in this case ±5%, both in POS and NEG these systems can already be affected concerning locomotion than in FLAT. Considering the context of obesity, our main outcome was energy expenditure parameters. The results at fixed speed demonstrated a large effect size (d=1.39) of POS*FLAT and FLAT*NEG (d=1.10), and, especially, they presented a significant and very large effect size (d=2.01) when comparing POS*NEG. At VT1 intensity, there was a moderate effect in favor of POS (d=0.89 *vs* FLAT and d=1.5 *vs* NEG). However, at VT2 intensity, the mean differences were smaller and the effect size was small (d=0.45 *vs* FLAT) or moderate (d=0.73 *vs* NEG). The same pattern was found for the other two energy parameters outcomes, Cost of Transport (*C*) and Oxigen Consumption (VO_2). These results agree in part with previous findings, in a study that sought a better combination of speed and inclination to obtain greater energy expenditure, all metabolic variables significantly increased with walking speed and/or grade.[24] Our results corroborate the increase in energy expenditure due to the increase in the slope but disagree about the speed increase relationship, since the speed for the conditions of VT1 and VT2 were considerably lower in the POS than FLAT and than NEG and, even thus, POS was able to generate higher values of caloric expenditure.

The response of our energy parameter results and the relationship with inclination and speed corroborate with other,[19] in which it was found that the net metabolic rate was similar (approximately 3.8 $W.kg^{-1} \approx 5.7 J.kg^{-1}.m^{-1}$) in the FLAT at 5.4km/h and in the moderate positive inclination 10%, however in considerably lower speeds (2.7 km/h^{-1}). Our values were relatively lower under similar conditions at FLAT at VT1 intensity (5.0 $km.h^{-1}$) with a *C* of 4.74 $J.kg^{-1}.m^{-1}$ and in the POS condition (+ 5%) at speed 4.5 $km.h^{-1}$ the *C* was 4.28 $J.kg^{-1}.m^{-1}$. Therefore, despite the similar pattern of lower speed in POS to *C* similar in FLAT at faster speeds, our results may have been lower due to the better physical fitness of our sample, with VO_{2peak} of 34.0 $ml.kg^{-1}.min^{-1}$, while the Ehlen's[19] sample presented VO_{2peak} of 29.6 $ml.kg^{-1}.min^{-1}$, which may represent a better walking economy in our sample.

One of the mechanisms involved in the amount of energy spent during locomotion is the total mechanical work (W_{tot}), considering its main components such as external mechanical work (W_{ext}) and internal mechanical work (W_{int}).[9,33,40] It is known that, at lower speeds, the greatest contribution to W_{tot} comes from W_{ext} and that at higher speeds W_{int} increases in proportion.[41,42] Our results showed that W_{ext} in the fixed speed situation was higher in POS compared to FLAT (d=0.56) and NEG (d=1.08), which suggests that the greater need for W_{ext} for the task may have generated greater metabolic cost in POS. Similar patterns occurred in the comparisons of VT1 and VT2, even considering the difference between the absolute speeds in the different slope conditions, that is, the amount of W_{ext} needed seems to depend more on the slope than on the speed. This relationship corroborates the results of Browning et al. (2013),[24] in which the W_{ext} increased with slope both obese and eutrophic. On the other hand, W_{int} presented a similar pattern concerning the inclination only at the fixed speed (POS> FLAT > NEG) because, at VT1 and VT2 situations, the behavior was inverse (NEG> FLAT > POS), which shows a greater influence of speed and Spatio-temporal parameters than the slope alone. This relationship corroborates with classic data in the literature, where it is established that W_{int} is directly related to speed[43] and stride frequency[41] and, to a lesser extent, to inclination.[42] To our knowledge, the present study is the first to quantify W_{int} of inclined locomotion in people with obesity. Considering W_{tot} as the sum of W_{ext} with W_{int}, at fixed speed, and at VT2 intensity, the same pattern is observed (POS > FLAT > NEG). However, at the VT1 condition, the POS and FLAT values were similar. It is possible to speculate that, in this condition, the greater contribution of W_{ext} in the POS was compensated by a greater proportion of W_{int} in the FLAT, due to the higher absolute speed (4.37 *vs* 5.0 $km.h^{-1}$), resulting in similar values of W_{tot}.

