Universidade Estadual de Londrina

TESE DE DOUTORADO EM EDUCAÇÃO FÍSICA

COMPARAÇÃO DE SISTEMAS DE TREINAMENTO COM PESOS COM CARGAS FIXAS E VARIÁVEIS SOBRE INDICADORES DE SAÚDE E DE DESEMPENHO FÍSICO EM MULHERES IDOSAS

ALEX SILVA RIBEIRO

ORIENTADOR: EDILSON SERPELONI CYRINO

Londrina/PR

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Orientador: Prof. Edilson Serpeloni Cyrino

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COMISSÃO EXAMINADORA

____

Prof. Dr. Edilson Serpeloni Cyrino
Universidade Estadual de Londrina

____

Prof. Dr. Denilson de Castro Teixeira
Universidade Estadual de Londrina

____

Prof. Dr. Ademar Avelar
Universidade Estadual de Maringá

____

Prof. Dr. José Maria Santarem
Universidade de São Paulo

____

Prof. Dr. Eduardo Lusa Cadore
Universidade Federal do Rio Grande do Sul

Londrina, ___, de ,_______________, de 2016.

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RESUMO

Introdução: O envelhecimento biológico vem acompanhado de modificações morfológicas, neuromusculares e metabólicas, que acarretam em prejuízos à saúde e qualidade de vida da população idosa. Neste sentido, o treinamento com pesos (TP) é uma importante estratégia recomendada para atenuar os processos deletérios induzidos pelo envelhecimento e promover melhora na saúde dessa população. **Objetivo**: Comparar sistemas de TP de cargas fixas e variáveis sobre indicadores de saúde e de desempenho físico em mulheres idosas. **Métodos**: Sessenta e oito mulheres idosas (68,9 ± 5,9 anos, 67,0 ± 13,0 kg, 155,3 ± 6,1 cm, e 27,6 ± 4,9 $kg.m^{-2}$) foram separadas em quatros grupos de acordo com a combinação da experiência prévia em TP e o sistema de treinamento: tradicional treinada (TT, n = 16), pirâmide treinada (PT, n = 17), tradicional iniciante (TI, n = 17) e pirâmide iniciante (PI, n = 18). No início e ao final de cada etapa de treinamento medidas de composição corporal (DEXA), força máxima (1RM) e análise bioquímica foram realizadas. O programa de TP foi realizado em três sessões semanais durante oito semanas, no qual as participantes dos grupos TT e TI realizaram três series de 8-12 repetições máximas com carga constante nas três séries, enquanto os grupos PT e PI realizaram três séries de 12/10/8 repetições máximas com aumento incremental da carga a cada série. **Resultados**: Interação significante para tempo vs. status de treino ($P < 0,05$) foi observada para o 1RM (TT = 5,0%, PT = 4,4%, TI = 13,2%, PI = 15,4%), massa muscular (TT = 1,4%, PT = 1,0%, IT = 3,8%, PI = 3,3%) e proteína C-reativa (TT = -60,2%, PT = -47,1%, TI = -25,5%, PI = -13,1%) sem diferenças entre os sistemas. Efeito isolado do tempo ($P < 0,05$) foi observado para a glicose sanguínea (TT = -7,6%, PT = -5,7%, TI = -5,6%, PI = -0,5%), triglicérides (TT = -15,8%, PT = -5,3%, TI = -26,8%, PI = -4,7%), lipoproteína de alta densidade (TT = 10,7%, PT = 4,7%, TI = 11,6%, PI =2,7 %), e lipoproteína de baixa densidade (TT = -23,8%, PT = -26,8%, TI = -34,7%, PI = -27,9%). **Conclusão:** Os resultados sugerem que o sistema pirâmide é similarmente eficiente ao tradicional para promover melhorias na força, hipertrofia muscular e biomarcadores sanguíneos em mulheres idosas.

Palavras-chave: treinamento de resistência, envelhecimento, força muscular, hipertrofia, lipoproteínas.

Ribeiro, Alex Silva. **Comparison of resistance training systems with constant and variable loads on health-related parameters and physical performance in older women**. 2016. 153f. Thesis (Doctoral of Physical Education) – Physical Education and Sport Center. Londrina State University, Londrina, 2016.

ABSTRACT

Introduction: Biological aging is accompanied by morphological, neuromuscular and metabolic changes that ultimately affect negatively the health and quality of life of the older individuals. In this sense, resistance training (RT) is an important strategy recommended to mitigate the harmful processes induced by aging and promote improvement in the health of this population. **Objective**: To compare RT systems that use constant and variable loads on health indicators and physical performance in older women. **Methods**: Sixty-eight elderly women (68.9 ± 5.9 years, 67.0 ± 13.0 kg, 155.3 ± 6.1 cm, and 27.6 ± 4.9 kg.m-2) were separated into four based on combination RT experience and training system: trained traditional (TT, n = 16) trained pyramid (TP, n = 17), novice traditional (NT, n = 17), and novice pyramid (NP, n = 18). At the beginning and the end of RT program measurements of body composition (DXA), one repetition maximum (1RM), and biochemical analysis were conducted. The RT program was carried out three days-per-week for eight weeks, where the traditional RT consisted of three sets of 8-12 repetitions maximum with constant load for the 3 sets, whereas the pyramid RT consisted of three sets of 12/ 10/8 repetitions maximum with incremental load for each set. **Results**: Significant interaction for time vs. training status (P <0.05) was observed for 1RM (TT = 5.0%, TP = 4.4%, NT = 13.2%, NP = 15.4%), skeletal muscle mass (TT = 1.4% TP = 1.0%, NT = 3.8% NP = 3.3%) and C-reactive protein (TT = -60.2%, TP = -47.1%, NT = -25.5%, NP = -13.1%) with no differences between systems. Isolated time effect (P <0.05) was observed for blood glucose (TT = -7.6%, TP = -5.7%, NT = -5.6%, NP = -0.5%), triglycerides (TT = -15.8%, TP = -5.3%, NT = -26.8%, NP = -4.7%), high-density lipoprotein (TT = 10.7%, TP = 4.7%, NT = 11.6%, NP = 2.7%), and low density lipoprotein (TT = -23.8%, TP = -26.8%, NT = 34.7%, NP = -27.9%). **Conclusion**: The results suggest that the pyramid system is similarly effective to traditional training for promoting improvements on strength, muscle hypertrophy and blood biomarkers in older women.

Key-words: strength training, aging, muscular strength, hypertrophy, lipoproteins.

LISTA DE SIGLAS

ANCOVA = análise de covariância – analysis of covariance

ANOVA = análise de variância – analysis of variance

CP = chest press

CRP = c-reactive protein

CT = colesterol total

CV = coefficient of variation

DEXA = absortometria radiológica de dupla energia

DP = desvio padrão

DXA = dual x-ray absortometry

ECW = extracellular water

ES = effect size

ET1 = etapa 1

ET2 = etapa 2

ET3 = etapa 3

ET4 = etapa 4

ET5 = etapa 5

GLI = glicose

GLU = glucose

HDL-C = lipoproteína de alta densidade – high-density lipoprotein

ICC = intraclass correlation coefficient

ICW = intracellular water

IGF-1 = fator de crescimento semelhante a insulin – insulin like growth factor

KE = knee extension

LDL-C = lipoproteína de baixa densidade – low-density lipoprotein

LLMQ = lower limb muscle quality

LLSMM = lower limb squeletal muscle mass

M1 = momento 1

M2 = momento 2

M3 = momento 3

M4 = momento 4

M5 = momento 5

M6 = momento 6

MIGOAP = massa isenta de gordura e osso apendicular

MME= massa muscular esquelética

NP = novice pyramid

NT = novice traditional

PC = preacher curl

PCR = proteína-C reativa

PI = pirâmide iniciante

RM = repetição máxima – repetition maximum

RT = resistance training

TBW = total body water

TC = total cholesterol

TD = traditional

TG = triglicérides – tryglicerides

TI = tradicional iniciante

TMQ = total muscle quality

TP = pyramid

TP = trained pyramid

TT = tradicional treinada – trained traditional

ULMQ = upper limb muscle quality

ULSMM = upper limb squeletal muscle mass

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1.1 INTRODUÇÃO

O aumento da população idosa é um fenômeno observado tanto em países desenvolvidos como em desenvolvimento, fato que ocorre, sobretudo, devido ao aumento da expectativa de vida. Estima-se que no Brasil a população com idade igual ou superior a 60 anos passará de menos de 20 milhões para, aproximadamente, 65 milhões, de 2010 a 2050 (1). Paralelamente a este processo de transição demográfica, importantes modificações no perfil epidemiológico, tanto da morbidade como mortalidade, devem ocorrer na população idosa.

Assim, o envelhecimento populacional tem sido um dos principais temas de discussão entre pesquisadores e profissionais das áreas de saúde, na perspectiva do aumento da longevidade, da melhoria das condições de saúde e de qualidade de vida do idoso. Para tanto, é necessário o estabelecimento de estratégias que favoreçam a autonomia, proporcione melhoria da autoestima e reduzam, sobremaneira, o desenvolvimento de doenças crônico-degenerativas. Vale destacar que a implementação de estratégias eficazes de promoção da saúde e qualidade de vida das pessoas idosas pode prevenir agravos no sistema de saúde pública, uma vez que os gastos com hospitalização, internação e medicamentos tendem a ser muito maiores em pessoas idosas (2), refletindo em aumento substancial nos gastos dos sistemas públicos de saúde (3).

Com o envelhecimento biológico ocorrem importantes modificações em diversos sistemas orgânicos que podem influenciar negativamente a saúde e a aptidão físico-funcional do idoso. Algumas das principais modificações provocadas pelo processo natural de envelhecimento serão abordadas nos tópicos a seguir, assim como o papel do exercício físico na prevenção e reabilitação da saúde do idoso.

1.1.2 Força muscular

A característica mais acentuada do envelhecimento é o declínio gradual da capacidade de geração de força muscular, fenômeno conhecido como dinapenia (4, 5). A força muscular é maximizada entre a segunda e terceira década de vida e se mantem relativamente estável ou diminui gradativamente ao longo dos próximos 20 anos, de modo que uma redução na ordem de 20 a 45% pode ser observada entre os 25 e 65 anos de idade e a partir da sexta década de vida, a perda de força muscular passa a ser exponencial atingindo um declínio de 12 a 15% a cada década (6-16). Embora o declínio progressivo da força muscular ocorra tanto em ambos os sexos, as mulheres possuem menores valores de força muscular em relação aos homens (4, 6, 7, 9-15, 17).

A força muscular é um componente fundamental da aptidão física para a manutenção da saúde, funcionalidade e qualidade de vida, visto que níveis reduzidos de força muscular favorecem quedas e fraturas (4, 16, 18, 19) e diminuem o nível de mobilidade e autonomia em idosos (5, 20-23). Além disso, a manutenção ou aumento da força muscular contribui para a prevenção de instabilidade articular, osteoporose (24), portanto, baixos níveis de força muscular estão associados a maior taxa de mortalidade (21, 25, 26).

A redução da força muscular com o avançar da idade está relacionada a alguns fatores como, por exemplo, déficits no sistema neuromuscular, tais como: redução na massa muscular, alteração na composição de fibras (redução das fibras do tipo II) e na ativação neural, aumento da coativação da musculatura antagonista, perda de unidades motoras, redução no número de axônios medulares e na velocidade de condução nervosa (5, 27-29).

1.1.3 Composição corporal

A redução na massa muscular associada a idade, fenômeno conhecido como sarcopenia é uma das principais alterações morfológicas que ocorre com o envelhecimento (4, 30-32). Isso parece ocorrer em virtude da célula muscular possuir um tamanho mínimo definido por predisposição genética, o que faz com que uma célula ao alcançar dimensões abaixo desse limiar, devido a atrofia das fibras musculares, desencadeie morte celular ou induza processo de desnervação (32).

Vale destacar que o processo de redução da massa muscular esquelética em indivíduos sedentários inicia-se por volta dos 30 anos de idade tornando-se mais acentuado a partir da quinta década de vida (30). Assim, se durante a terceira e a quarta década de vida perde-se em torno de 0,2 kg de massa muscular por ano (3-5% por década) a taxa de redução pode alcançar aproximadamente 0,5 kg por ano (5-10% por década) em pessoas acima dos 50 anos (33, 34). Portanto, a redução da massa muscular pode chegar a 40% em pessoas idosas (35, 36), afetando principalmente as fibras de contração rápida (30, 37).

Considerando que a musculatura esquelética está relacionada com a mobilidade e função do sistema locomotor de idosos [21, 31], a redução da massa muscular pode comprometer a autonomia da ação, a capacidade de locomoção e sustentação de objetos, a manutenção de equilíbrio, o nível de atividade física habitual [4, 30], favorecendo quedas e dificultando a realização de atividades cotidianas [21, 29, 38], afetando assim a independência e qualidade de vida dos idosos. Além disso, a redução da musculatura esquelética também está relacionada a problemas de saúde, tais como disfunções crônico-degenerativas [39], diabetes, osteoporose, artrite [40, 41], doenças cardíacas, câncer de colo, aumento da resistência periférica à insulina [42, 43], aumento da pressão arterial em repouso e do estado inflamatório basal do organismo [44], sendo considerada um importante preditor de longevidade em idosos [21, 31, 45]. Em parte, a redução da massa muscular relacionada ao processo de envelhecimento pode ocorrer devido a uma perda importante da água corporal total, sobretudo, de fluídos intracelulares [46-48].

Embora o envelhecimento esteja claramente associado com a progressiva perda de massa muscular (sarcopenia) e com redução da força muscular (dinapenia) [5, 21, 49], tais fenômenos não ocorrem na mesma magnitude, de modo que a taxa de declínio de força muscular ocorre em maior magnitude e velocidade em relação ao declínio de massa muscular [50, 51]. Neste contexto, a relação entre força e volume muscular tem sido definida como qualidade muscular, que operacionalmente, indica a produção de força especifica produzida por um determinado volume muscular [4, 51]. Tal informação parece bastante relevante no ponto de vista da funcionalidade, uma vez que pode indicar mudanças intrínsecas associadas ao desempenho do sistema musculoesquelético no contexto do envelhecimento, que vão além das análises isoladas de força e massa muscular [51-54].

Uma outra consequência negativa do envelhecimento é o aumento dos depósitos de gordura, sobretudo, visceral [30], que ocorre em parte devido a redução da massa muscular e, consequentemente, redução da taxa metabólica em repouso [55]. Adicionalmente, as fibras musculares perdidas são subsequentemente substituídas pela infiltração de gordura levando também a um acúmulo de gordura intramuscular o que é mais pronunciado nas mulheres [33, 34, 56]. O excesso de gordura corporal visceral é um fator de risco para o desenvolvimento de diabetes, hipertensão arterial, doença coronariana, doença renal, osteoartrite, dislipidemias, doenças pulmonares, diversos tipos de câncer e problemas psicológicos [57].

1.1.4 Biomarcadores metabólicos

O processo de envelhecimento guarda estreita relação com os fatores de risco à saúde, tais como aumento da resistência à insulina, intolerância à glicose (GLI), dislipidemia e inflamação crônica [58-61], alterações metabólicas que acabam predispondo o indivíduo idoso a um maior risco para o desenvolvimento de algumas doenças, com destaque para as doenças cardiovasculares, que são a principal causa de morbidade e mortalidade nesta faixa etária [62]. Em relação ao perfil lipêmico, este inclui a medida da quantidade dos principais lipídios circulantes no plasma, como triglicérides (TG), colesterol total (CT) e suas frações, conhecidas como lipoproteínas, que incluem a lipoproteína de alta densidade (HDL-C) e a lipoproteína de baixa densidade (LDL-C).

Mais recentemente, especial atenção tem sido dispensada ao papel da inflamação no evento cardiovascular, uma vez que tanto o envelhecimento quanto o sedentarismo estão associados a produção endógena de citocinas pró-inflamatórias [59, 61], um fenômeno que acarreta estado inflamatório basal, sendo considerado um fator de risco independente para o desenvolvimento de doenças cardiovasculares [63-65]. O estado de inflamação pode ser identificado pelas concentrações de proteína-C reativa (PCR) no sangue [66], um biomarcador bastante utilizado para identificação de inflamação sistêmica e predição de doenças cardiovasculares e metabólicas [67-70].

1.1.5 O papel do exercício físico na prevenção e reabilitação da saúde do idoso

O idoso, particularmente, sedentário encontra-se em um estado vulnerável no que tange a suscetibilidade para o desenvolvimento, sobretudo, de doenças crônico-degenerativas e redução da capacidade funcional. Assim, a prática de exercícios físicos tem sido encorajada para essa população especificamente, uma vez que existem fortes indicativos de que a adoção e, principalmente, a manutenção de um estilo de vida fisicamente ativo, pode reverter ou pelo menos atenuar grande parte dos efeitos deletérios à saúde observados com o avançar da idade [35, 60, 71-74].

Entre os diferentes tipos de exercícios físicos recomendados para idosos destacam-se os exercícios resistidos. Nesse sentido, o treinamento com pesos (TP) tem sido a estratégia mais frequentemente recomendada para indivíduos idosos [35, 60, 75, 76], em virtude dos inúmeros benefícios associados a essa prática para a saúde, que incluem importantes ganhos de força e massa muscular [31, 77, 78]; aumento na potência muscular [71, 78-80]; aumento da resistência muscular [81]; aumento da flexibilidade [82]; aumento da velocidade de caminhada e habilidades funcionais [72, 83-86]; melhoria do equilíbrio, coordenação e agilidade [72, 86-88]; prevenção de lesões [78, 89]; melhoria da estabilidade dinâmica e redução na incidência de quedas [78]; redução da gordura corporal [90-95]; incrementos na massa livre de gordura [71, 74, 96, 97]; aumento da densidade e do conteúdo mineral ósseo [78, 94, 98, 99]; aumento da hidratação intracelular [100]; aumento da taxa metabólica de repouso [78, 101-104]; melhoria da pressão arterial de repouso [78, 95, 105], melhoria do perfil lipídico [58, 78, 106] e do perfil glicêmico [106, 107]; melhoria do estado inflamatório [44, 64, 106, 108] e do estresse oxidativo [109].

Entretanto, tais respostas adaptativas ao TP são dependentes da manipulação de uma série de variáveis de treinamento [75], de modo que a manipulação adequada e progressiva do volume e da intensidade pode otimizar e determinar a magnitude dos benefícios, sobretudo no que tange aos ganhos de força e hipertrofia muscular [75]. Nesse sentido, embora os principais posicionamentos sobre prescrição de TP [60, 75, 76] recomendem a utilização de cargas fixas relativas a uma determinada zona de repetições, em séries simples ou múltiplas, sistema conhecido como tradicional, com base nas inúmeras evidências sobre a efetividade desse sistema de treinamento, outros sistemas de treinamento têm sido desenvolvidos ao longo do tempo por instrutores, atletas e praticantes de TP na tentativa de maximizar os benefícios.

Entretanto, grande parte dos sistemas de TP que vêm sendo aplicados nos centros de treinamento não foram testados cientificamente, embora sejam bastante populares entre os praticantes, o que não garante a efetividade do uso dessas diferentes estratégias de treinamento. Entre os diferentes sistemas de TP, o sistema conhecido como piramidal é um dos mais frequentemente utilizados por atletas e não-atletas com a finalidade de aumento de força e hipertrofia muscular.

O sistema piramidal utiliza-se de múltiplas séries e permite a manipulação de duas importantes variáveis do TP, ou seja, a carga e o número de repetições [110]. Operacionalmente o sistema piramidal é dividido em pirâmide crescente e decrescente. No sistema de pirâmide crescente, inicia-se com moderada ou baixa carga, e eleva-se a carga gradativamente ao longo das séries, paralelamente a esse aumento da carga, devido a interdependência entre volume e intensidade o número de repetições diminui. Por outro lado, no sistema de pirâmide decrescente a carga é reduzida gradativamente com o avançar das séries, simultaneamente, com o aumento no número de repetições. Em sua forma completa, no sistema piramidal crescente, o aumento de carga é repetido nas múltiplas séries até se atingir a carga que permita uma única repetição. Entretanto, a variação da forma original é a mais utilizada pelos praticantes, ou seja, um sistema conhecido como meia pirâmide, no qual estipula-se de três a cinco séries e a variação ocorre na zona de 15/12/10/8/6 repetições máximas (110).

Uma das principais vantagens do sistema piramidal é a possibilidade do uso de diferentes sobrecargas (volume vs. intensidade) em detrimento ao sistema tradicional onde a sobrecarga é relativamente constante. Neste sentido, estudos indicam que a intensidade pode exercer uma função importante na otimização das adaptações ao treinamento (111-115). Particularmente em indivíduos idosos, recentes meta-analises (116-118) e duas revisões sistemática (119, 120) que investigaram a relação dose-resposta entre aumento de força e variáveis do TP em indivíduos idosos, observaram uma dose-resposta entre a carga de treino e aumento de força, demonstrando que o incremento da carga é fundamental para ganhos de força em idosos. Esses achados podem ser explicados pelo fato de que os componentes neurais que contribuem para o incremento da força são adaptações mais sensíveis em cargas mais elevadas. Logo, o repertório motor associado ao uso do sistema piramidal apresenta-se enriquecido, com possível efeito sobre a otimização dos ajustes neurais.

Vale destacar que a manipulação da sobrecarga de treino é favorável a muitas adaptações induzidas pelo TP (75), uma vez que a partir da variação de cargas e repetições, pode-se otimizar estímulos mecânicos e metabólicos necessários para o acréscimo de proteína muscular (113, 121). Adicionalmente, a manipulação de volume e intensidade também pode favorecer outras importantes respostas metabólicas, com impacto positivo sobre o perfil lipêmico (122, 123) e inflamatório (63).

Portanto, considerando que o sistema piramidal por característica atende aos pressupostos básicos para aumento de força e hipertrofia muscular, como o estresse mecânico, estresse metabólico, dano muscular e a interação entre eles (113, 121), e ainda, permite a utilização de maiores cargas em relação ao sistema tradicional para uma mesma zona de repetições (exemplo: 8-12 repetições máximas), é possível que este sistema de treino possa provocar adaptações diferenciadas em relação ao sistema tradicional, que por sua vez já tem sua eficiência bem estabelecida na literatura científica.

Vale ressaltar que, via de regra, os sistemas de TP são sugeridos para indivíduos experientes em TP com intuito de ultrapassar ou limitar os platôs de adaptações que surgem com o treinamento, uma vez que o uso prolongado de um único sistema de treinamento, pode levar ao estabelecimento de platôs adaptativos [75]. No entanto, o sistema proposto por Thomas L. DeLorme, conhecido como sistema DeLorme em alusão a pessoa que introduziu sistematicamente a sua aplicação, é considerado uma variação do sistema piramidal. Este princípio de aumento de carga em séries subsequentes era aplicado por DeLorme para melhorar a força de membros previamente lesionados de soldados que voltavam da II Guerra Mundial [124]. O aumento significativo de força muscular observado nos pacientes submetidos a esse tipo de intervenção proporcionava menor tempo de internação em comparação aos pacientes que realizaram a reabilitação com grande número de repetições e baixa carga. Portanto, acredita-se que pessoas menos treinadas também possam se beneficiar deste tipo de treinamento [124].

Não obstante, a experiência prévia ao TP pode afetar a magnitude das adaptações [125-127]. Por exemplo, indivíduos com baixos níveis de aptidão física são mais susceptíveis a maiores ganhos de força e massa muscular quando comparados a pessoas treinadas [125, 127], uma vez que sujeitos mais treinados são menos sensíveis a novas adaptações em comparação aos iniciantes. Considerando que as adaptações morfológicas, neuromusculares e metabólicas induzidas pelo TP se processam ao longo de semanas, meses e até anos, existe a possibilidade que pessoas com diferentes níveis de treinamento tenham diferentes respostas adaptativas, particularmente, nas primeiras semanas de treinamento [128]. Ainda, pessoas mais treinadas, via de regra possuem maior massa muscular esquelética, este por sua vez é um tecido metabolicamente ativo e um dos principais sítios de metabolização de GLI e triglicerídeos, além disso, existem indicativos sugerindo que as respostas sobre a PCR podem ser dependentes do tempo [128] e do status de treinamento [129]. Neste contexto, surge uma segunda indagação: será que as adaptações promovidas pelo sistema pirâmide são dependentes do status de treinamento?

Considerando a dificuldade em analisar as informações disponíveis na literatura até o momento sobre diferentes sistemas de TP, ainda é necessário um melhor entendimento das adaptações promovidas pelo sistema piramidal sobre a força muscular e na composição corporal. Portanto, estudos que avaliem as respostas adaptativas do TP sobre os componentes da composição corporal e força muscular utilizando diferentes sistemas de TP podem proporcionar importantes informações para indivíduos que buscam o desenvolvimento de força e melhora dos componentes da composição corporal. Além disso, as informações produzidas podem auxiliar na tomada de decisão de pesquisadores e profissionais da área do TP para prescrição e orientação de programas de treinamento com o intuito de otimizar os ganhos em força e hipertrofia muscular. Assim, espera-se com este trabalho, oferecer para profissionais e pesquisadores, informações e princípios com fundamentação científica para o planejamento e desenvolvimento de programas de TP eficazes para a terceira idade.

1.2 OBJETIVOS

1.2.1 Objetivo geral

- Comparar sistemas de TP com cargas fixas e variáveis sobre indicadores de saúde e de desempenho físico em mulheres idosas.

1.2.2 Objetivos específicos

- Comparar as respostas do sistema de TP pirâmide versus o tradicional na força e hipertrofia muscular de mulheres idosas: um estudo *cross over* (Artigo 1);
- Comparar as respostas do sistema de TP pirâmide versus o tradicional na composição corporal e biomarcadores sanguíneos de mulheres idosas: um estudo *cross over* (Artigo 2);
- Verificar a influência da experiência prévia ao TP sobre as adaptações induzidas pelo sistema pirâmide e tradicional na força e hipertrofia muscular de mulheres idosas (Artigo 3);
- Verificar a influência da experiência prévia ao TP sobre as adaptações induzidas pelo sistema pirâmide e tradicional sobre a composição corporal e biomarcadores sanguíneos de mulheres idosas (Artigo 4).

1.3 MÉTODOS

1.3.1 Participantes

Este estudo faz parte de um projeto de pesquisa mais amplo intitulado “Impacto de diferentes frequências semanais ao treinamento com pesos em mulheres idosas”, realizado durante os anos letivos de 2012-1015.

Sessenta e oito mulheres idosas fizeram parte do experimento. Os sujeitos foram recrutados para participarem do projeto mediante distribuição de panfletos em residências, feiras e regiões comerciais próximas ao local de treinamento, além de informativos em jornais, rádio e televisão. A amostra foi então selecionada preliminarmente por meio de entrevista e anamnese clínica. Como critérios iniciais de inclusão, as participantes deveriam ter idade igual ou superior a 60 anos, serem do sexo feminino, fisicamente independentes, não serem portadores de disfunção cardíaca, não possuir problemas articulares que impedissem a prática dos exercícios ou testes, não deveriam receber reposição hormonal e não estarem envolvidas com a prática de atividade física regular sistematizada mais do que uma vez por semana, ao longo dos últimos seis meses anteriores ao início do estudo. Finalmente, as participantes foram incluídas no estudo somente após serem avaliadas por um médico cardiologista e liberadas sem restrição para a participação em programas de exercícios físicos. Como critério de exclusão, foi adotado uma aderência mínima de 85% das sessões de treinamento.

Após receberem informações sobre a finalidade e os procedimentos do estudo, todas as participantes selecionadas assinaram um Termo de Consentimento Livre e Esclarecido (APÊNDICE A). Este estudo foi aprovado pelo Comitê de Ética em Pesquisa da Universidade Estadual de Londrina (ANEXO A), de acordo com as normas da Resolução 196/96 do Conselho Nacional de Saúde sobre pesquisa envolvendo seres humanos.

1.3.2 Delineamento do estudo

O estudo teve uma duração de 64 semanas que foram divididas em cinco etapas (ET1, ET2, ET3, ET4 e ET5). Ao longo das duas primeiras etapas as participantes foram submetidas ao TP durante 24 semanas (3-14 e 17-28). As ET1 e

ET2 tiveram duração de 12 semanas cada. Após este período, as participantes que realizaram TP prévio foram aleatoriamente separadas em dois grupos, a saber: tradicional treinado (TT) e pirâmide treinado (PT). Ainda, neste mesmo momento, novas participantes foram selecionadas a participarem do estudo para compor os grupos de idosas iniciantes que foram separadas aleatoriamente em outros dois grupos, a saber: tradicional iniciante (TI) e pirâmide iniciante (PI).

Na terceira etapa do experimento, todas as participantes foram submetidas a um mesmo programa de TP durante oito semanas (semanas 31-38), no qual os grupos PT e PI realizaram o treinamento no sistema piramidal, ao passo que os grupos TT e TI realizaram o treinamento no sistema tradicional. Ao término da ET3, foi dado um período de interrupção de 12 semanas (ET4). Após a interrupção, na ET5 foi realizado um delineamento cruzado (*cross over)* entre as participantes do TI e PI, assim, aquelas que executaram o TP no sistema piramidal na ET3 foram submetidas a oito semanas de treinamento no sistema tradicional. Por outro lado, aquelas iniciaram o programa de treinamento no sistema tradicional realizaram o programa de oito semanas no sistema piramidal.

No início da primeira etapa (M1) e ao final de cada etapa (M2, M3, M4, M5, M6 e M7), duas semanas foram utilizadas para avaliações, por meio de medidas antropométricas, de testes de uma repetição máxima (1RM), medidas de absortometria radiológica de dupla energia (DEXA) e bioimpedância espectral para a avaliação dos componentes da composição corporal, e coletas de sangue para análise bioquímica. A Figura 1 apresenta o delineamento experimental do estudo.

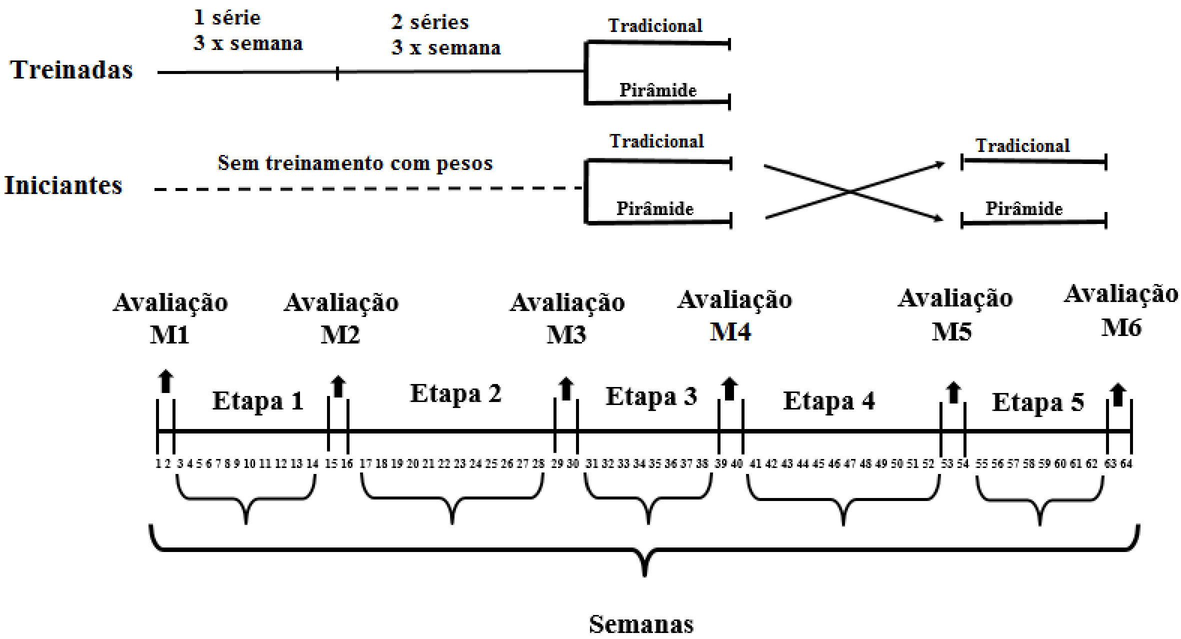

Figura 1.1 – Delineamento experimental. M = momento.

1.3.3 Medidas antropométricas e de composição corporal

A massa corporal foi mensurada em uma balança de leitura digital, marca Balmak, modelo Classe III (São Paulo, Brasil), com escala de 0,1 kg, ao passo que a estatura foi determinada por meio de um estadiômetro acoplado à mesma, com escala de 0,1 cm, com selo do INMETRO. A partir dessas medidas, foi calculado o índice de massa corporal, por meio da razão entre a massa corporal e o quadrado da estatura, sendo a massa corporal expressa em quilogramas (kg) e a estatura em metros (m).

A DEXA foi utilizada para a avaliação da massa livre de gordura e da massa gorda. As medidas de DEXA foram realizadas em um equipamento da marca Lunar Prodigy, modelo GE Healthcare, ID 14739 (Madison, WI, USA), mediante escaneamento de corpo inteiro. A calibragem do equipamento seguiu as recomendações do fabricante e, tanto a calibragem quanto as análises foram realizadas por um técnico do laboratório com experiência nesse tipo de avaliação. As participantes foram submetidas aos exames trajando roupas leves, descalços e sem portar nenhum objeto metálico ou qualquer outro acessório junto ao corpo. Os sujeitos permaneceram deitados e imóveis sobre a mesa do equipamento até a finalização da medida. Após a varredura de corpo inteiro, o programa fornece os dados de massa gorda, massa óssea e massa livre de gordura, para o corpo todo e regiões específicas (tronco e membros superiores e inferiores). Os membros foram demarcados e separados do tronco e da cabeça por linhas padronizadas geradas pelo *software* do próprio equipamento. As linhas foram ajustadas pelo técnico, por meio de pontos anatômicos específicos, que podem ser visualizados no manual do equipamento. A massa muscular esquelética total foi estimada a partir da quantificação da massa do tecido magro e mole apendicular, mediante a utilização da equação preditiva proposta por Kim et al. (130).

$$MME = (1{,}13 \times MIGOAP) - (0{,}02 \times idade) + (0{,}61 \times sexo) + 0{,}97$$

Onde MME = massa muscular esquelética. MIGOAP = massa isenta de gordura e osso apendicular. Sexo: mulher = 0, homem = 1.

A quantidade de água corporal total e suas frações intracelular e extracelular foram estimadas por bioimpedância espectral, utilizando um analisador multifrequencial (Xitron 4200 Bioimpedance Spectrum Analyzer). As participantes foram posicionadas em decúbito dorsal, em uma maca isolada de condutores elétricos, com as pernas abduzidas num ângulo de 45º. Após a limpeza da pele com álcool, dois eletrodos foram colocados na superfície da mão direita e dois no pé direito, de acordo com os procedimentos descritos na literatura (131). Na tentativa de minimizar possíveis erros de estimativa, as idosas foram orientadas a urinar cerca de 30 min antes da realização das medidas, absterem-se da ingestão de alimentos ou bebidas nas últimas quatro horas, evitar a prática de exercícios físicos vigorosos por pelo menos 24 h, absterem-se do consumo de bebidas alcoólicas e cafeinadas por no mínimo 48 h e evitar o uso de diuréticos ao longo dos sete dias precedentes a cada avaliação.