One of the main concerns for a training program for people with obesity is the risk of injury due to impact and joint overload and GRFv is one of the methods to assess the impact during walking.[44] Our results showed that the condition with the greatest vertical reaction forces was FLAT, both in mean force (kg) and mean relative force (% body mass), corroborating with previous findings that loading rates were greater during level walking at 1.50 versus 0.75 $m.s^{-1}$ with +6° slope.[19] Interestingly, in the comparison of fixed speed conditions, the POS showed lower GRFv values, that is, it is possible to estimate that a slight increase in the slope is capable of reducing the impacts during this activity. At VT1 intensity, the results were similar between the three slopes, however at VT2 intensity, with a greater difference between the absolute speeds, the POS values were considerably lower than FLAT and NEG. Our results corroborate those described by Ehlen et al. (2001)[19] because when comparing predefined speeds on different slopes, it was possible to verify that during early and late stance, peak normal GRFv were greater in trials with faster speeds and lower grades. So, the slower speed/slope is the condition that rates of loading are much slower, given the smaller peak normal GRF. Another important point in graded walking is the possible increase in joint compression load of the lower extremities compared to walking on flat.[45] In a study with eutrophic adults, it was found that the mean hip compression forces did not change in Uphill up to 6° (10%) as well, with a significant increase from 12° (21%), that is, few degrees of inclination seem do not increase the forces of joint compression.[16,46]

Regarding the hemodynamic parameters, in the fixed speed condition, there was a greater demand for HR, SV, and CO in the POS condition and lower HR in the NEG condition. These findings agree with previous,[47] because it also found a higher peak cardiac output in concentric exercise, such as the POS condition concerning the eccentric exercise, such as the NEG condition, and this with lower values concerning the FLAT condition. At VT1 and VT2 intensities, we observed an adjustment of the system to the metabolic demand related to the iso-intensity condition, as the values were similar in the different slopes for HR, VS, and CO. On the other hand, the results disagree in part with Agarwal et al (2017),[25] because there was no less cardiovascular load in the conditions of VT1 and VT2 in the NEG condition, possibly due to the small % of slope and the difference in absolute speeds. However, in the condition of fixed speed, this idea was confirmed, which means that can be a good alternative for individuals with some type of cardiovascular limitation, frequent situation in individuals with obesity.

The main limitation for extrapolating our results is the small number of participants evaluated. We would like to clarify that the reason for this small N is related to the pandemic caused by COVID-19 because, in the period of completion of the tests, data collections had to be stopped. Another limitation was that W_{mec} considered, according to the methodology adopted, only its positive portion, which may bring underestimated results about the negative slope, due to its predominance of negative W_{mec}. Besides, due to the limitation of the equipment, it was possible to measure only the GRF on the vertical axis, and in inclined conditions, it would be important to consider especially the anteroposterior axis as well.

Therefore, from an integrative view between the main systems related to the Physiomechanics of locomotion of individuals with obesity, we highlight that the positive inclination can be an alternative with a series of benefits for the practice of aerobic exercise for this population. Especially, by promoting a greater metabolic demand, under lower absolute speeds, which can reduce the impact during locomotion. Importantly, walking at slower speeds also reduces the perceived exertion of the exercise, which may result in increased activity time and adherence even when walking uphill. On the other hand, there was a greater cardiovascular load in some situations, in which the negative inclination may be a better alternative to decrease this load.

Founding source

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3 CONSIDERAÇÕES FINAIS

O objetivo geral desta Tese foi comparar os efeitos da inclinação positiva e negativa em diferentes condições de velocidade sobre as respostas máximas e submáximas relacionadas especialmente ao gasto calórico, ao trabalho mecânico, ao impacto articular e à demanda cardiovascular durante a caminhada/corrida de adultos com obesidade. A hipótese central foi de que deveria haver influência da inclinação sobre os parâmetros energéticos, mecânicos e hemodinâmicos da locomoção de adultos com obesidade. Especificamente, sob uma mesma condição de intensidade, a inclinação positiva deve promover maior gasto energético, maior trabalho mecânico total, menor força de impacto, enquanto a inclinação negativa deve possibilitar maiores velocidades absolutas, menor demanda cardiovascular e menor percepção de esforço.

De maneira geral, foi possível aceitar a hipótese do pesquisador e rejeitar a hipótese nula. Visto que, reunindo as informações obtidas no desenvolvimento deste trabalho é possível observar que com a utilização de pouca angulação para gerar uma locomoção em plano inclinado positivo uma série vantagens sob o ponto de vista energético e mecânico de exercício físico para pessoas com obesidade pode ser observada. Por outro lado, a inclinação negativa parece ser uma boa estratégia para o engajamento de indivíduos com baixa tolerância ao exercício, mesmo que com menor demanda metabólica.

Buscando a melhor compreensão do estado da arte sobre os desfechos relacionados à locomoção de pessoas com obesidade em plano inclinado positivo e/ou negativo, o artigo de Revisão Sistemática demonstrou que a utilização da inclinação para a prescrição do exercício em ambiente aberto ou em esteira, apesar de apresentar uma série de resultados benéficos, não é encontrada de maneira consistente na literatura. De maneira interessante, o treinamento de Caminhada Nórdica apresentou bons resultados para indivíduos com obesidade, principalmente em função da maior distribuição das cargas articulares e menor sensação de esforço

Sobre as respostas aos testes máximos foi possível desenvolver três protocolos em diferentes tipos de inclinação que foram capazes de atender às recomendações gerais para um teste máximo em esteira. O teste em inclinação positiva promoveu demanda metabólica e sensação de esforço semelhante às outras inclinações, porém sob uma menor carga externa (velocidades absolutas). Por isso, a condição de inclinação positiva parece ser a mais favorável para indivíduos com obesidade para um teste máximo.

Buscando respostas sob o ponto de vista integrativo dos principais sistemas envolvidos na locomoção em plano inclinado, foi possível observar que a inclinação leve positiva é capaz de promover uma maior demanda metabólica, em menores velocidades absolutas, o que pode reduzir a carga sobre o sistema osteo-articular. De maneira interessante, a percepção de esforço parece ser adaptável aos diferentes tipos de inclinação, mesmo considerando a importante diferença entre as velocidades absolutas em condições de iso-intensidade entre os diferentes tipos de inclinação.

4 APLICAÇÕES PRÁTICAS

Considerando a inclinação como ferramenta para utilização na prescrição de treinamento para pessoas com obesidade, serão considerados três cenários para aplicação prática dos resultados obtidos. A inclinação aqui considerada é a mesma avaliada nos protocolos de testes máximos e submáximos, ou seja, de ±5%.

Cenário 1: paciente/aluno com obesidade grau 1 ou 2, fisicamente ativo, com uma boa capacidade aeróbica, sem comprometimento físico que exija atenção na realização do exercício. Objetivo geral do aluno é aumentar o gasto calórico, pois em conjunto com a avaliação nutricional, foi visto que é necessário que o treinamento promova maiores quantidades de gasto calórico, buscando o balanço energético negativo e consequente emagrecimento. Neste contexto, de acordo com os resultados deste trabalho, seria interessante a utilização da inclinação positiva, com intensidades em uma zona aeróbica intensiva, zona de limiar e, em menor proporção, zona anaeróbica. Este aluno irá conseguir atingir a intensidade prescrita muito provavelmente em uma situação de caminhada, gerando menores impactos articulares do que se estivesse no plano (provavelmente em situação de corrida) e, principalmente, obtendo um maior gasto calórico. Assim, seria possível atingir o objetivo final de promover o balanço energético negativo em condições seguras e eficientes de exercício.

Cenário 2: paciente/aluno com obesidade grau 1 ou 2, sedentário, com baixa capacidade de suportar o exercício em tempo superior a 10 minutos em intensidade moderada, sem comprometimento físico que exija atenção na realização do exercício. Objetivo geral neste momento é o engajamento na atividade e que haja um somatório de volume semanal de acordo com as recomendações gerais de uma pessoa fisicamente ativa. Neste contexto, de acordo com os resultados deste trabalho, seria interessante a utilização da inclinação negativa, com intensidades de zona aeróbica extensiva, considerando que nesta condição existe uma menor percepção de esforço durante a atividade e não há aumento considerável no impacto articular. Seria esperado um possível aumento no volume de treinamento a cada semana, promovendo as adaptações centrais esperadas neste tipo de condição.