1.3.4 Avaliação da força muscular

Para a avaliação da força muscular foi utilizado o teste de 1RM em três exercícios, envolvendo os segmentos do tronco, membros inferiores e membros superiores. A ordem de execução dos exercícios testados foi a seguinte: supino vertical, cadeira extensora e rosca *Scott*, respectivamente. As idosas foram instruídas previamente sobre todos os procedimentos e técnicas exigidas nos testes e em seguida submetidas a três sessões de testes, que foram realizadas no período da manhã, com intervalo de 48 h entre cada sessão. Em cada sessão de teste, foi realizado um aquecimento anterior ao início da primeira tentativa, para cada exercício, por meio da realização de uma série de 6 a 10 repetições com aproximadamente 50% da carga à qual as idosas foram testadas inicialmente. A partir disso, foi permitido um intervalo de dois minutos e então a realização do teste. As idosas tiveram três tentativas para cada exercício e intervalo de três a cinco minutos entre elas, além de um intervalo fixo de cinco minutos entre os exercícios. Para cada tentativa, as idosas foram encorajadas a realizar duas repetições. Caso houvesse a realização de ao menos uma repetição, a carga foi aumentada, e após o intervalo, uma segunda tentativa foi executada. No caso de não haver execução de uma repetição, a carga foi reduzida e uma terceira e última tentativa foi realizada. A carga registrada como 1RM foi aquela na qual cada participante conseguiu realizar uma única repetição máxima [(132)]. Foram destinados três avaliadores por exercício, sendo designado um avaliador fixo para cada exercício em todos os momentos do estudo. Vale ressaltar que a forma e a técnica de execução de cada exercício foram padronizadas e continuamente monitoradas na tentativa de garantir a eficiência do teste.

1.3.5 Qualidade muscular

O índice de qualidade muscular total foi determinado pela divisão da força total (somatório da carga dos três exercícios) pela massa muscular esquelética total. A qualidade muscular de membro superior foi determinada a partir divisão da carga mobilizada no exercício rosca *Scott* pela massa isenta de gordura e osso de membro superior, enquanto a qualidade muscular de membro inferior foi determinada a partir da divisão da carga mobilizada no exercício cadeira extensora pela massa isenta de gordura e osso de membro inferior [51].

1.3.6 Coleta de sangue e análises bioquímicas

O sangue foi coletado na veia antecubital, com as participantes na posição sentada, após jejum de 12 h. As amostras foram depositadas em tubos a vácuo com gel separador sem anticoagulante, e centrifugadas por 10 min a 3.000 rpm para separação do soro. Em seguida, as amostras foram processadas por um técnico de laboratório de Análises Clínicas, no Hospital Universitário da universidade local, em um sistema autoanalisador bioquímico Dimension RxL Max – Siemens Dade-Behring, de acordo com métodos padronizados, seguindo os protocolos recomendados pelos fabricantes.

Os níveis séricos de PCR, GLI, CT, HDL-C e TG foram determinados diretamente, enquanto a equação de Friedewald (133): LDL-C = CT - (HDL-C + TG/5), foi utilizada para a estimativa da LDL-C. As concentrações sanguíneas de testosterona e fator de crescimento semelhante a insulina (IFG-1) foram determinadas de acordo com os métodos mediante o método de quimiluminescência utilizando um analisador imunoensaio LIAISON (Soaring S.T.A, Saluggia, Italy).

1.3.7 Hábitos alimentares

Registros alimentares de três dias foram utilizados para monitoramento dos hábitos alimentares das participantes nas semanas de avaliação do estudo (APÊNDICE B). Os dias da semana adotados para o preenchimento dos registros foram segunda, quinta e domingo. As informações sobre a forma de preenchimento dos registros foram fornecidas individualmente aos participantes por nutricionistas habituados a esse procedimento. Medidas caseiras padronizadas foram utilizadas para a estimativa da quantidade de alimentos e bebidas consumidas. O consumo energético total e as proporções ingeridas de macronutrientes foram determinadas por meio do programa para avaliação nutricional Nut Win, versão 1.5. Todas as participantes foram orientadas para não modificarem seus hábitos alimentares diários durante todo o período de duração do estudo. A ingestão de água foi *ad libitum*.

1.3.8 Programa de treinamento com pesos

O programa de TP supervisionado foi realizado conduzido seguindo as recomendações da literatura (60, 75, 76). Todas as sessões de TP foram conduzidas no período da manhã. O programa nas ET1 e ET2 teve duração de 12 semanas cada. Tanto a ET1 quanto a ET2 consistiram de uma única programação, a diferença entre essas etapas foi determinada pelo número de séries a ser executada por exercício, sendo utilizada uma série na ET1, e duas séries na ET2. Esse procedimento tende a gerar uma sobrecarga progressiva além de uma quebra da homeostase do treinamento. A carga utilizada nestas duas primeiras etapas foi compatível a faixa de 10-15 RM. Para a ET3 e ET5, os sujeitos alocados nos grupos tradicional realizaram três séries de 8-12 RM com carga fixa nas três séries, ao passo que as participantes dos grupos pirâmide realizaram três séries consistindo de 12, 10 e 8 RM com aumento incremental de cargas a cada série, caracterizando o método pirâmide. Todos os grupos foram submetidos ao respectivo programa de TP por oito semanas.

Em todas as etapas o programa foi realizado com frequência de três sessões semanais em dias alternados (segundas, quartas e sextas-feiras), e foi composto por oito exercícios, envolvendo diferentes grupamentos musculares, obedecendo a uma rotina alternada por segmento, os exercícios realizados bem como a sua respectiva ordem foram: supino vertical, *leg press* horizontal, remada articulada, cadeira extensora, rosca S*cott*, mesa flexora, tríceps no *pulley* e panturrilha sentada. Durante todo o período do estudo o intervalo de recuperação estabelecido entre as séries e os exercícios foi de 60 a 120 s. As participantes foram orientadas a executarem as ações musculares concêntrica e excêntrica em uma razão de 1 : 2, respectivamente.

As cargas utilizadas foram compatíveis com o número de RM estipuladas para as três séries de cada exercício. Os instrutores realizaram os ajustes da carga de cada exercício de acordo com a capacidade de evolução de cada participante ao longo do estudo, a fim de garantir que os sujeitos estavam se exercitando com a maior carga possível mantendo a técnica adequada do exercício. A progressão para o treino tradicional foi realizada quando as idosas completaram o limite superior de repetições em duas sessões consecutivas, e para o sistema pirâmide a progressão foi realizada quando a participante foi capaz de realizar duas repetições a mais da previamente estipulada na última série. Para ambos os sistemas o peso foi aumentado de 2-5% para os exercícios para os membros superiores e 5-10% para os exercícios para os membros inferiores para a próxima sessão, seguindo os procedimentos propostos pelo Colégio Americano de Medicina do Esporte [(75)], e assim garantir que as participantes estavam sendo exercitadas com a mesma intensidade relativa durante todo o período do experimento. Os sujeitos foram orientados, ainda, para não participarem de nenhum outro tipo de programa de treinamento durante o período do estudo, de modo que o impacto do TP possa ser avaliado de forma isolada.

1.3.9 Análise estatística

As informações sobre tendência central e dispersão dos dados estão apresentados em média e desvio padrão, respectivamente. Análise de variância (ANOVA) *two-way* para medidas repetidas foi utilizada para comparação entre os grupos e os momentos nos artigos 1 e 2, ao passo que para os artigos 3 e 4 análise de covariância (ANCOVA) foi utilizada, com as medidas da linha de base sendo adotadas como covariáveis. O teste de *Mauchly* foi aplicado para verificar a esfericidade, em caso de violação deste pressuposto, as análises foram ajustadas pela correção de *Greenhouse-Geiser*. A comparação dos quatro grupos, no momento pré intervenção nos artigos 3 e 4, foi realizada mediante aplicação de ANOVA *one-way*. O teste de *Levene* foi utilizado para verificar a homogeneidade das variâncias. O teste *post hoc* de *Bonferroni*, para comparações múltiplas, foi empregado para a identificação das diferenças específicas nas variáveis em que os valores de F encontrados forem superiores aos do critério de significância estatística estabelecido. A magnitude do tamanho das diferenças foi calculada pelo tamanho do efeito proposto por Cohen [134] utilizando a seguinte fórmula.

$$M_2 – M_1 / DP$$

Onde M1 representa a média pré-treinamento, M2 a média prós-treinamento, e DP a média dos desvios padrão pré e pós treinamento.

O tamanho do efeito de 0,20 - 0,49 foi considerado pequeno, 0,50 - 0,79 como moderado e ≥ 0,80 como de grande magnitude. Para todas as análises estatísticas foi aceito uma significância de $P < 0,05$. Para processamento dos dados, foi utilizado o programa estatístico *STATISTICA* versão 10.0.

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CAPÍTULO 2

Artigo original 1

Traditional and pyramidal resistance training effects on muscular strength and hypertrophy in older women: a randomized crossover trial

Running head: resistance training with different systems

Abstract

The purpose of this study was to investigate the effect of resistance training (RT) performed in a pyramid versus traditional system on muscular strength and hypertrophy in older women. Twenty-five older women (67.6 ± 5.1 years, 65.9 ± 11.1 kg, 154.7 ± 5.8 cm, and 27.5 ± 4.5 kg.m^{-2}) performed a RT program in traditional (TD) and pyramid (PR) system in a balanced crossover design. At the beginning and the end of each RT phase measurements of 1 repetition maximum (RM) tests and dual X-ray absorptiometry were conducted to determine changes in strength and skeletal muscle mass, respectively. The TD program consisted of 3 sets of 8-12 RM with constant load for the 3 sets, whereas the PR training consisted of 3 sets of 12/10/8 RM with incremental loads for each set. Training was performed in two phases of 8 weeks each, with a 12-week washout between these 8-weeks phases. Significant ($P < 0.05$) increases were observed in both groups for muscular strength in the 1RM chest press (TD = + 12.4%, PR = + 11.5%), knee extension (TD = + 12.5%, PR = + 11.8%), preacher curl (TD = + 10.9%, PR = + 8.6%), and for skeletal muscle mass (TD = + 3.6%, PR = + 2.4%) with no differences between groups. We conclude that the pyramid system is similarly effective to traditional to promote positive adaptations in muscular strength and hypertrophy in older women.

Keywords: strength training, aging, training system, skeletal muscle mass.

2.1 Introduction

Aging is associated with various physiological changes that detrimentally affect the neuromuscular system, including a reduction in muscular strength and skeletal muscle mass [1, 2]. The loss of strength and muscle mass are two of the main reasons for a reduction of daily activities in older individuals, thus negatively affecting functional autonomy and quality of life [1-3]. Older women are particularly susceptible to the damaging effects of sarcopenia and dynapenia due to hormonal alterations after menopause, and because women usually have lower initial levels of strength and muscle mass than men [2, 4, 5].

Resistance training (RT) has been promoted as a means to attenuate the deleterious effects of aging [6-8]. Technical aspects of RT's prescription involves a number of variables; among them, the volume and intensity are key components [8]. The volume refers to the quantitative part of the training and can be manipulated by the number of sets, repetitions, exercises and weekly frequency [8]. Alternatively, intensity refers to the degree of effort that an individual exerts during a given exercise, it can be modified by manipulating elements such as rest interval, speed, and external load [8].

Studies indicate a clear dose-response relationship between intensity and muscular strength increase in older individuals [9-13]. However, for muscular hypertrophy, greater loads do not necessarily reflect major adaptations [14, 15]. Muscular hypertrophy is stimulated due to the balance between mechanical and metabolic stress, muscular damage and the interaction between these factors [16], in which moderate volume and intensity are purported to optimize hypertrophic adaptations [8]. This is mainly due to the interdependence between intensity and volume; that is, high intensity exercises do not allow an appropriate training volume to create an optimal anabolic environment. In order to optimize intensity and volume and therefore achieve superior adaptations, the adoption of RT systems that allow the execution of higher intensities without drastic reductions in volume have been suggested.

The pyramid system, due to its inherent characteristic of varying loads and number of repetitions, permits exercise performance at higher intensities without necessarily a loss in the volume from a specific loading zone standpoint, thus maintaining a favorable anabolic environment for increased strength and muscle hypertrophy. However, although the pyramid system is widely used by practitioners, there is little scientific basis to support its actual effectiveness. Therefore, the main objective of this study was to investigate the effect of RT performed in a pyramid system on muscular strength and hypertrophy in older women. We hypothesized that the pyramid system would result in greater increases in strength and hypertrophy compared to a traditional system. The rationale for this hypothesis is based on the dose-response relationship between intensity and volume on muscular strength and hypertrophy.

2.2 Methods

2.2.1 Participants

Participant recruitment was carried out through newspaper and radio advertisings, and home delivery of leaflets in the central area and residential neighborhoods. All participants completed health history and physical activity questionnaires and met the following inclusion criteria: 60 years old or more, physically independent, free from cardiac or orthopedic dysfunction, not receiving hormonal replacement therapy, and not performing any regular physical exercise for more than once a week over the six months preceding the beginning of the study. Participants passed a diagnostic, graded exercise stress test with 12-lead electrocardiogram reviewed by a cardiologist and were released with no restrictions for participation in this study. Forty older women were accessed for eligibility. After individual interviews, 11 were dismissed as potential candidates because they did not meet the inclusion criteria for the study. The remaining 29 older women were selected for participation and then randomly assigned to one of two groups according to the RT system: a group that performed RT in the traditional system (TD, n = 14) or a group that performed RT in the pyramid system (PR, n = 15). A total of 25 participants (67.6 ± 5.1 years, 65.9 ± 11.1 kg, 154.7 ± 5.8 cm, and 27.5 ± 4.5 kg.m^{-2}) completed all stages of the experiment, and were included in the analyses. The reasons for withdrawal were reported as lack of time, difficulty to travel to University, lack of motivation, and personal reasons. Adherence to the program was satisfactory, with all subjects participating in >85% of the total sessions. Figure 2.1 is a schematic representation of participants' recruitment and allocation.

Written informed consent was obtained from all participants after a detailed description of study procedures was provided. This investigation was conducted according to the Declaration of Helsinki, and was approved by the local University Ethics Committee.

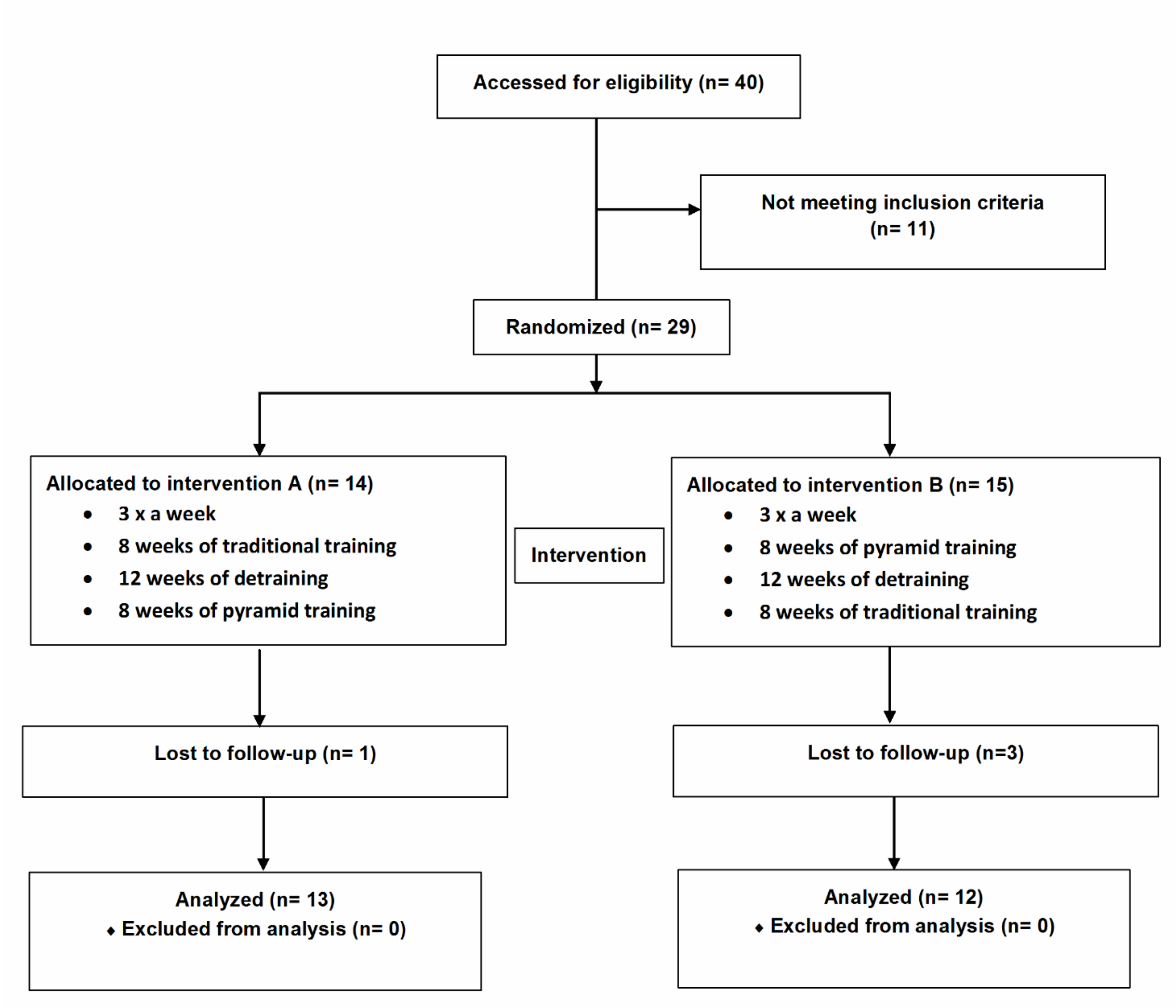

Figure 2.1 – Schematic representation of participants' recruitment and allocation.

2.2.2 Experimental design

The study was carried out over a period of 36 weeks divided into 3 phases. In the first phase, participants were randomly separated into two groups to perform 8-weeks (weeks 3-10) of RT according to the respective system (TD and PR). At phase 2, participants were given a 12-week period of detraining (weeks 13-24) in which no resistance exercise was performed. The intent of the detraining phase was to return participant's physical fitness levels to baseline values. Phase 3 employed a crossover so that those who previously performed the PR system underwent 8 weeks of training in the TD system (weeks 27-34) and those who previously performed the TD system engaged in an 8-week program in the PR system. At the beginning and the end of each stage of the experiment, two weeks were used for evaluations (weeks 1-2, 11-12, 25-

26 and 35-36) consisting of anthropometric measures, tests of 1 repetition maximum (1RM), body composition analysis by dual energy X-ray absorptiometry (DXA), and blood work for biochemical analysis. The experimental design is displayed in Figure 2.2.

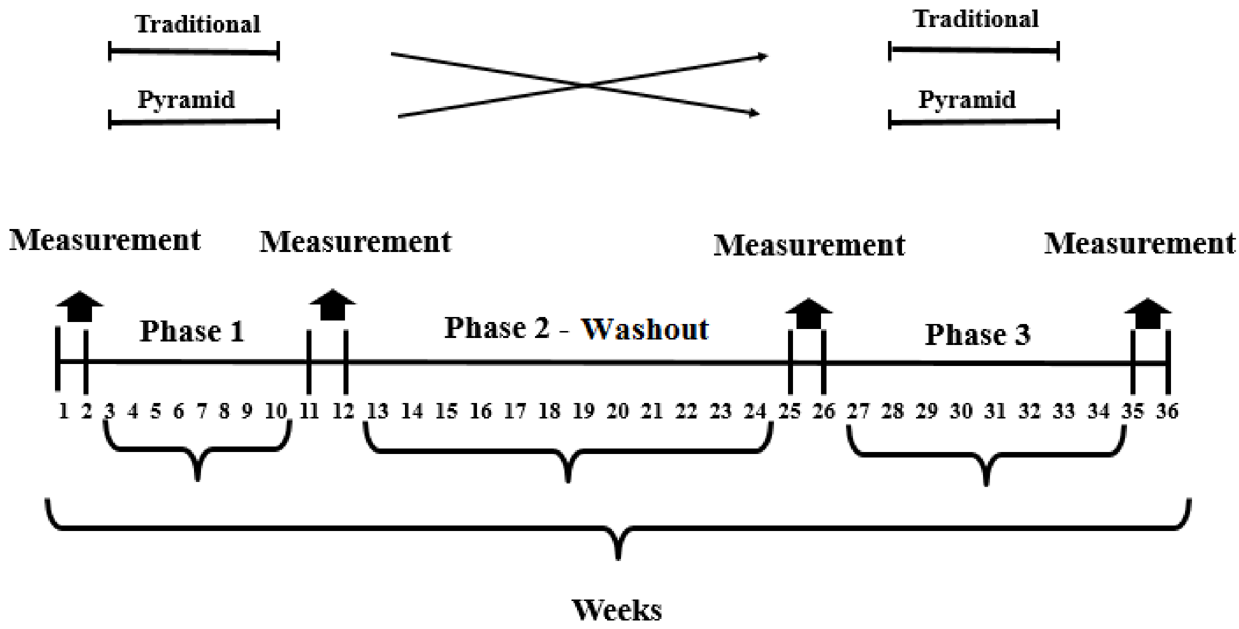

Figure 2.2 – Experimental design.

2.2.3 Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Balmak, Laboratory Equipment Labstore, Curitiba, Paraná, Brazil), with the participants wearing light workout clothing and no shoes. Height was measured with a stadiometer attached on the scale to the nearest 0.1 cm with subjects standing sans shoes. Body mass index was calculated as body mass in kilograms divided by the square of height in meters.

2.2.4 Muscle mass

Skeletal muscle mass was estimated by the predictive equation proposed by Kim et al. [(17)]. The appendicular fat-free mass used for the equation was determined by DXA scan (Lunar Prodigy, model NRL 41990, GE Lunar, Madison, WI). Prior to scanning, participants were instructed to remove all objects containing metal. Scans were performed with the subjects lying in the supine position along the table’s longitudinal centerline axis. Feet were taped together at the toes to immobilize the legs while the hands were maintained in a pronated position within the scanning region. Subjects remained motionless during the entire scanning procedure. Both calibration and analysis were carried out by a skilled laboratory technician. The equipment calibration followed the manufacturer’s recommendations. The software generated standard lines that set apart the limbs from the trunk and head. These lines were adjusted by the same technician using specific anatomical points determined by the manufacturer. Analyses during the intervention were performed by the same technician who was blinded to intervention time point. Previous test-retest scans resulted in a standard error of measurement of 0.29 kg and intraclass correlation coefficient of 0.997 for skeletal muscle mass.

2.2.5 Body water

Total body water (TBW), intracellular water (ICW) and extracellular water (ECW) content were assessed using a spectral bioelectrical impedance device (Xitron 4200 Bioimpedance Spectrum Analyzer). Before measurement the participants were instructed to remove all objects containing metal. Measurements were performed on a table that was isolated from electrical conductors, with subjects lying supine along the table´s longitudinal centerline axis, legs abducted at an angle of 45°, and hands pronated. After cleaning the skin with alcohol, 2 electrodes were placed on surface of the right hand and 2 on the right foot in accordance with procedures described by Sardinha et al. [(18)]. Subjects were instructed to urinate about 30 minutes before the measures, refrain from ingesting food or drink in the last four hours, avoid strenuous physical exercise for at least 24 hours, refrain consumption of alcoholic and caffeinated beverages for at least 48 hours, and avoid the use of diuretics during 7 days prior each assessment. Before each measurement day equipment was calibrated as per the manufacturer´s recommendations. The values generated by equipment software for ICW and ECW were used for analysis, the TBW was estimated by the sum of ICW and ECW. Based on the test-retest measured 24–48 h apart in our laboratory, resulted in standard error of measurement of 0.32 L for ECW, 0.19 L for ICW, and 0.38 L for TBW, and intraclass correlation coefficient > 0.98 for ECW, > 0.99 for ICW, and > 0.98 for TBW.

2.2.6 Muscular strength

Maximal dynamic strength was evaluated using the 1RM test assessed on chest press (CP), knee extension (KE), and preacher curl (PC) performed in this exact order. Testing for each exercise was preceded by a warm-up set (6-10 repetitions), with approximately 50% of the estimated load used in the first attempt of the 1RM. This warm-up was also used to familiarize the subjects with the testing equipment and lifting technique. The testing procedure was initiated 2 minutes after the warm-up. The subjects were instructed to try to accomplish two repetitions with the imposed load in three attempts in both exercises. The rest period was 3 to 5 min between each attempt, and 5 min between exercises. The 1RM was recorded as the last resistance lifted in which the subject was able to complete only one single maximal execution (19). Execution technique for each exercise was standardized and continuously monitored to ensure reliability. All 1RM testing sessions were supervised by 2 experienced researchers for greater safety and integrity of the subjects. Verbal encouragement was given throughout each test. Three 1RM sessions were performed separated by 48 hours (ICC $\geq$ 0.96). The highest load achieved among the 3 sessions was used for analysis in each exercise. Total strength was determined by the sum of the 3 exercises.

2.2.7 Biochemical analysis

Serum levels of testosterone and IFG-1 were measured after 12 h fasting by a laboratory technician. The blood was taken from the antecubital vein. The subjects were instructed not to perform vigorous exercise for the preceding 24 h and to avoid alcohol or caffeinated beverages 72 h before collection. Measurements were performed by standard methods in a specialized laboratory at University Hospital. Samples were deposited in vacuum tubes with a gel separator without anticoagulant and were centrifuged for 10 min at 3000 rpm for serum separation. Inter and intra assays CVs were <10% as determined in human serum. Thereafter, testosterone and IFG-1 concentrations were determined. The analyses were carried out using a biochemical auto-analyzer system (Dimension RxL Max - Siemens Dade Behring) according to established methods in the literature consistent with the manufacturer's recommendations. The amounts of IGF-1 and testosterone were determined by chemiluminescence method using a LIAISON Immunoassay Analyzer (Soaring S.T.A, Saluggia, Italy).

2.2.8 Dietary intake

Participants were instructed by a dietitian to complete a food record on three nonconsecutive days (two week days and one weekend day) pre- and post-training. Subjects were given specific instructions regarding the recording of portion sizes and quantities to identify all food and fluid intake, in addition to viewing food models in order to enhance precision. Total dietary energy, protein, carbohydrate, and lipid content were calculated using nutrition analysis software (Avanutri Processor Nutrition Software, Rio de Janeiro, Brazil; Version 3.1.4). All subjects were asked to maintain their normal diet throughout the study period.

2.2.9 Volume of load

During every resistance training session, researchers recorded the load and number of repetitions performed by participants for each set of the 8 exercise. Afterwards, the volume of load for each exercise was calculated by multiplying the load by the number of repetitions and sets. The total volume of load was the sum of all 8 exercises. Then the sum of the 3 sessions of a week was utilized as the weekly volume of load.

2.2.10 Resistance training program

Supervised RT was performed during the morning hours in the State University facilities. The protocol was based on recommendations for RT in an older population to improve muscular strength and hypertrophy [6, 8]. Physical education professionals to ensure consistent and safe performance personally supervised all participants. Subjects performed RT using a combination of free weights and machines. The sessions were performed 3 times per week on Mondays, Wednesdays, and Fridays during the morning hours. The RT program was a whole body program with 8 exercises comprising one exercise with free weights and seven with machines performed in the following order: chest press, horizontal leg press, seated row, knee extension, preacher curl (free weights), leg curl, triceps pushdown, and seated calf raise.

Participants of the TD group performed 3 sets of 8-12 repetitions maximum with the same load in the 3 sets. While the participants of the PR group performed 3 sets with the load increasing and number of repetitions simultaneously decreasing for each set, thus, the number of repetitions used in each set was 12/10/8/ repetition maximum, respectively, with variable resistance. For both systems, the participants carried out exercises until muscle failure or an inability to sustain exercise performance with proper form.

Participants were instructed to inhale during the eccentric phase and exhale during the concentric phase while maintaining a constant velocity of movement at a ratio of approximately 1:2 seconds (concentric and eccentric phases, respectively). Participants were afforded 1 to 2 min of rest interval between sets and 2 to 3 min between each exercise. Instructors adjusted the loads of each exercise according to the subject's abilities and improvements in exercise capacity throughout the study in order ensure that the subjects were exercising with as much resistance as possible while maintaining proper exercise technique. Progression for the traditional training was planned when the upper limits of the repetitions-zone were completed for two consecutive training sessions and for pyramid training when the participant was able to perform two more repetitions in the last set. For both systems weight was increased 2-5% for the upper limb exercises and 5-10% for the lower limb exercises to the next session [(8)].

2.2.11 Statistical analyses

Two-way analysis of variance (ANOVA) for repeated measures was applied for comparisons. When F-ratio was significant, Bonferroni's post hoc test was employed to identify the mean differences. The effect size (ES) was calculated as post training mean minus pre training mean divided by pooled standard deviation of pre and post training [(20)]. For all statistical analyses, significance was accepted at $P < 0.05$. The data were analyzed using STATISTICA software version 10.0 (STATSOFT INC., TULSA, OK, USA).

2.3 Results

Total energy and macronutrients daily intake at pre and post training are shown in Table 2.1. There were no significant ($P > 0.05$) main effects, indicating that the relative daily energy and macronutrient intake were not different between groups and did not change over time.

Table 2.1. Dietary intake at pre and post training according to resistance training system. Data are expressed as mean and standard deviation.

	Traditional	Pyramid	Effects	F	*P*
Carbohydrate (g.kg^{-1}.d^{-1})			Group	1.20	0.28
Pre training	2.8 ± 1.4	2.8 ± 0.9	Time	0.18	0.67
Post training	2.8 ± 1.2	3.2 ± 1.8	Interaction	2.51	0.13
Protein (g.kg^{-1}.d^{-1})			Group	1.03	0.32
Pre training	0.8 ± 0.3	0.9 ± 0.4	Time	0.12	0.72
Post training	0.8 ± 0.2	1.0 ± 0.6	Interaction	0.02	0.87
Lipids (g.kg^{-1}.d^{-1})			Group	0.27	0.60
Pre training	0.5 ± 0.4	0.6 ± 0.4	Time	0.97	0.33
Post training	0.6 ± 0.3	0.8 ± 0.7	Interaction	0.04	0.88
Energy (kcal.kg^{-1}.d^{-1})			Group	0.77	0.39
Pre training	19.5 ± 10.9	21.5 ± 8.9	Time	0.07	0.79
Post training	17.6 ± 4.6	24.9 ± 16.0	Interaction	0.81	0.38

Figure 2.3 shows the results for the muscular strength, fat free mass and skeletal muscle mass at pre- and post-training for both groups. There were no significant group by time interaction for any of the exercises analyzed and for the sum of the 3 exercises (CP: F = 0.04, *P* = 0.83; KE: F = 0.08, *P* = 0.77; PC: F = 1.09, *P* = 0.30; TS: F = 0.23, *P* = 0.62). Likewise, there were no significant main effects of group (CP: F = 0.01, *P* = 0.97; KE: F = 0.03, *P* = 0.85; PC: F = 0.04, *P* = 0.82; TS: F = 0.02, *P* = 0.87). However, a significant main effect of time was observed (CP: F = 132.16, *P* < 0.001; KE: F = 107.82, *P* < 0.001; PC: F = 84.83, *P* < 0.001; TS: F = 155 13, *P* < 0.001), in which increased were observed for CP (TD = 12.4%, ES = 0.86 PR = 11.5%, ES = 0.74), for KE (TD = + 12.5%, ES = 0.61; PR = + 11.8%, ES = 0.62), for PC (TD = + 10.9%, ES = 0.63; PR = + 8.6% ES = 0.54), and for TS (TD = + 11.6%, ES = 0.78; PR = + 10.6%, ES = 0.71). For the body composition components there were no significant group by time interaction for any of the components (fat-free mass: F = 1.30, *P* = 0, 25; skeletal muscle mass: F = 2.87, *P* = 0.09). Similarly, no main effect of group was observed (fat-free mass: F = 0.09, *P* = 0.75; skeletal muscle mass: F = 0.05, *P* = 0.82). However, statistical significance for the main effect of time was observed (fat-

free mass: F = 29.74, $P < 0.001$; skeletal muscle mass: F = 65.58, $P < 0.001$) in which both groups increased fat-free mass (TD = + 2.1%, ES = 0.27; PR = + 1.3%, ES = 0.18) and skeletal muscle mass (TD = + 3.6%, ES = 0.32; PR = +2 4%, ES = 0.24).

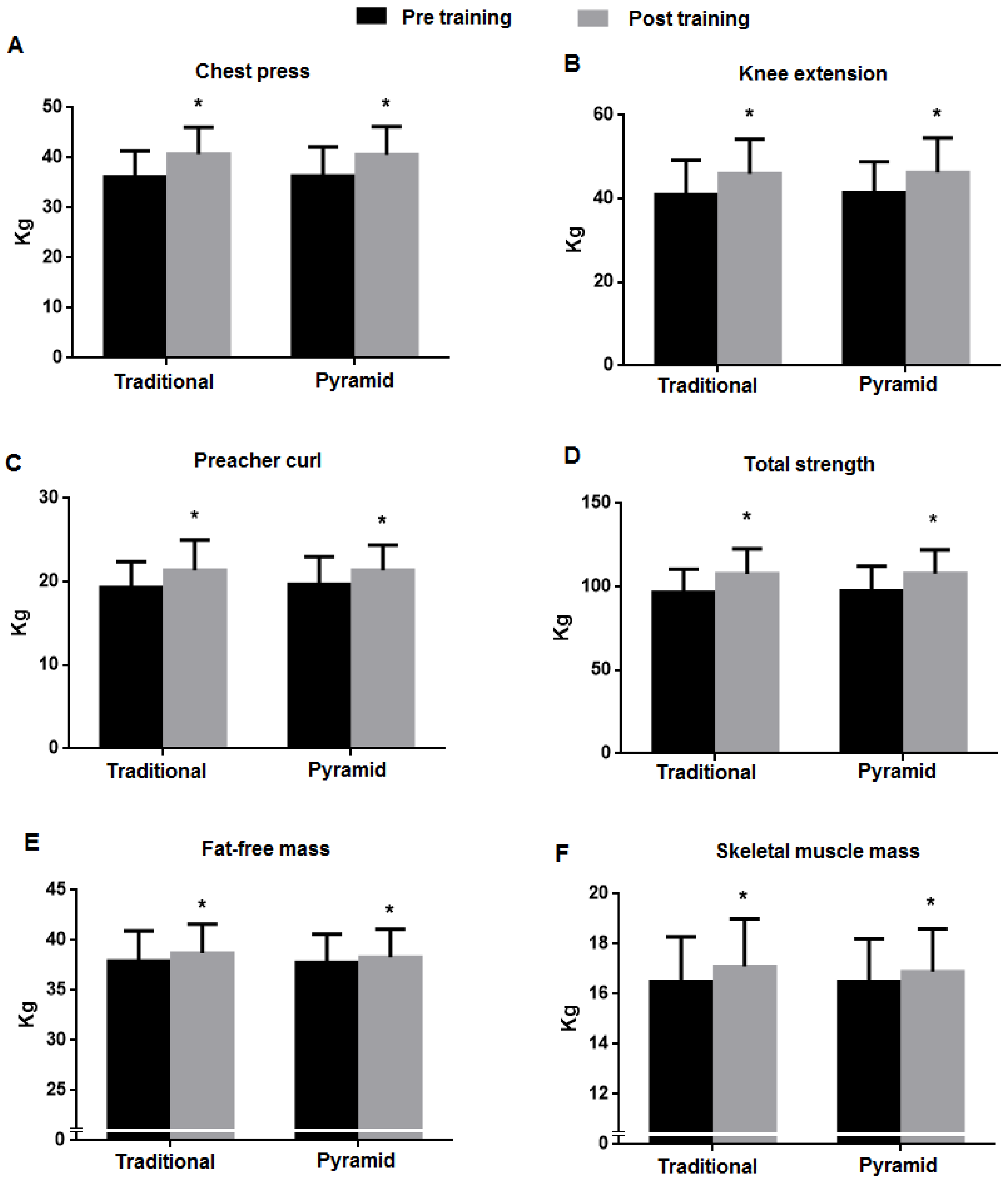

Figure 2.3 – Muscular strength, fat-free mass, and skeletal muscle mass at pre and post training. * $P < 0.05$ vs. pre training. Data are expressed as mean and standard deviation. There were no statistical significant group by time interaction.

Figure 2.4 depicts the weekly volume load. There was a significant group by time interaction (F = 6.59, $P < 0.001$), in which differences between the two groups started from the third week, with the traditional system reaching higher volume of loads in comparison to pyramid.