Cenário 3: paciente/aluno com obesidade grau 1 ou 2, sedentário, com razoável condição aeróbica e com recomendação médica para realizar exercícios desde que haja possibilidade de diminuição de impacto articular. Neste contexto, de acordo com os resultados deste trabalho, seria interessante também a utilização da inclinação positiva, pois é possível atingir intensidades de zona aeróbica (entre primeiro e segundo limiar ventilatório) com valores de impacto reduzidos em relação ao plano e à inclinação negativa.

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APÊNDICES

APENDICE 1: PARECER DE APROVAÇÃO DO COMITÊ DE ÉTICA EM PESQUISA DA UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

UFRGS - PRÓ-REITORIA DE PESQUISA DA UNIVERSIDADE FEDERAL DO RIO GRANDE DO

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Influência do Plano Inclinado Positivo e Negativo na Fisiomecânica da Caminhada de Adultos Obesos: Respostas Relacionadas ao Gasto Energético, Trabalho Mecânico, Variáveis Cardíacas e Pico de Impacto.

Pesquisador: Luiz Fernando Martins Kruel

Área Temática:

Versão: 3

CAAE: 82934018.9.0000.5347

Instituição Proponente: Universidade Federal do Rio Grande do Sul

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 2.660.010

Apresentação do Projeto:

Projeto de Pesquisa para Qualificação de Doutorado. Adequadamente apresentado.

Objetivo da Pesquisa:

Comparar os efeitos da caminhada em plano inclinado positivo e negativo sobre as respostas relacionadas ao gasto energético, ao trabalho mecânico, ao consumo de oxigênio, ao estresse cardiovascular e ao pico de impacto em adultos obesos.

- Comparar os efeitos da inclinação positiva e negativa em diferentes velocidades sobre as variáveis metabólicas da caminhada entre adultos obesos e eutróficos;- Comparar os efeitos da inclinação positiva e negativa em diferentes velocidades sobre as variáveis mecânicas da caminhada entre adultos obesos e eutróficos;- Comparar os efeitos da inclinação positiva e negativa em diferentes velocidades sobre as variáveis cardiovasculares da caminhada entre adultos obesos e eutróficos.

Avaliação dos Riscos e Benefícios:

Apropriadamente apresentada em sua nova versão.

Comentários e Considerações sobre a Pesquisa:

DELINEAMENTO

Endereço: Av. Paulo Gama, 110 - Sala 317 do Prédio Anexo 1 da Reitoria - Campus Centro
Bairro: Farroupilha **CEP:** 90.040-060
UF: RS **Município:** PORTO ALEGRE
Telefone: (51)3308-3738 **Fax:** (51)3308-4085 **E-mail:** etica@propesq.ufrgs.br

Este estudo será caracterizado como tipo ex-post facto, quantitativo, transversal e comparativo, tendo dois grupos, um obeso (experimental) e um eutrófico (controle) que realizarão os testes de caminhada sem inclinação, no plano inclinado positivo e no plano inclinado negativo.
POPULAÇÃO DE ESTUDO
Critérios de inclusão Serão incluídos homens e mulheres com idade entre 18 e 45 anos, classificados como eutróficos (IMC entre 18,5 e 24,9) ou obesos de grau 1 [Índice de Massa Corporal (IMC) entre 30 e 34,9 kg.m-2)] e grau 2 (IMC entre 35 e 39.9 kg.m-2), isentos da prática regular de exercícios físicos há pelo menos três meses. A prática regular de exercício foi definida como realização de qualquer modalidade de treinamento físico por no mínimo 20 minutos em três ou mais dias da semana. O grupo eutrófico será pareado ao grupo obeso por idade e sexo. Além disso, a estatura será pareada por faixas de 10cm (faixa 1: 155-165cm; faixa 2: 166- 175cm; faixa 3: 176-185cm).
Critérios de exclusão Serão adotados como critérios de exclusão do estudo a presença de histórico de lesões músculo-tendíneas, articulares, doenças crônicas relacionadas a problemas cardíacos e respiratórios e qualquer outro comprometimento muscular ou articular que impeça a realização de exercícios físicos com segurança.
RECRUTAMENTO E ELEGIBILIDADE A seleção dos participantes ocorrerá de forma não-probabilística, por voluntariedade. O recrutamento será realizado por divulgação em jornal de grande circulação e por meios eletrônicos. Os participantes entrarão em contato por telefone ou pela internet, quando serão convidados a agendarem uma primeira visita à Escola de Educação Física, Fisioterapia e Dança (ESEFID) da Universidade Federal do Rio Grande do Sul (UFRGS).
CÁLCULO AMOSTRAL necessidade de um "n" mínimo de 15 participantes em cada grupo. Para o equilíbrio da distribuição entre homens e mulheres, será adotado um "n" de 20 participantes por grupo, sendo 10 homens e 10 mulheres.
VARIÁVEIS DE CONTROLE Nível de atividade física: através da aplicação o Questionário Internacional de Atividade Física (IPAQ), versão curta.
As coletas de dados ocorrerão no Laboratório de Pesquisa do Exercício, Setor de Biodinâmica, da Escola de Educação Física, Fisioterapia e Dança da UFRGS. Cada participante deverá comparecer ao laboratório em seis dias para realizar as avaliações. No primeiro dia, será realizada a explicação e leitura do Termo de Consentimento Livre e Esclarecido (TCLE), apontando os riscos e benefícios da participação na pesquisa e será explicado todo o protocolo de testes. Após passarão por uma avaliação

antropométrica e serão convidados a realizarem a familiarização com a esteira rolante e os equipamentos, além do teste incremental máximo na esteira na condição sem inclinação. Nas próximas duas visitas, serão realizados os testes máximos em condição de inclinação. Em um dos dias em inclinação positiva e no outro inclinação negativa, com a ordem definida por sorteio. Nos outros três dias de coleta (um dia para cada inclinação: plano, positiva e negativa), primeiramente será realizada a colocação dos pontos refletivos necessários para o sistema de cinemetria, após serão colocados os eletrodos do sistema de monitoramento hemodinâmico e a máscara de análise de gases respiratórios. Após, será realizado o protocolo de testes nas seguintes condições nos três planos de caminhada: velocidade referente ao 1º Limiar Ventilatório (V1LV); velocidade referente ao 2º limiar ventilatório (V2LV); e velocidade fixa (4,5 km.h-1). A ordem será randomizada e cada uma destas condições será executada por cinco minutos, seguidos e, no mínimo, 15 minutos de descanso ou até que os valores de repouso (FC e VO2) sejam reestabelecidos. Será utilizado um sistema de cinemetria para avaliação dos padrões de movimento e posterior cálculo das variáveis biomecânicas, um sistema de ergoespirometria para avaliação das variáveis bioenergéticas, um sistema de monitoramento hemodinâmico para avaliação das variáveis cardiovasculares e um sistema de sensores de força sob a esteira para avaliação das forças de reação do solo durante a caminhada. Os testes devem ser marcados na mesma faixa horária nos diferentes dias para cada indivíduo. Os indivíduos serão orientados a seguir seus hábitos alimentares e de atividade física sem alterações durante o período de coletas. Quando mulheres, serão evitados os períodos pré-menstrual e menstrual.

Considerações sobre os Termos de apresentação obrigatória:

1- TCLE: adequadamente apresentado em sua nova versão

2- Orçamento: alunos foram excluídos como responsáveis pelos custos envolvidos;

3- Cronograma: adequado.

Instrumento de coleta de dados: foi anexado mas de forma eticamente inapropriada, por apresentar campos com espaço de preenchimento com nome dos participantes.Para fins de preservação de privacidade, este campo deve ser suprimido e substituído por codificação alfanumérica. Solicitação atendida.

Conclusões ou Pendências e Lista de Inadequações:

Em condições de aprovação.

Considerações Finais a critério do CEP:

Aprovado.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1062850.pdf	01/05/2018 22:06:47		Aceito
Projeto Detalhado / Brochura Investigador	ProjetoDoc_Henrique_Pos_SegundoParecer_CEP.pdf	01/05/2018 22:05:58	HENRIQUE BIANCHI OLIVEIRA	Aceito
Outros	CartaResposta_parecer_2581948.pdf	24/04/2018 22:16:44	HENRIQUE BIANCHI OLIVEIRA	Aceito
Projeto Detalhado / Brochura Investigador	ProjetoDoc_Henrique_Pos_PrimeiroParecer_CEP.pdf	24/04/2018 22:15:17	HENRIQUE BIANCHI OLIVEIRA	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE_v2.pdf	24/04/2018 22:14:45	HENRIQUE BIANCHI OLIVEIRA	Aceito
Folha de Rosto	Folha_de_Rosto_Henrique.pdf	06/02/2018 23:19:29	HENRIQUE BIANCHI OLIVEIRA	Aceito
Cronograma	CronoHenrique.pdf	29/01/2018 16:09:51	HENRIQUE BIANCHI OLIVEIRA	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