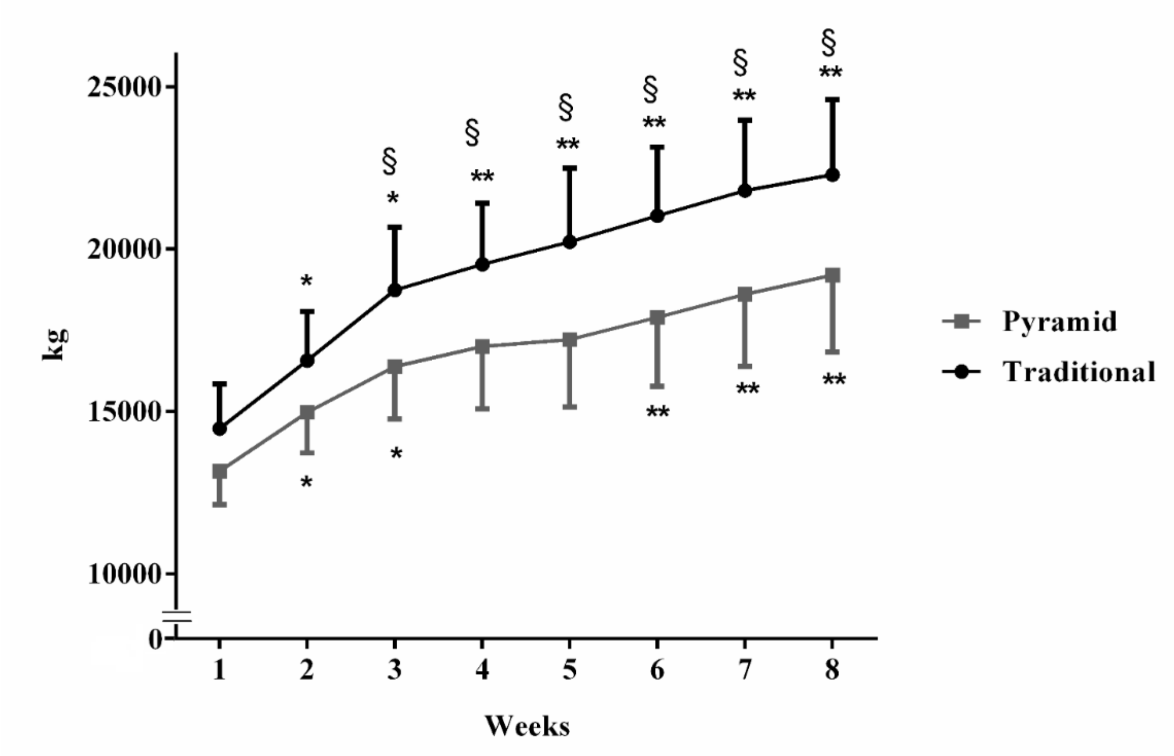

Figure 2.4 – Weekly volume of load during a resistance-training program in older women according to resistance-training system. * $P < 0.05$ vs. previous week. ** $P < 0.05$ vs. two previous weeks. § $P < 0.05$ vs. Pyramid. There is a significant statistical group by time interaction.

Values at pre and post training for TBW, ICW, ECW, IGF-1, and testosterone are presented in Table 2.2. Both systems elicited increases in intracellular water. There were no significant differences for any hormones. The effect of 12 weeks detraining is presented in Table 2.3, there were no group by time interaction for any of the outcomes analyzed, indicating that the system did not influence the outcomes.

Table 2.2. Total body water and its intra and extracellular fractions, and anabolic hormones in older women at pre and post training according to resistance training system. Data are expressed as mean and standard deviation.

	Traditional	Pyramid	Effects	F	*P*
Total body water (L)					
Pre training	29.0 ± 2.7	29.2 ± 3.1	Group	< 0.01	0.98
Post training	29.4 ± 3.2	29.5 ± 3.3	Time	0.73	0.39
Δ%	1.4	1.0	Interaction	1.09	0.30
Effect size	0.14	0.09			
Intracellular water (L)					
Pre training	15.8 ± 1.9	16.1 ± 2.1	Group	< 0.01	0.95
Post training	16.3 ± 2.2*	16.5 ± 2.2*	Time	2.27	0.05
Δ%	3.2	2.5	Interaction	1.16	0.10
Effect size	0.24	0.19			
Extracellular water (L)					
Pre training	13.1 ± 1.4	13.1 ± 1.5	Group	0.01	0.90
Post training	13.0 ± 1.4	12.9 ± 1.4	Time	2.41	0.12
Δ%	-0.8	-1.5	Interaction	0.06	0.80
Effect size	-0.07	-0.14			
IGF-1 ($ng.mL^{-1}$)					
Pre training	137.1 ± 35.0	134.2 ± 43.7	Group	3.01	0.10
Post training	140.1 ± 32.9	137.5 ± 39.2	Time	0.30	0.58
Δ%	2.2	2.5	Interaction	0.17	0.68
Effect size	0.09	0.08			
Testosterone ($ng.mL^{-1}$)					
Pre training	0.35 ± 0.7	0.33 ± 0.4	Group	1.37	0.25
Post training	0.36 ± 0.5	0.34 ± 0.3	Time	0.29	0.59
Δ%	2.9	3.0	Interaction	1.56	0.22
Effect size	0.02	0.03			

Table 2.3 – Changes after 12 weeks of detraining. Data expressed as mean and standard deviation.

	Traditional (n = 13)				Pyramid (n = 12)				*P* value		
	Before	After			Before	After			Group	Time	Interaction
Dietary pattern	Mean ± standard deviation		ES	Δ%	Mean ± standard deviation		ES	Δ%			
Energy (kcal.kg^{-1}.d^{-1})	22.9 ± 7.9	22.9 ± 7.5	0.00	0.0	20.7 ± 8.9	22.2 ± 9.7	0.16	7.2	0.77	0.83	0.84
Carbohydrate (g.kg^{-1}.d^{-1})	2.7 ± 0.9	3.0 ± 0.9	0.33	11.1	2.6 ± 0.6	3.0 ± 1.2	0.44	15.4	0.99	0.33	0.86
Protein (g.kg^{-1}.d^{-1})	1.1 ± 0.5	1.1 ± 0.5	0.00	0.0	0.9 ± 0.4	0.9 ± 0.3	0.00	0.0	0.46	0.87	0.89
Lipid (g.kg^{-1}.d^{-1})	0.8 ± 0.4	0.6 ± 0.2	-0.40	-25.0	0.7 ± 0.5	0.6 ± 0.3	-0.25	-14.3	0.79	0.66	0.78
Muscular strength											
Chest press (kg)	39.7 ± 5.3	38.0 ± 6.2*	-0.30	-4.3	37.4 ± 4.1	35.6 ± 4.9*	-0.40	-4.8	0.26	< 0.001	0.94
Knee extension (kg)	44.6 ± 4.9	43.3 ± 5.6*	-0.25	-2.9	44.2 ± 9.3	42.4 ± 9.5*	-0.19	-4.1	0.82	< 0.001	0.61
Preacher curl (kg)	22.0 ± 3.7	20.3 ± 3.9*	-5.53	-9.1	21.1 ± 2.9	19.1 ± 2.7*	-0.71	-9.5	0.44	< 0.001	0.68
Total strength (kg)	106.3 ± 12.6	101.6 ± 14.6*	-0.35	-4.4	102.7 ± 13.6	97.2 ± 14.2*	-0.40	-5.4	0.47	< 0.001	0.53
Body composition											
Fat-free mass (kg)	39.0 ± 2.4	38.2 ± 2.9*	-0.30	-2.1	38.1 ± 3.1	37.6 ± 3.5*	-0.15	-1.3	0.54	0.01	0.48
Muscle mass (kg)	17.3 ± 1.6	17.0 ± 1.7*	-0.18	-1.7	16.4 ± 1.7	16.1 ± 1.7*	-0.18	-1.8	0.19	0.01	0.96
Total body water (L)	29.3 ± 3.3	29.2 ± 3.4	-0.03	-0.3	28.8 ± 2.9	28.8 ± 2.7	0.00	0.0	0.72	0.94	0.96
Intracellular water (L)	16.3 ± 2.5	15.8 ± 2.4*	-0.20	-3.1	16.0 ± 1.9	15.6 ± 1.3*	-0.25	-2.5	0.77	0.05	0.89
Extracellular water (L)	13.0 ± 1.4	13.3 ± 1.6	0.20	2.3	12.8 ± 1.3	13.1 ± 1.4	0.22	2.3	0.71	0.09	0.77
Hormones											
IGF-1 (ng.mL^{-1})	143.1 ± 32.4	139.0 ± 28.9	-0.26	-2.9	138.8 ± 42.8	133.9 ± 39.5	-0.12	-3.5	0.21	0.09	0.32
Testosterone (ng.mL^{-1})	0.37 ± 0.8	0.35 ± 0.7	-0.03	-5.4	0.32 ± 0.2	0.29 ± 0.1	-0.20	-9.4	0.15	0.06	0.28

Note. ES = Effect size. * $P < 0.05$ vs. Before.

2.4 Discussion

The main and novel finding of this study was that the RT performed in pyramid system is equally as effective as a traditional system for promoting adaptations in muscular strength and hypertrophy in older women. Based on the premise that intensity and volume of training are two primary variables to stimulate neuromuscular adaptations [8, 16], we had hypothesized that the pyramid system would produce superior results. Contrary to our hypothesis, the results of this study failed to demonstrate a superiority of the pyramid over the traditional system.

To date, there is a paucity of longitudinal data on the topic. However, Hunter et al. [21] observed that a varied daily loading approach (80, 65 and 50% of 1RM) reduced the difficulty of performing daily activity tasks to a greater extent than training with a constant load (80% of 1RM) despite similar increases in strength and fat free mass between groups. However, some methodological issues between experiments need to be point out. For example, the Hunter et al. [21] study had a wider range of variance of load, not to mention the inclusion of elderly men and women that might confound the results since older women respond differently than older men to a RT program [22]. Moreover, we used a crossover design, an experimental procedure that reduces inter-individual bias and therefore strengthens our findings.

A confounding issue when evaluating muscle mass increases in studies that compare different intensities of training is that total volume often differs between models [23]. When the objective is to analyze hypertrophic responses, studies show that the total volume can be a deciding factor. For example, studies that compared different intensities with matched volume did not find statistical differences in muscle hypertrophy between low and high intensities [24, 25]. While studies with higher intensity but without volume equalization, lower intensity promotes inferior hypertrophic gains compared to moderate intensities [26, 27]. In this sense, the pyramid system theoretically allows training with higher loads, at least during the final sets of an exercise, without reducing the training volume from a loading zone standpoint. The results observed in this study indicate that increases in skeletal muscle mass are similar between the RT systems, despite a significantly lower volume load in the pyramid condition. A clear dose-response relationship has been reported between RT volume and muscle strength and hypertrophy [28]. However, beneficial effects for increasing volume undoubtedly follows an inverted-U curve, whereby once a given threshold is reached any further increases in volume would have no further effects and at some point lead to a regression in gains. The results of our study would seem to suggest that the threshold for volume in the population studied was achieved in the pyramid system, making the discrepancies in volume of load irrelevant from a hypertrophic standpoint. Alternatively, it is possible that increased intensities of load used in the later sets may have compensated for the reduced volume, thereby balancing out gains between conditions. These hypotheses warrant further investigation.

A potential factor that may contribute to the hypertrophic response is a chronic increase in intracellular hydration [29, 30], since the elevation of ICW content stimulates pathways that increase protein synthesis as well as those that diminish protein degradation [31, 32]. The present study observed changes in intracellular water. These findings are in line with previous work from our laboratory [33] showing that RT chronically increases intracellular water content in young men and women. Regimented RT has been shown to enhance glycogen storage, with an increase in resting concentrations of 66% reported following 5 months of regimented RT [34]. These changes are seemingly mediated by a combination of enzymatic upregulation as well as a greater glycogen storage capacity of larger muscles. Since every gram of glycogen attracts three grams of water [35], this provides a basis whereby consistent RT can elicit chronic increases in cellular hydration [34].

Blood concentrations of anabolic hormones are diminished with aging [36-38], which may lead to an attenuation of anabolic effects on muscles. No statistically significant changes were observed with respect to testosterone and IGF-1 levels after the RT period. These results are in line with previous studies that investigated the effects of RT on testosterone and IGF-1 in older women [39, 40]. Despite low levels of anabolic hormones, older women nevertheless are able realize significant increases in muscular hypertrophy following regimented RT. Importantly, our analysis only measured serum hormonal values; it remains possible the RT program induced changes at the hormone receptor level that enhanced anabolic processes [41].

Finally, it is important to note that findings here are specific to untrained elderly women and cannot necessarily be extrapolated to other populations. Whether results would differ for younger individuals, men, or those with previous resistance training experience remains to be determined.

2.5 Conclusion

We conclude that RT performed in pyramid system is an effective method to promote positive adaptations on muscular strength and hypertrophy in older women. However, it does not provide any inherent advantages over a traditional RT system. Thus, the practitioner can seemingly decide which system to use based on personal preference.

2.6 References

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CAPÍTULO 3

Artigo original 2

Resistance training in different systems improves muscular quality, and metabolic biomarkers in older women: a randomized crossover study

Abstract

The purpose of this study was to investigate the effect of resistance training (RT) performed in a pyramid versus traditional system on muscular quality and metabolic biomarkers in older women. Twenty-five older women (67.6 ± 5.1 years, 65.9 ± 11.1 kg, 154.7 ± 5.8 cm, and 27.5 ± 4.5 kg.m^{-2}) performed a RT program in traditional (TD) and pyramid (PR) system in a balanced crossover design. At the beginning and the end of each RT phase measurements of body fat, muscular quality, and serum levels of C-reactive protein (CRP), glucose (GLU), total cholesterol (TC), high-density lipoprotein (HDL-C), low-density lipoprotein (LDL-C) and triglycerides (TG) were conducted. The TD program consisted of 3 sets of 8-12 repetitions maximum (RM) with a constant load for the 3 sets, whereas the PR training consisted of 3 sets of 12/10/8 RM with incremental loads for each set. The training was performed in two phases of 8 weeks each, with a 12 week washout period between phases. Percent body fat decreased significantly ($P < 0.05$) in both groups (TD = -2.5%, PR = -1.8%) without a difference between them. Significant ($P < 0.05$) increases were observed in both groups for total muscular quality (TD = + 8.6%, PR = + 6.8%), upper limb muscle quality (TD = + 7.4%, PR = + 7.3%), and lower limb muscular quality (TD = + 8.3%, PR = + 8.1%) with no differences between groups. A significant main effect of time (P <0.05) was observed for GLU (TD = -4.5%, PR = -1.9%), TG (TD = -18.0%, PR = -11.7%), HDL-C (TD = +10.6, PR = +7.8%), LDL-C (TD = -23.3%, PR = -21.0%), and CRP (TD = -19.4%, PT= -14.3%). These results suggest that RT improves muscular quality, metabolic and inflammatory profile of elderly women independently of the system.

Keywords: aging, C-reactive protein, lipoproteins, muscular quality, strength training.

3.1 Introduction

Various morphological alterations are associated with biological aging that ultimately affect health and quality of life in older individuals. Reduction of muscular strength and skeletal muscle mass are two of the most significant changes that occur with aging, and the maintenance of muscle mass and strength is a fundamental component of health, functionality, and quality of life in older ages [1]. The strength produced per unit of muscle mass can be defined as muscle quality [2]. Such approach may be a more meaningful and sensitive indicator of muscle function than the analysis of strength or muscle mass alone [2].

Aging is also associated with biochemical alterations that increase the risk of developing cardiovascular disease, which is the major cause of morbidity and mortality in the older ages [3]. Among the risk factors, serum blood levels of glucose (GLU) and lipids profile have been shown to have a greater impact on cardiovascular disease risk in women compared to men [4]. Chronic inflammation has also been implicated as playing a role in cardiovascular disease [5]. To this end, elevations in C-reactive protein (CRP), an inflammation biomarker, may be considered an important independent indicator of mortality for cardiovascular and metabolic diseases [6].

Resistance training (RT) is an intervention that has been recommended to counteract the age-related dysfunctions [7, 8]. In addition to its effects on enhancing muscular strength and muscle mass, RT provides numerous additional benefits to older adults health that may directly impact cardiovascular disease risk including positive improvements in GLU, lipid profile [9-11], and a reduction in inflammatory biomarkers [12-14].

The principal guidelines to RT prescription [7, 8] recommend the use of same loads related to a given repetitions zone, a system known as traditional training. Such recommendations are based on abundant evidence about the effectiveness of this training system. However, other training systems have been developed over time by instructors, athletes, and practitioners in an attempt to maximize benefits. Among the different RT systems, the pyramid system is very popular and frequently used by athletes and non-athletes in order to improve the adaptations induced by RT. The pyramid system is characterized by increasing the load with a parallel decrease in repetitions across sets. Hypothetically, these alterations in 2 important variables may optimize the metabolic and mechanical stimuli necessary for muscle protein accretion [15]. Additionally, manipulation of volume and intensity can also promote other important metabolic responses, with a positive impact on the lipids profile [16, 17] and in inflammation biomarkers [18], since metabolic and inflammatory changes induced by RT may be dependent on the specific characteristics of the program [16-18]. Therefore, the purpose of this study was to compare the effects of RT performed in a pyramid versus traditional system on muscular quality and metabolic biomarkers in older women. We hypothesized that the pyramid system would provide superior improvements in the outcomes induced by RT.