PORTO ALEGRE, 17 de Maio de 2018

Assinado por:
MARIA DA GRAÇA CORSO DA MOTTA
(Coordenador)

Endereço: Av. Paulo Gama, 110 - Sala 317 do Prédio Anexo 1 da Reitoria - Campus Centro
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APENDICE 2: TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Instituição de pesquisa: Universidade Federal do Rio Grande do Sul

Estamos realizando uma pesquisa que tem como objetivo avaliar os efeitos da caminhada em plano inclinado positivo e negativo sobre o gasto energético em diferentes velocidades dessa atividade. Dessa forma, gostaríamos de convidá-lo para participar deste estudo. Para que isso seja possível, você deve ler com atenção sobre os procedimentos que serão explicados a seguir, tendo total liberdade de negar caso não concorde com uma ou mais situações do projeto.

Você terá que comparecer em seis dias distintos, separados com no mínimo 72 horas de intervalo, em horário a combinar, no Setor de Biodinâmica do Laboratório de Pesquisa do Exercício (LAPEX) na Escola de Educação Física, Fisioterapia e Dança da UFRGS, localizado no prédio do Centro Natatório. No primeiro dia, será realizada uma avaliação da composição corporal que consiste em verificar a quantidade de gordura e massa magra do corpo, por meio de exame de imagem por raio-x de dupla absorção (com muito baixo nível de radiação) realizado com uso de trajes leves (calção ou bermuda e camiseta). Neste dia, será realizada a familiarização com os instrumentos utilizados para a coleta de dados, a saber: utilização de máscara de silicone para medida de consumo de oxigênio (essa máscara será esterilizada a cada uso, não oferecendo risco); utilização de marcadores reflexivos (bolinhas reflexivas, em 35 pontos que serão mostrados nesse momento), que serão coladas na pele com uma fita dupla-face de silicone de fácil remoção (é possível que a pele apresente uma pequena vermelhidão após a retirada da fita, mas não apresenta qualquer risco para a saúde); utilização da esteira, pois os testes de caminhada serão realizados sobre uma esteira rolante e as regras de segurança sobre a esteira devem ser explicitadas, entendendo que há o risco de quedas durante os testes. Entretanto, terá uma equipe de prontidão altamente qualificada para fazer os procedimentos de primeiros socorros, enquanto um professor responsável da coleta fará a ligação para a Assistência Médica de Emergência (SAMU) que lhe encaminhará para o Hospital de Pronto Socorro de Porto Alegre e os demais custos por eventuais lesões que possam ocorrer decorrentes da pesquisa ocorrerão por conta dos participantes. Após a familiarização, será realizado um teste com aumento de velocidade até o seu máximo esforço, cuidadosamente monitorado pelos pesquisadores.

É possível que haja certo desconforto por cansaço, embora o exercício seja mantido em um nível de esforço seguro. No caso de haver desconforto durante a sessão, o exercício será imediatamente suspenso, e, se necessário for, será realizado o atendimento adequado. Esta primeira sessão de avaliações terá uma duração de aproximadamente duas horas.

Nas próximas duas visitas, será realizado mais um teste de esforço máximo em cada dia (um dia com a esteira levemente inclinada “para cima” e um dia com a esteira levemente inclinada “para baixo”). Estes testes são fundamentais para o ajuste da velocidade da caminhada que será realizada nos dias subsequentes. Estas duas sessões terão duração de aproximadamente uma hora.

Os próximos três dias de avaliação, serão realizadas as avaliações principais da pesquisa, em horário a ser combinado. Nestes dias, serão realizado o teste de consumo de oxigênio de repouso (você deverá permanecer sentado, parado, por quinze minutos, enquanto são coletados os dados de consumo de oxigênio com a máscara de neoprene). Após isso, serão coladas as bolinhas refletivas com fita dupla-face nos 35 pontos de interesse para o sistema de captura de imagens. Você então irá realizar os testes de caminhada sobre a esteira em três velocidades (4,5 km/h, velocidade relativa ao primeiro limiar ventilatório e velocidade relativa ao segundo limiar ventilatório), que serão sorteadas para saber a ordem, com intervalo de descanso entre cada velocidade de quinze minutos. Em cada dia de avaliação, será utilizada uma das inclinações da esteira (-5%, 0 e +5%). Nestas três últimas sessões, a duração será de aproximadamente uma hora.

O sistema de captura de imagens utilizado não registra as imagens em “visão real”, ele apenas é capaz de captar a posição das bolinhas refletivas, via infravermelho, o que garante total sigilo de identidade sobre os avaliados, assim como será feito com quaisquer outros dados coletados. Todos os dados coletados serão guardados em sigilo por cinco anos para diversas análises e após serão totalmente apagados.

Durante a realização do exercício, você poderá sentir algum desconforto como náuseas e enjoo, devido à intensidade do exercício físico. Caso ocorra isso ele terá um acompanhamento adequado para seu restabelecimento total. No entanto, com o protocolo proposto não se espera esses sintomas.

A participação no estudo é voluntária, e você tem o direito a receber informações dos seus resultados ao longo do estudo em qualquer momento bem como, desistir da participação em qualquer estagio do processo. Os resultados deste estudo serão mantidos confidenciais e quando divulgados preservarão o anonimato dos participantes. Você está livre para realizar perguntas antes, durante e após o estudo.

O pesquisador responsável se compromete a acompanhar o andamento de sua participação e prestar eventuais informações a qualquer momento do estudo, assim como realizar o ressarcimento dos custos relativos ao transporte ao laboratório de pesquisa para as avaliações. Também se compromete, caso houver uma nova informação que altere o que foi previsto durante a obtenção deste consentimento informado, a avisar imediatamente aos participantes do estudo e o Comitê de Ética, providenciando uma nova versão deste termo de consentimento. Qualquer evento adverso relevante que ocorra com algum dos participantes será comunicado ao CEP da UFRGS pelo pesquisador responsável em um prazo máximo de 48 horas.

Qualquer dúvida ou dificuldade você pode entrar em contato com os pesquisadores responsáveis Henrique Bianchi Oliveira ou Luiz Fernando Martins Kruel pelos telefones (51) 98156-5600 ou 3308-5820 ou se preferir pode tirar suas dúvidas diretamente no comitê de ética em pesquisa da Universidade Federal do Rio Grande do Sul, o qual este localizado Av. Paulo Gama, 110 - 7º andar - Porto Alegre/RS ou pelo Fone/Fax: 51 3308-4085 - E-mail: pro-reitoria@propesq.ufrgs.br.

Ao final dos seis dias de avaliações, você receberá um relatório da sua composição corporal, um laudo sobre a sua capacidade cardiorrespiratória e uma prescrição de treinamento aeróbico utilizando os resultados dos testes realizados (o que pode levar até um mês para ser processado e finalizado).

Eu, ____ fui informado sobre os objetivos acima especificados e da justificativa desta pesquisa, de forma clara e detalhada, e aceito participar voluntariamente do estudo.

Este termo de consentimento livre e esclarecido deverá ser preenchido em duas vias, sendo uma mantida com o participante e outra mantida arquivada pelo pesquisador.

Porto Alegre, _____ de _________________________de_______.

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Assinatura do participante da pesquisa

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Assinatura do pesquisador responsável

APÊNDICE 3: OUTPUT G*POWER CÁLCULO AMOSTRAL

F tests – ANOVA: Repeated measures, within factors

Analysis:	A priori: Compute required sample size		
Input:	Effect size f(V)	=	1.3
	α err prob	=	0.05
	Power (1−β err prob)	=	0.80
	Number of groups	=	1
	Number of measurements	=	12
	Nonsphericity correction ϵ	=	1
Output:	Noncentrality parameter λ	=	18.5900000
	Critical F	=	1.8767320
	Numerator df	=	11.0000000
	Denominator df	=	110
	Total sample size	=	11
	Actual power	=	0.8069533

APÊNDICE 4: REGISTRO SISTEMA PROSPERO