3.2 Methods

3.2.1 Participants

Participant recruitment was carried out through newspaper and radio advertisings, and home delivery of leaflets in the central area and residential neighborhoods. All participants completed health history and physical activity questionnaires and met the following inclusion criteria: 60 years old or more, physically independent, free from cardiac or orthopedic dysfunction, not receiving hormonal replacement therapy, and not performing any regular physical exercise for more than once a week over the six months preceding the beginning of the study. Participants passed a diagnostic, graded exercise stress test with 12-lead electrocardiogram reviewed by a cardiologist and were released with no restrictions for participation in this study. Forty older women were accessed for eligibility. After individual interviews, 11 were dismissed as potential candidates because they did not meet the inclusion criteria for the study. The remaining 29 elderly women were selected for participation and then randomly divided into one of two groups according to the RT system: a group that performed RT in the traditional system (TD, n = 14) or a group that performed RT in the pyramid system (PR, n = 15). A total of 25 participants (67.6 ± 5.1 years, 65.9 ± 11.1 kg, 154.7 ± 5.8 cm, and 27.5 ± 4.5 $kg.m^{-2}$) completed all stages of the experiment, and were included in the analyses. The reasons for withdrawal were reported as lack of time, difficulty of displacement, lack of motivation, and personal reasons. Adherence to the program was satisfactory, with all subjects participating in >85% of the total sessions. Figure 3.1 is a schematic representation of participant recruitment and allocation. Written informed consent was obtained from all subjects after a detailed description of study procedures was provided. This investigation was conducted according to the Declaration of Helsinki, and was approved by the local University Ethics Committee.

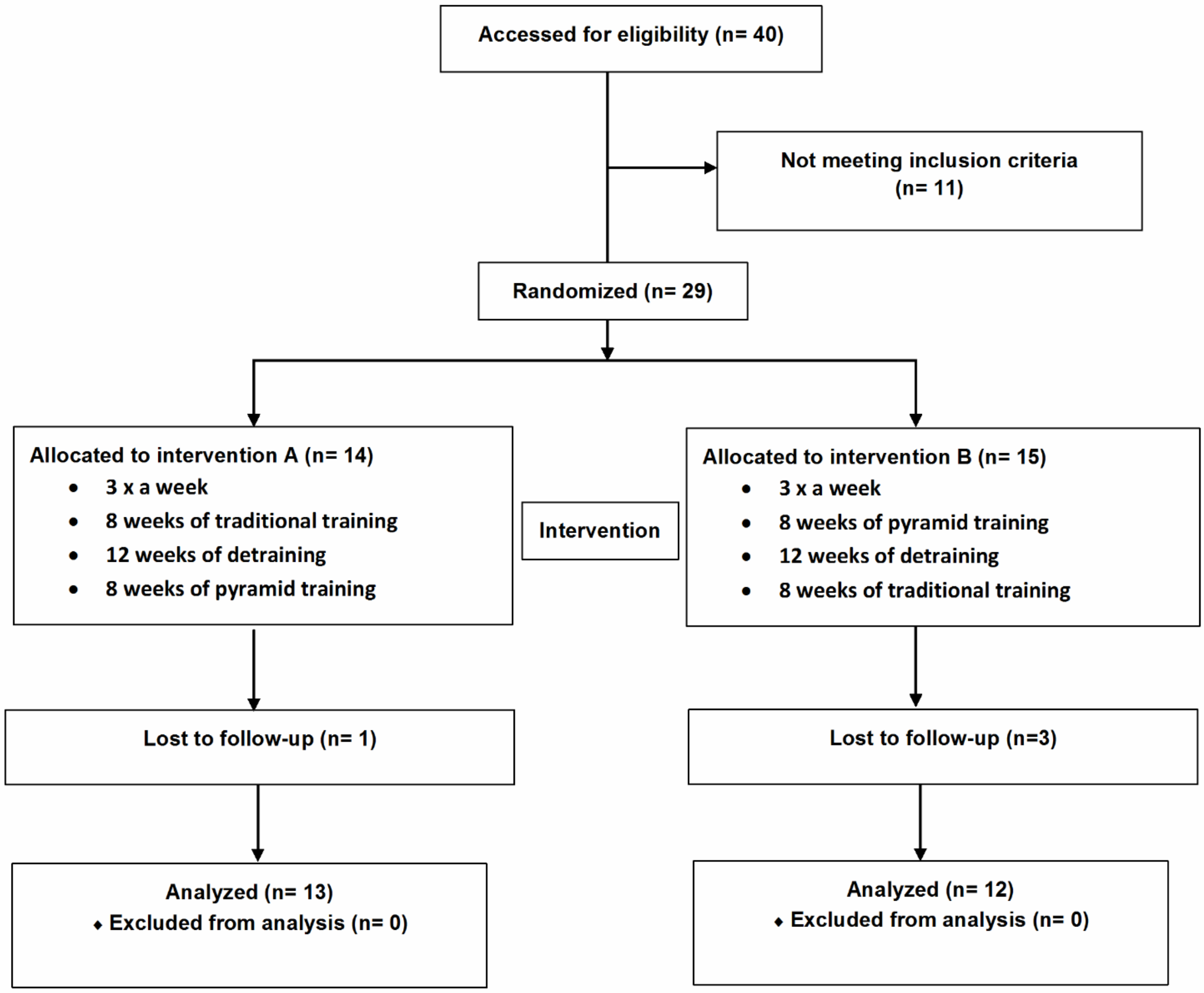

Figure 3.1 – Schematic representation of participants' recruitment and allocation.

3.2.2 Experimental design

The study was carried out over a period of 36 weeks divided into 3 phases. In the first phase, participants were randomly separated into two groups to perform 8-weeks (weeks 3-10) of RT according to the respective system (TD and PR). At phase 2, participants were given a 12-week period of detraining (weeks 13-24) in which no resistance exercise was performed. The intent of the detraining phase was to return participant's physical fitness levels to baseline values. Phase 3 employed a crossover so that those who previously performed the PR system underwent 8 weeks of training in the TD system (weeks 27-34) and those who previously performed the TD system engaged in an 8-week program in the PR system. At the beginning and the end of each stage of the experiment two weeks were used for evaluations (weeks 1-2, 11-12, 25-26 and 35-36) consisting of anthropometric measures, body composition analysis by dual energy X-ray absorptiometry (DXA), and blood work for biochemical analysis. The experimental design is displayed in Figure 3.2.

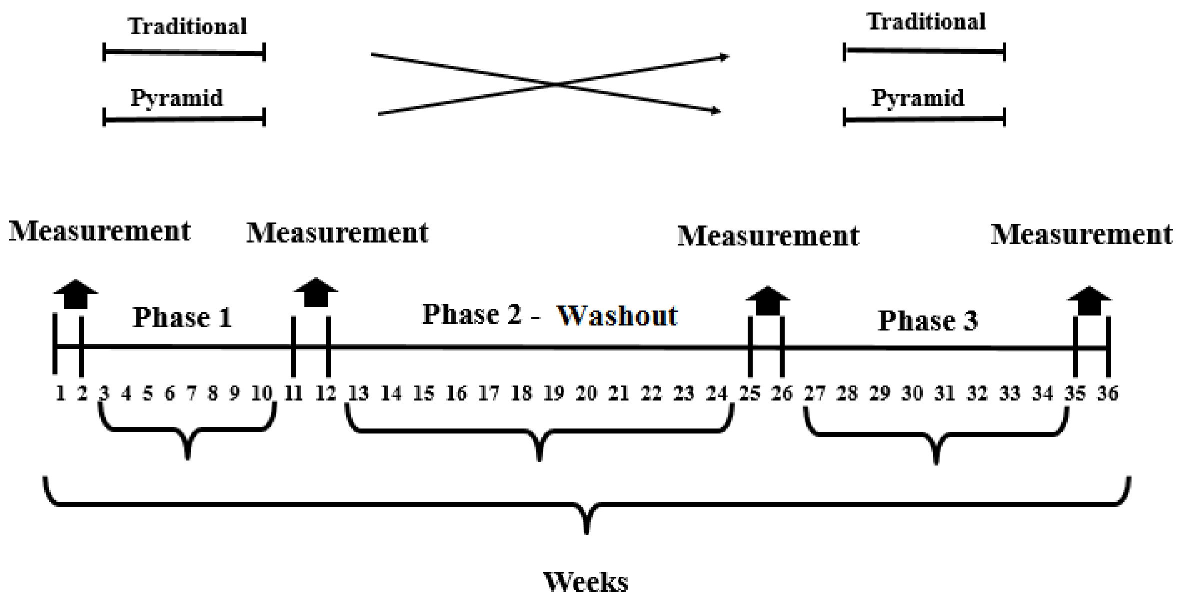

Figure 3.2 – Experimental design.

3.2.3 Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Balmak, Laboratory Equipment Labstore, Curitiba, Paraná, Brazil), with the participants wearing light workout clothing and no shoes. Height was measured with a stadiometer attached on the scale to the nearest 0.1 cm with subjects standing sans shoes. Body mass index was calculated as body mass in kilograms divided by the square root of height in meters.

3.2.4 Body composition

Whole body DXA scans (Lunar Prodigy, model NRL 41990, GE Lunar, Madison, WI) were used to asses body fat and appendicular lean soft tissue. The skeletal muscle mass was estimated by the predictive equation proposed by Kim et al. [19]. Prior to scanning, participants were instructed to remove all objects containing metal. Scans were performed with the subjects lying in the supine position along the table's longitudinal centerline axis. Feet were taped together at the toes to immobilize the legs while the hands were maintained in a pronated position within the scanning region. Subjects remained motionless during the entire scanning procedure. Both calibration and analysis were carried out by a skilled laboratory technician. The equipment calibration followed the manufacturer's recommendations. The software generated standard lines that set apart the limbs from the trunk and head. These lines were adjusted by the same technician using specific anatomical points determined by the manufacturer. Analyses during the intervention were performed by the same technician who was blinded to intervention time point. Previous test-retest scans of 10 older women measured 24-48 h apart resulted in a standard error of measurement of 0.29 kg 0.90 kg for skeletal muscle mass and percentage of body fat, respectively, and intraclass correlation coefficient of >0.990 and >0.980 for skeletal muscle mass and percentage of body fat, respectively.

3.2.5 Muscular strength

Maximal dynamic strength was evaluated using the 1RM test assessed on chest press, knee extension, and preacher curl performed in this exact order. Testing for each exercise was preceded by a warm-up set (6-10 repetitions), with approximately 50% of the estimated load used in the first attempt of the 1RM. This warm-up was also used to familiarize the subjects with the testing equipment and lifting technique. The testing procedure was initiated 2 minutes after the warm-up. The subjects were instructed to try to accomplish two repetitions with the imposed load in three attempts in both exercises. The rest period was 3 to 5 min between each attempt, and 5 min between exercises. The 1RM was recorded as the last resistance lifted in which the subject was able to complete only one single maximal execution [20]. Execution technique for each exercise was standardized and continuously monitored to ensure reliability. All 1RM testing sessions were supervised by 2 experienced researchers for greater safety and integrity of the subjects. Verbal encouragement was given throughout each test. Three 1RM sessions were performed separated by 48 hours (ICC ≥ 0.96). The highest load achieved among the 3 sessions was used for analysis in each exercise. Total strength was determined by the sum of the 3 exercises.

3.2.6 Muscular quality

The total muscle quality index was determined by dividing the total strength that was determined by the sum of the 3 exercises by the total skeletal muscle mass. Upper limb muscle quality was determined from division of the load mobilized in the preacher curl exercise by the arms lean soft tissue, while the lower limb muscle quality was be determined from division of the load mobilized in knee extension exercise by the legs lean soft tissue (2).

3.2.7 Biochemical analysis

Serum levels of high-sensitivity C-reactive protein (CRP), glucose (GLU), total cholesterol (TC), high-density lipoprotein (HDL-C), low-density lipoprotein (LDL-C), and triglycerides (TG) were measured after 12 h fasting by a laboratory technician. The blood was taken from the antecubital vein. The subjects were instructed not to perform vigorous exercise for the preceding 24 h and to avoid alcohol or caffeinated beverages 72 h before collection. Measurements were performed by standard methods in a specialized laboratory at University Hospital. Samples were deposited in vacuum tubes with a gel separator without anticoagulant and were centrifuged for 10 min at 3000 rpm for serum separation. Thereafter, the PCR, TG, and HDL-C concentrations were determined. The LDL-C was calculated using the Friedewald, Levy, & Fredrickson (21) equation, where LDL-C = TC - (HDL-C + TGL/5). The analyses were carried out using a biochemical auto-analyzer system (Dimension RxL Max - Siemens Dade Behring) according to established methods in the literature consistent with the manufacturer's recommendations. The participants were stratified according to the classification reported in literature for lipid profile, (22) glucose, (23) and CRP (24).

3.2.8 Resistance training program

Supervised RT was performed in the State University fitness facilities. The protocol was based on recommendations for RT in an older population to improve muscular strength and hypertrophy (8, 25). Physical education professionals to ensure consistent and safe performance personally supervised all participants. Subjects performed RT using a combination of free weights and machines. The sessions were performed 3 times per week on Mondays, Wednesdays, and Fridays during the morning hours. The RT program was a whole body program with 8 exercises comprising one exercise with free weights and seven with machines performed in the following order: chest press, horizontal leg press, seated row, knee extension, preacher curl (free weights), leg curl, triceps pushdown, and seated calf raise.

Participants of the TD group performed 3 sets of 8-12 repetitions maximum with the same load in the 3 sets. While the participants of the PR group performed 3 sets with the load increasing and number of repetitions simultaneously decreasing for each set, thus, the number of repetitions used in each set was 12/10/8/ repetition maximum, respectively, with variable resistance. For both systems, the participants carried out exercises until muscle failure or an inability to sustain exercise performance with proper form.

Participants were instructed to inhale during the eccentric phase and exhale during the concentric phase while maintaining a constant velocity of movement at a ratio of approximately 1:2 seconds (concentric and eccentric phases, respectively). Participants were afforded 1 to 2 min of rest interval between sets and 2 to 3 min between each exercise. Instructors adjusted the loads of each exercise according to the subject's abilities and improvements in exercise capacity throughout the study in order ensure that the subjects were exercising with as much resistance as possible while maintaining proper exercise technique. Progression for the traditional training was planned when the upper limits of the repetitions-zone were completed for two consecutive training sessions and for pyramid training when the participant was able to perform two more repetitions in the last set. For both systems weight was increased 2-5% for the upper limb exercises and 5-10% for the lower limb exercises to the next session (7).

3.2.9 Statistical analyses

Two-way analysis of variance (ANOVA) for repeated measures was applied for comparisons. When F-ratio was significant, Bonferroni's post hoc test was employed to identify the mean differences. The effect size (ES) was calculated as post training mean minus pre training mean divided by pooled standard deviation of pre and post training (26). For all statistical analyses, significance was accepted at $P < 0.05$. The data were analyzed using STATISTICA software version 10.0 (STATSOFT INC., TULSA, OK, USA).

3.3 Results

The changes from pre to post training in body fat, appendicular muscle mass and muscle quality are displayed in Table 3.1. No significant interactions were observed. However, a significant main effect of time was observed for body fat, upper and lower limb muscle mass, and for total muscle quality as well as upper and lower muscle quality, with both system showing similar improvements.

Table 3.2 displays the metabolic parameters at pre and post training. There were no significant interaction for any variable. Main effects of time were observed for GLU, TG, HDL-C, LDL-C, and CRP, with both groups showing similar improvements. Table 3 presents the number of subjects before and after the RT program, according to the metabolic and inflammatory profile classification. The effect of 12 weeks detraining is presented in Table 4. There were no interactions for any of the outcomes analyzed.

Table 3.1 – Body fat, appendicular skeletal muscle mass and muscle quality in older women according to resistance training system. Data are expressed as mean and standard deviation.

	Traditional	Pyramid	Effects	F	*P*
Body fat (%)					
Pre training	39.7 ± 7.7	39.8 ± 7.7	Group	0.01	0.89
Post training	38.7 ± 8.0*	39.1 ± 7.6*	Time	28.08	< 0.001
Δ%	-2.5	-1.8	Interaction	1.17	0.18
Effect size	-0.13	-0.09			
ULSMM (kg)					
Pre training	3.5 ± 0.4	3.5 ± 0.3	Group	0.05	0.81
Post training	3.7 ± 0.4*	3.6 ± 0.3*	Time	9.54	< 0.05
Δ%	5.7	2.9	Interaction	3.29	0.08
Effect size	0.50	0.33			
LLSMM (kg)					
Pre training	11.4 ± 1.3	11.4 ± 1.3	Group	0.06	0.80
Post training	11.9 ± 1.4*	11.7 ± 1.3*	Time	46.42	< 0.001
Δ%	4.4	2.6	Interaction	2.19	0.14
Effect size	0.37	0.23			
TMQ					
Pre training	5.8 ± 0.7	5.9 ± 0.8	Group	0.14	0.70
Post training	6.3 ± 0.8*	6.3 ± 0.8*	Time	80.15	< 0.001
Δ%	8.6	6.8	Interaction	0.05	0.81
Effect size	0.67	0.50			
ULMQ					
Pre training	5.4 ± 0.6	5.5 ± 0.7	Group	0.26	0.60
Post training	5.8 ± 0.7*	5.9 ± 0.6*	Time	48.28	< 0.001
Δ%	7.4	7.3	Interaction	< 0.01	0.98
Effect size	0.62	0.62			
LLMQ					
Pre training	3.6 ± 0.7	3.7 ± 0.7	Group	0.17	0.73
Post training	3.9 ± 0.8*	4.0 ± 0.8*	Time	50.66	< 0.001
Δ%	8.3	8.1	Interaction	0.02	0.86
Effect size	0.40	0.40			

Note: ULSMM = upper limb skeletal muscle mass. LLSMM = lower limb skeletal muscle mass. TMQ = total muscle quality. ULMQ = upper limb muscle quality. LLMQ = lower limb muscle quality. * $P < 0.05$ vs. pre training.

Table 3.2. Metabolic biomarkers in older women according to resistance training system before and after the intervention. Data are expressed as mean and standard deviation.

	Traditional	Pyramid	Effects	F	*P*
Glucose (mg.dL^{-1})					
Pre training	99.2 ± 17.7	96.2 ± 9.8	Group	0.19	0.66
Post training	94.7 ± 17.7*	94.4 ± 10.0*	Time	5.46	0.02
Δ%	-4.5	-1.9	Interaction	1.10	0.29
Effect size	-0.25	-0.18			
Total cholesterol (mg.dL^{-1})					
Pre training	215.8 ± 48.7	209.0 ± 39.8	Group	0.92	0.34
Post training	212.6 ± 40.0	201.7 ± 35.0	Time	0.53	0.47
Δ%	-1.5	-3.8	Interaction	0.08	0.77
Effect size	-0.07	-0.21			
Triglycerides (mg.dL^{-1})					
Pre training	140.9 ± 75.4	130.1 ± 60.5	Group	0.34	0.55
Post training	111.1 ± 49.6*	114.9 ± 51.3*	Time	3.98	0.04
Δ%	-18.0	-11.7	Interaction	1.93	0.17
Effect size	-0.40	-0.27			
HDL-C (mg.dL^{-1})					
Pre training	49.8 ± 12.7	51.1 ± 12.7	Group	0.38	0.53
Post training	55.1 ± 14.5*	55.1 ± 13.0*	Time	4.47	0.03
Δ%	+10.6	+7.8	Interaction	2.08	0.15
Effect size	0.38	0.31			
LDL-C (mg.dL^{-1})					
Pre training	137.7 ± 36.7	130.8 ± 39.1	Group	0.29	0.58
Post training	105.6 ± 37.9*	103.3 ± 32.9*	Time	23.97	< 0.001
Δ%	-23.3	-21.0	Interaction	0.14	0.70
Effect size	-0.86	-0.76			
C-reactive protein (mg.L^{-1})					
Pre training	3.1 ± 2.1	2.8 ± 2.2	Group	0.20	0.65
Post training	2.5 ± 2.1*	2.4 ± 1.5*	Time	3.74	0.04
Δ%	-19.4	-14.3	Interaction	0.53	0.46
Effect size	-0.29	-0.22			

Note: HDL-C = high-density lipoprotein. LDL-C = low-density lipoprotein. * $P < 0.05$ vs. pre training.

Table 3.3. Number of subjects at pre- and post-training, according to blood biomarkers.

Variables	Traditional		Pyramid	
	Pre-training	Post-training	Pre-training	Post-training
	n (%)	n (%)	n (%)	n (%)
Glucose (mg.dL^{-1})				
Altered (≥100)	9 (36)	6 (24)	6 (24)	5 (20)
Normal (<100)	16 (64)	19 (76)	19 (76)	20 (80)
Total cholesterol (mg.dL^{-1})				
High (≥240)	6 (24)	6 (24)	6 (24)	4 (16)
Borderline (200-239)	10 (40)	10 (40)	6 (24)	7 (28)
Desirable (<200)	9 (36)	9 (36)	13 (52)	14 (56)
Triglycerides (mg.dL^{-1})				
Very high (≥500)	0 (0)	0 (0)	0 (0)	0 (0)
High (200-499)	4 (16)	2 (8)	4 (16)	2 (8)
Borderline (150-199)	5 (20)	3 (12)	3 (12)	4 (16)
Desirable (<150)	16 (64)	20 (80)	18 (72)	19 (76)
HDL-C (mg.dL^{-1})				
High (≥60)	7 (28)	9 (36)	9 (36)	9 (36)
Good (40-59)	12 (48)	13 (52)	14 (56)	14 (56)
Low (<40)	6 (24)	3 (12)	2 (7)	2 (7)
LDL-C (mg.dL^{-1})				
Very high (≥190)	3 (12)	0 (0)	2 (8)	0 (0)
High (160-189)	3 (12)	2 (8)	5 (20)	2 (8)
Borderline (130-159)	7 (28)	4 (16)	2 (8)	4 (16)
Desirable (100-129)	8 (32)	6 (24)	10 (40)	3 (12)
Optimal (<100)	4 (16)	13 (52)	6 (24)	16 (54)
C-reactive protein (mg.L^{-1})				
Low risk (<1)	0 (0)	5 (20)	0 (0)	3 (12)
Moderate risk (1-3)	18 (72)	15 (60)	19 (76)	16 (64)
High risk (>3)	7 (28)	5 (20)	6 (24)	6 (24)

Note. HDL-C = high-density lipoprotein. LDL-C = low-density lipoprotein.

Table 3.4 – Changes after 12 weeks of detraining. Data expressed as mean and standard deviation.

	Traditional (n = 13)				Pyramid (n = 12)				*P* value		
	Before	After			Before	After			**Group**	**Time**	**Interaction**
Body composition	Mean ± standard deviation		ES	Δ%	Mean ± standard deviation		ES	Δ%			
Body fat (%)	36.6 ± 8.2	37.9 ± 7.4*	0.17	3.6	40.9 ± 8.1	41.7 ± 7.3*	0.10	2.0	0.20	0.01	0.37
Upper limb muscle mass (kg)	3.7 ± 0.4	3.6 ± 0.4*	-0.25	-2.7	3.5 ± 0.3	3.4 ± 0.3*	-0.33	-2.9	0.21	0.01	0.68
Lower limb muscle mass (kg)	12.0 ± 1.1	11.7 ± 1.2*	-0.26	-2.5	11.4 ± 1.4	11.1 ± 1.4*	-0.21	-2.6	0.26	< 0.001	0.83
Total muscle quality	6.1 ± 0.6	6.0 ± 0.8*	-0.14	-1.6	6.2 ± 0.8	6.0 ± 0.8*	-0.25	-3.2	0.84	0.01	0.19
Upper limb muscle quality	5.9 ± 0.8	5.6 ± 0.9*	-0.35	-5.1	6.0 ± 0.5	5.5 ± 0.4*	-1.11	-8.3	0.92	< 0.001	0.42
Lower limb muscle quality	3.7 ± 0.4	3.7 ± 0.5	0.00	0.0	3.9 ± 0.9	3.8 ± 0.9	-0.11	-2.6	0.62	0.18	0.42
Metabolic biomarkers											
Glucose (mg.dL^{-1})	87.9 ± 8.8	94.6 ± 7.2*	0.84	7.62	93.6 ± 10.3	104.5 ± 22.1*	0.51	8.52	0.08	0.01	0.50
Total cholesterol (mg.dL^{-1})	208.0 ± 45.5	208.3 ± 47.3	0.01	0.14	208.3 ± 39.0	215.0 ± 37.5	0.18	3.2	0.83	0.44	0.49
Triglycerides (mg.dL^{-1})	102.7 ± 45.5	113.5 ± 67.2	0.19	10.5	121.3 ± 51.2	125.0 ± 54.1	0.07	3.1	0.46	0.40	0.68
HDL-C (mg.dL^{-1})	54.0 ± 14.5	49.7 ± 12.2*	-0.32	-8.0	58.8 ± 12.6	52.2 ± 14.4*	-0.49	-11.2	0.50	< 0.001	0.21
LDL-C (mg.dL^{-1})	76.3 ± 16.7	135.9 ± 45.0*	1.93	78.1	83.1 ± 7.7	137.7 ± 28.7*	3.00	65.7	0.59	< 0.001	0.76
C-reactive protein (mg.L^{-1})	1.4 ± 1.4	2.6 ± 1.2*	0.92	85.7	2.1 ± 1.6	3.5 ± 2.3*	0.72	66.7	0.21	< 0.001	0.80

Note. ES = Effect size. * *P* < 0.05 vs. Before.

3.4 Discussion

The main and novel finding is that RT performed in either a traditional or pyramid system improves muscular quality as well as metabolic biomarkers in this population. We had hypothesized that training in a pyramid fashion would produce superior improvements in the aforementioned outcomes; our hypothesis was refuted. To the authors' knowledge, this is the first study to compare the adaptive responses from different RT systems on muscular quality and metabolic biomarkers in older women.

The relationship between strength and muscle volume has been described as muscular quality, which reflects the strength produced by a specific muscular volume [2, 27, 28]. Our results showed that muscle quality increased after training regardless of the system used, indicating more strength was produced per unit of muscle mass in the women's arms and legs. These results corroborate previous studies that reported an increase in muscle quality after a RT period [29-32]. Our study expands on previous findings by comparing muscle quality in 2 different RT systems, and showing that both conditions equally improved this outcome. Another important feature of our study is that we examined changes in muscle quality on a regional basis which is especially important in the elderly because the age-related decline in muscle quality observed in women are different between limbs, with a greater age-related decline has been seen in legs than in arms [33]. The mechanisms related to improvements in muscle quality are complex and not fully understood. However, it has been speculated that improvements from RT may be related to factors such as neural adaptations, increased muscle cross sectional area, increased muscle power, increased contractile protein, increased resting fascicle length due to addition of sarcomeres in series, muscle fiber re-innervation, alterations in muscle architecture, and/or a reduction in lipid deposits within the muscle [2].

Reductions in body fat in this investigation occurred without difference between groups. Previous research has shown decreased body fat in older women after a period of RT [34, 35]. These results may be partly attributed to similar increases in lean soft tissue, given its relationship with resting metabolic rate [36, 37]. Another factor to consider is that RT protocols have been shown to produce increases in excess post-exercise oxygen consumption [38].

The inflammatory state may be identified by the CRP blood levels [39], which is the most widely used biomarker of systemic inflammation and considered an independent factor of cardiovascular disease [40-42]. Our results indicate that both RT systems are effective for improving inflammatory status as reflected by a reduction in blood levels of CRP. Previous studies have found reductions in CRP after a RT program in older women [12, 18, 43-47]. For example, Lera Orsati et al. [46] showed that RT performed 3 times a week was able to reduce CRP levels in sedentary obese elderly women after 16 weeks of training. Similarly, Phillips et al. [12] observed a 33% reduction on CRP in obese postmenopausal women after 12 weeks of RT. Muscle contraction produce anti-inflammatory myokines that antagonize pro-inflammatory cytokines, which thus may help to lower CRP levels [48]. Myokines are sensitive to the intensity of exercise [48], and given that the pyramid system allows the use of higher loads in the final set we speculated it would result in a greater anti-inflammatory response; this hypothesis was refuted. Moreover, changes in some body composition components such as body fat and skeletal muscle mass may play an important role in mediating inflammatory levels [18, 40, 43-45, 47], and RT has a positive impact on both of these outcomes. The positive changes in body composition experienced by both groups may therefore be ultimately responsible for the improvements noted in CRP levels. On the other hand, some investigations have observed that reductions in CRP are independent of body composition changes [12, 46]. Alternatively, some authors have reported no effect of RT on CRP in older individuals [49, 50]. These conflicting results may be at least partly related to methodological issues between studies such as training protocols that used different volumes and/or intensities, differences in characteristics of the subjects (e.g. obese versus non-obese), and differences in baseline CRP levels. Another important issue is the disparate inter-individual response to RT [51]. These conflicting findings warrant further investigation to elucidate the mechanisms responsible for the beneficial impact of RT on inflammatory measures.

Another risk factor for cardiovascular disease studied was the lipid profile. No reductions in TC were noted for either group post-intervention. However, it is noteworthy that the TC includes both LDL-C and HDL-C, and given the antagonistic differences between these two lipoproteins on health, analysis of TC alone can be misleading. With respect to specific lipoproteins fractions and TG, we observed beneficial changes to both HDL-C and LDL-C as well as to the TG irrespective of the training system. There is evidence suggesting that the manipulation of RT variables can influence the alterations in lipid profile [16, 17], but our study failed to demonstrate a disparate response in this regard. Therefore, the information regarding optimal intensity, volume and type of training to promote significant changes in blood lipids are still incipient. Our results are in line with previous studies that found positive effects of RT on lipoprotein fractions in older women [10, 11, 52]. The mechanisms of the RT effect on lipid profile have yet to be fully elucidated, and this study does not present mechanistic insight. That said, it is reasonable to speculate that lipid-lowering benefits of RT may lie in an increased ability of skeletal muscle to use fat [53, 54]. This effect is conceivably due to enzymatic changes that regulate the metabolism of lipoproteins, which includes an increase in lipoprotein lipase that mediates LDL plasma removal and lipid oxidation, and an increase in lecithin-cholesterol acyltransferase, an enzyme responsible for HDL-C transfer [53]. However, other studies show no improvement in lipoprotein profile after a period of RT [46, 55]. Discrepancies across findings are not clear, but may be related to factors such as initial lipid levels, age, duration and intensity of training, body fat, and duration of experiments. Moreover, it is inherently difficult to control the diet of participants throughout an experimental period, further confounding the ability to draw mechanistic conclusions. In addition, the responsiveness of the lipid profile induced by RT is dependent on genotype [56, 57], raising the likelihood that genetic factors ultimately determine the degree to which RT influences lipid profile.

With respect to fasting blood glucose, our experiment noted significant reductions after participation in the RT program. This reduction is logical given that RT primarily relies on the glycolytic pathway for energy [58] and thus the immediate effects from the exercise bout alone helps to improve glucose homeostasis. Moreover, RT enhances insulin sensitivity via multiple mechanisms including an increase in skeletal muscle mass and qualitative improvement in muscle metabolic properties such as increased density of GLUT-4 transporters and an increase in the content/activity of the enzyme glycogen synthase [59]. It therefore is not surprising that the present study observed reductions on blood glucose. As with other health-related markers, however, no differences were found between conditions, suggesting both approaches are equally effective in improving glucose homeostasis.

Finally, the results reported here are specific to older women and cannot necessarily be extrapolated to other populations. Moreover, we were not able to monitor physical activity levels outside of the study environment, which may have confounded results. On the other hand, to our knowledge the present study is the first to investigate the effect of different RT systems on muscle quality, metabolic biomarkers in older women using a crossover design, thus representing an important contribution to the current body of literature.

3.5 Conclusion

The results suggest that RT is an effective strategy to improve the muscular quality, metabolic and inflammatory profile of older women, and that these adaptations are not dependent on the training system.

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CAPÍTULO 4

Artigo original 3

Traditional and pyramidal resistance training effects on muscular strength and hypertrophy in older women with differing levels of experience

Running head: resistance training with different systems

Abstract

The purpose of this study was to investigate the effect of resistance training (RT) performed in a pyramid versus traditional system on muscular strength and hypertrophy in untrained and trained older women. Sixty-eight older women (68.9 ± 5.9 years, 67.0 ± 13.0 kg, 155.3 ± 6.1 cm, and 27.6 ± 4.9 kg.m^{-2}) were separated into 4 groups based on combinations of RT experience and training protocol: trained traditional (TT, n = 16), trained pyramid (TP, n = 17), novice traditional (NT, n = 17), and novice pyramid (NP, n = 18). At the beginning and the end of RT programs measurements of 1 repetition maximum (RM) tests and dual X-ray absorptiometry were conducted to determine changes in strength and skeletal muscle mass, respectively. The RT program was carried out 3 days-per-week for 8 weeks, where the traditional RT consisted of 3 sets of 8-12 RM with constant load for the 3 sets, whereas the pyramid RT consisted of 3 sets of 12/10/8 RM with incremental loads for each set. Significant ($P < 0.05$) time vs. training status interactions were observed, in which NT and NP groups showed a higher increase than TT and TP groups for muscular strength in the 1RM chest press (TT = +2.9%, TP = +2.4%, NT = +11.3%, NP = +11.4%), knee extension (TT = +6.7%, TP = +6.3%, NT = +15.7%, NP = +19.1%), preacher curl (TT = +4.9%, TP = +4.1%, NT = +12.2%, NP = +11.9%), and for skeletal muscle mass (TT = +1.4%, TP = +1.0%, NT = +3.8%, NP = +3.3%) with no differences between systems. The results suggest that the pyramid system is similarly effective to traditional training for promoting positive adaptations in muscular strength and hypertrophy in older women independently of the training status level.

Keywords: strength training, aging, training system, skeletal muscle mass.

4.1 Introduction

The age-related reductions in muscular strength and skeletal muscle mass levels observed in older women are negatively associated with the health, functional autonomy, survival and quality of life [1-3]. Resistance training (RT) is a well-recognized method of exercise for eliciting increases in muscular strength and hypertrophy, and thus has been promoted as a means to attenuate these deleterious effects of aging [4-6].

Regular RT induces muscular strength and hypertrophy through mechanical, metabolic and hormonal process [6, 7]. A review of literature indicates that mechanical stress is the primary stimulus for this response whereby mechanical loading leads to a series of intracellular events that ultimately regulates gene expression and protein synthesis [7-9]. Mechanical stress associated with RT exercise disturbs the integrity of skeletal muscle, causing mechano-chemically-transduced molecular and cellular responses in myofibres and satellite cells. This conversion of mechanical energy into chemical signals mediates intracellular anabolic and catabolic pathways, ultimately leading to a shift in muscle protein balance that favors synthesis over degradation [7, 8]. Moreover, mechanical stress itself has been shown to directly stimulate the serine-threonine kinase mechanistic target of rapamycin, which has been shown to be a key factor to stimulate protein synthesis in a load-dependent manner [7, 8]. Mechanical loading also elicits acute increases in anabolic hormones such as testosterone and insulin like growth factor (IGF-1), although the hypertrophic effects of this response remains equivocal [7, 8, 10]. Given these outcomes, increasing mechanical tension during RT could hypothetically have a positive impact on mediating intracellular anabolic signaling and thus promote a more robust hypertrophic response.

Specifically, in older women, studies have shown a clear dose-response between intensity and an increase in muscular strength and hypertrophy [11-14]. Nevertheless, there is an interdependence between volume and intensity in which increasing RT intensity results in a decreased training volume. For this reason, the adoption of RT systems that allow the execution of higher intensities without drastic reductions in volume have been suggested to optimize volume and intensity. The pyramid system, due to its inherent characteristic of varying loads and number of repetitions, permits exercise performance at higher intensities without necessarily reducing the volume from a specific loading zone standpoint. This may promote a favorable anabolic environment for increased strength and muscle hypertrophy, maximizing the combination of mechanical (heavy loads) and metabolic (accumulation of metabolic byproducts) stimuli.

Adaptive responses to training are individual and dependent on an individual's training experience with RT [15-17]. In untrained individuals, the ability to compare muscular adaptations to different systems is confounded by the fact they tend to respond favorably to multiple training stimuli. Therefore, experiments seeking to compare different forms of training manipulation that include untrained individuals must be interpreted with a degree of circumspection as results may be primarily a function of the unfamiliarity of exercise, and virtually any training system may provide a sufficient stimulus to bring about training adaptations. Accordingly, studying the response of individuals with longer training experience may be necessary to determine the potential advantages of different RT systems. On the other hand, further muscular adaptations become progressively more difficult as one gains training experience because the so-called "window of adaptation" decreases during long-term RT [18]. Although improvements do not occur at same rate over long-term periods, the proper manipulation of program variables such as volume and intensity can limit training plateaus and increase the ability to achieve a higher level of muscular fitness. Given evidence showing that greater loads are superior for maximizing strength in advanced lifters [19], it is important to assess whether a system that allows higher loads in the over the course of a RT session without a corresponding reduction in training volume enhances long-term gains in muscular strength and hypertrophy.

The purpose of this study was to examine the effects of different RT systems on muscular strength and hypertrophy in resistance-trained and untrained older women. Based on speculation that varying loads result in a greater training stimulus, we hypothesized that the pyramid system would elicit a greater increase in muscular strength and hypertrophy than a traditional training system, with greater effects seen in trained older women.

4.2 Methods

4.2.1 Participants

Sixty-eight older women (≥ 60 years old) volunteered to participate in this study. Participant recruitment was carried out through newspaper and radio advertisings, and home delivery of leaflets in the central area and residential neighborhoods. Participants were randomly assigned to one of four groups according to RT experience and training system: trained traditional (TT, n = 16), trained pyramid (TP, n = 17), novice traditional (NT, n = 17), and novice pyramid (NP, n = 18). The participants in the advanced groups had previously carried out 24 weeks of RT. All participants completed health history and physical activity questionnaires and met the following inclusion criteria: 60 years old or more, physically independent, free from cardiac or orthopedic dysfunction, not receiving hormonal replacement therapy, and not performing any regular physical exercise more than once a week over the six months preceding the beginning of the study. Participants passed a diagnostic, graded exercise stress test with 12-lead ECG reviewed by a cardiologist and were released with no restrictions for participation in this study. Adherence to the program was satisfactory, with all subjects participating in >85% of the total sessions. Written informed consent was obtained from all subjects after a detailed description of study procedures was provided. This investigation was conducted according to the Declaration of Helsinki, and was approved by the local University Ethics Committee.

4.2.2 Participants' responsiveness

The determination of participants' responsiveness was based on their relative changes. Subjects were classified as high responder with improvements ≥ 20.0%, moderate responders with improvements from 10.0% to 19.9%, low responders with improvements from 1.0 to 9.9%, non responders with improvements ≤ 0.99%, or no changes, or impairment in the outcomes.

4.2.3 Experimental design

The study was carried out over a period of 40 weeks that were divided into 3 phases. The first two phases consisted of 12-week periods where participants who were ultimately placed in the advanced group underwent a RT program for 24 weeks (weeks 3-14 and 17-28). In the third phase of the experiment, new participants were recruited to form the group comprised of novices, and all participants then performed 8-weeks of RT (weeks 31-38). At the beginning of phase 1 and 3, and at the end of the third phase, 2 weeks were used for evaluations consisting of anthropometric measures, tests of one repetition maximum (1RM), body composition analysis by dual energy X-ray absorptiometry (DXA), and blood work for biochemical analysis. The experimental design is displayed in Figure 4.1.

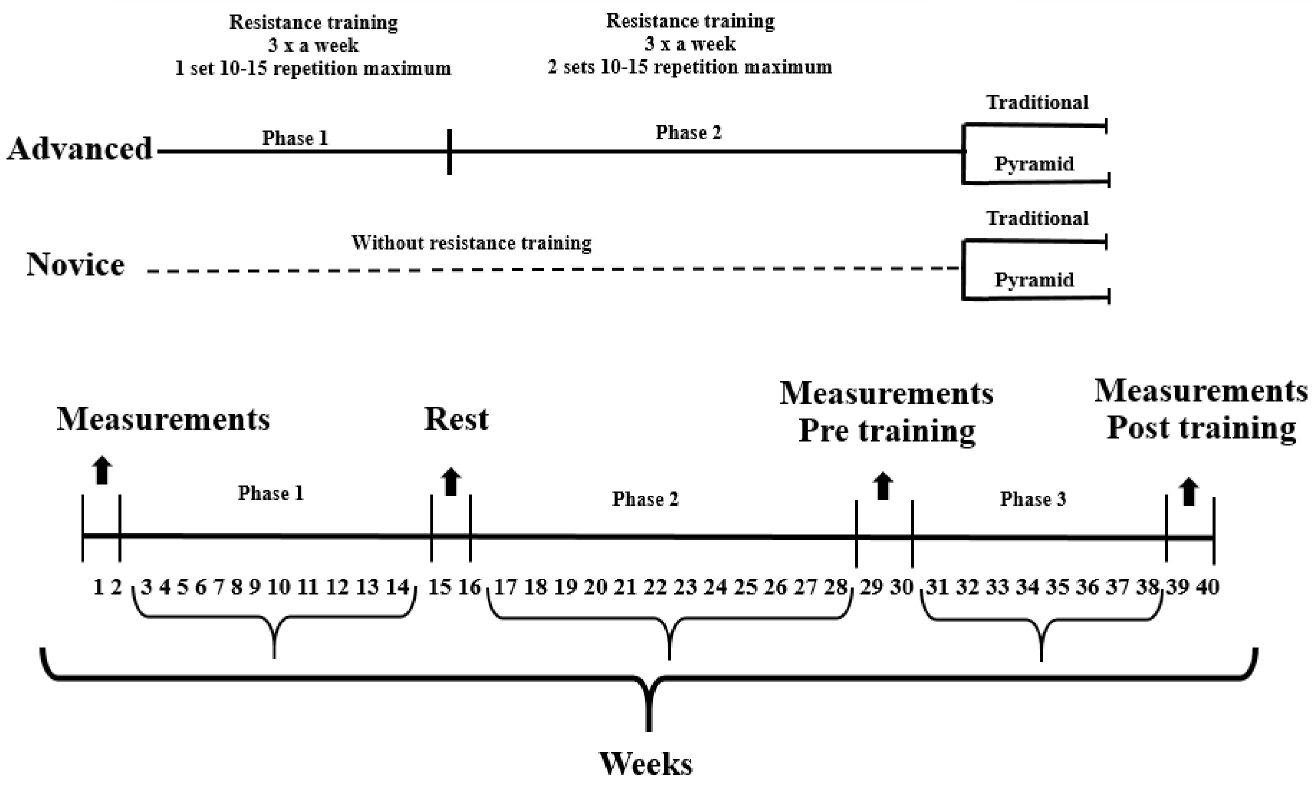

Figure 4.1 – Experimental design.

4.2.4 Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Balmak, Laboratory Equipment Labstore, Curitiba, Paraná, Brazil), with participants wearing light workout clothing and no shoes. Height was measured with a stadiometer attached on the scale to the nearest 0.1 cm with subjects standing sans shoes. Body mass index was calculated as body mass in kilograms divided by the square of height in meters.

4.2.5 Body composition

Skeletal muscle mass was estimated by the predictive equation proposed by Kim et al. [20]. The appendicular fat-free mass used for the equation was determined by DXA scan (Lunar Prodigy, model NRL 41990, GE Lunar, Madison, WI). Prior to scanning, participants were instructed to remove all objects containing metal. Scans were performed with the subjects lying in the supine position along the table's longitudinal centerline axis. Feet were taped together at the toes to immobilize the legs while the hands were maintained in a pronated position within the scanning region. Subjects remained motionless during the entire scanning procedure. Both calibration and analysis were carried out by a skilled laboratory technician. The equipment calibration followed the manufacturer's recommendations. The software generated standard lines that set apart the limbs from the trunk and head. These lines were adjusted by the same technician using specific anatomical points determined by the manufacturer. Analyses during the intervention were performed by the same technician who was blinded to intervention time point. Previous test-retest scans resulted in a standard error of measurement of 0.29 kg and intraclass correlation coefficient of 0.997 for skeletal muscle mass.

4.2.6 Body water

Total body water (TBW), intracellular water (ICW) and extracellular water (ECW) content were assessed using a spectral bioelectrical impedance device (Xitron 4200 Bioimpedance Spectrum Analyzer). Before measurement the participants were instructed to remove all objects containing metal. Measurements were performed on a table that was isolated from electrical conductors, with subjects lying supine along the table´s longitudinal centerline axis, legs abducted at an angle of 45º, and hands pronated. After cleaning the skin with alcohol, 2 electrodes were placed on surface of the right hand and 2 on the right foot in accordance with procedures described by Sardinha et al. [(21)]. Subjects were instructed to urinate about 30 minutes before the measures, refrain from ingesting food or drink in the last four hours, avoid strenuous physical exercise for at least 24 hours, refrain consumption of alcoholic and caffeinated beverages for at least 48 hours, and avoid the use of diuretics during 7 days prior each assessment. Before each measurement day equipment was calibrated as per the manufacturer´s recommendations. The values generated by equipment software for ICW and ECW were used for analysis, the TBW was estimated by the sum of ICW and ECW. Based on the test-retest measured 24–48 h apart in our laboratory, resulted in standard error of measurement of 0.32 L for ECW, 0.19 L for ICW, and 0.38 L for TBW, and intraclass correlation coefficient > 0.98 for ECW, > 0.99 for ICW, and > 0.98 for TBW.

4.2.7 Muscular strength

Maximal dynamic strength was evaluated using the 1RM test assessed on chest press (CP), knee extension (KE), and preacher curl (PC) performed in this exact order.

Testing for each exercise was preceded by a warm-up set (6-10 repetitions), with approximately 50% of the estimated load used in the first attempt of the 1RM. This warm-up was also used to familiarize the subjects with the testing equipment and lifting technique. The testing procedure was initiated 2 minutes after the warm-up. The subjects were instructed to try to accomplish two repetitions with the imposed load in three attempts in both exercises. The rest period was 3 to 5 min between each attempt, and 5 min between exercises. The 1RM was recorded as the last resistance lifted in which the subject was able to complete only one single maximal execution [22]. Execution technique for each exercise was standardized and continuously monitored to ensure reliability. All 1RM testing sessions were supervised by 2 researchers for greater safety and integrity of the subjects. Verbal encouragement was given throughout each test. Three 1RM sessions were performed separated by 48 hours (ICC ≥ 0.96). The highest load achieved among the 3 sessions was used for analysis in each exercise. Total strength was determined by the sum of the 3 exercises.

4.2.8 Biochemical analysis

Serum levels of testosterone and IFG-1 were measured after 12 h fasting by a laboratory technician. The blood was taken from the antecubital vein. The subjects were instructed not to perform vigorous exercise for the preceding 24 h and to avoid alcohol or caffeinated beverages 72 h before collection. Measurements were performed by standard methods in a specialized laboratory at University Hospital. Samples were deposited in vacuum tubes with a gel separator without anticoagulant and were centrifuged for 10 min at 3000 rpm for serum separation. Inter and intra assays CVs were <10% as determined in human serum. Thereafter, testosterone and IFG-1 concentrations were determined. The analyses were carried out using a biochemical auto-analyzer system (Dimension RxL Max - Siemens Dade Behring) according to established methods in the literature consistent with the manufacturer’s recommendations. The amounts of IGF-1 and testosterone were determined by chemiluminescence method using a LIAISON Immunoassay Analyzer (Soaring S.T.A, Saluggia, Italy).

4.2.9 Volume load

During every resistance training session, researchers recorded the load and number of repetitions performed by participants for each set of the 8 exercise.

Afterwards, the volume load for each exercise was calculated by multiplying the load by the number of repetitions and sets. The total volume load was the sum of all 8 exercises. Then the sum of the 3 sessions of a week was determined to be the weekly volume load.

4.2.10 Dietary intake

Participants were instructed by a dietitian to complete a food record on three nonconsecutive days (two week days and one weekend day) pre- and post-training. Subjects were given specific instructions regarding the recording of portion sizes and quantities to identify all food and fluid intake, in addition to viewing food models in order to enhance precision. Total dietary energy, protein, carbohydrate, and lipid content were calculated using nutrition analysis software (Avanutri Processor Nutrition Software, Rio de Janeiro, Brazil; Version 3.1.4). All subjects were asked to maintain their normal diet throughout the study period.

4.2.11 Resistance training program

Supervised RT was performed during the morning hours in the State University facilities. The protocol was based on recommendations for RT in an older population to improve muscular strength and hypertrophy (4, 6). All participants were personally supervised by physical education to ensure consistent and safe performance. Subjects performed RT using a combination of free weights and machines.

The sessions were performed 3 times per week on Mondays, Wednesdays, and Fridays. The RT program was a whole body program with 8 exercises comprising one exercise with free weights and seven with machines performed in the following order: chest press, horizontal leg press, seated row, knee extension, preacher curl (free weights), leg curl, triceps pushdown, and seated calf raise.

Participants of the advanced group performed 1 set of 10-15 repetitions maximum during the first 12-week phase, and then 2 sets of 10-15 repetitions maximum in the second 12-weeks phase. Afterwards, participants of the TT and NT groups performed 3 sets of 8-12 repetitions maximum with the same load in the 3 sets. While the participants of the TP and NP groups performed 3 sets with the load increasing and number of repetitions simultaneously decreasing for each set, thus, the number of repetitions used in each set was 12/10/8/ repetition maximum, respectively, with variable resistance. For both systems, the participants carried out exercises until muscle failure or an inability to sustain exercise performance with proper form.

Participants were instructed to inhale during the eccentric phase and exhale during the concentric phase while maintaining a constant velocity of movement at a ratio of approximately 1:2 seconds (concentric and eccentric phases, respectively). Participants were afforded 1 to 2 min of rest interval between sets and 2 to 3 min between each exercise. Instructors adjusted the loads of each exercise according to the subject's abilities and improvements in exercise capacity throughout the study in order ensure that the subjects were exercising with as much resistance as possible while maintaining proper exercise technique. Progression for the traditional training was planned when the upper limits of the repetitions-zone were completed for two consecutive training sessions and for pyramid training when the participant was able to perform two more repetitions in the last set. For both systems weight was increased 2-5% for the upper limb exercises and 5-10% for the lower limb exercises to the next session [6].

4.2.12 Statistical analyses

One-way analysis of variance (ANOVA) was applied for anthropometric baseline comparisons. Three-way analysis of covariance (ANCOVA) for repeated measures was applied for comparisons, with baseline scores used as covariates. When F-ratio was significant, Bonferroni's post hoc test was employed to identify the mean differences. The effect size (ES) was calculated as post training mean minus pre training mean divided by pooled standard deviation of pre and post training [23]. For all statistical analyses, significance was accepted at $P < 0.05$. The data were analyzed using STATISTICA software version 10.0 (STATSOFT INC., TULSA, OK, USA).

4.3 Results

Anthropometric characteristics of both groups are presented in Table 4.1. No differences between groups were observed for age, body mass, stature, and body mass index at baseline. Total energy and macronutrients daily intake at pre and post training are shown in Table 4.2. There were no significant ($P > 0.05$) main effects, indicating that the relative daily energy and macronutrient intake were not different between groups and did not change over time.

Table 4.1 - Anthropometric characteristics of the sample at baseline. Data are expressed as mean and standard deviation.

	TT (n = 16)	TP (n = 17)	NT (n = 17)	NP (n = 18)	*P*
Age (years)	69.1 ± 6.1	70.4 ± 5.9	69.2 ± 6.2	66.9 ± 5.2	0.22
Body mass (kg)	67.9 ± 14.2	70.3 ± 16.1	63.3 ± 9.2	66.3 ± 11.9	0.92
Height (cm)	158.2 ± 5.8	155.1 ± 6.4	154.5 ± 5.2	153.5 ± 6.3	0.45
Body mass index ($kg.m^{-2}$)	27.0 ± 5.2	29.0 ± 5.4	26.5 ± 3.5	28.1 ± 5.1	0.88

Note: TT = trained traditional. TP = trained pyramid. NT = novice traditional. NP = novice pyramid.

Table 4.2 - Dietary intake at pre and post training according to resistance training system. Data are expressed as mean and standard deviation.

	Trained		Novice		Effects - ANCOVA	*P*
	Traditional	Pyramid	Traditional	Pyramid		
Carbohydrate (g.kg^{-1}.dia^{-1})					Time	0.47
Pre training	2.9 ± 0.8	2.3 ± 0.8	3.2 ± 2.1	2.5 ± 0.8	Time x training status	0.13
Post training	3.2 ± 2.5	2.7 ± 1.2	2.7 ± 1.0	3.0 ± 1.4	Time x system	0.40
Δ%	10.3	17.4	-15.6	20.0	Time x system x training status	0.08
Effect Size	0.18	0.40	-0.32	0.45		
Protein (g.kg^{-1}.dia^{-1})					Time	0.40
Pre training	1.0 ± 0.5	0.7 ± 0.3	0.7 ± 0.3	0.7 ± 0.3	Time x training status	0.42
Post training	1.1 ± 0.5	0.7 ± 0.3	0.8 ± 0.3	1.0 ± 0.7	Time x system	0.83
Δ%	10.0	0.0	14.3	42.9	Time x system x training status	0.43
Effect Size	0.20	0.00	0.33	0.60		
Lipids (g.kg^{-1}.dia^{-1})					Time	0.73
Pre training	0.8 ± 0.4	0.6 ± 0.2	0.4 ± 0.1	0.5 ± 0.3	Time x training status	0.30
Post training	0.7 ± 0.6	0.5 ± 0.2	0.5 ± 0.5	0.7 ± 0.5	Time x system	0.67
Δ%	-12.5	-16.7	25.0	-40.0	Time x system x training status	0.83
Effect Size	-0.20	-0.50	0.33	-0.33		
Energy (kcal.kg^{-1}.dia^{-1})					Time	0.51
Pre training	23.6 ± 7.6	17.6 ± 5.5	21.6 ± 11.1	17.7 ± 6.9	Time x training status	0.93
Post training	26.6 ± 17.9	18.2 ± 7.8	18.8 ± 10.4	23.3 ± 13.3	Time x system	0.52
Δ%	12.7	3.4	-13.0	31.6	Time x system x training status	0.27
Effect Size	0.24	0.09	-0.26	0.55		

The muscular strength, fat-free mass and skeletal muscle mass outcomes are presented in Figure 4.2. Statistically significant time vs. training status interactions were observed for 1RM in the 3 exercises and for the total strength (sum of the 3 exercises), in which the NT and NP presented greater increases compared to TT and TP. Significance time vs. training status interaction were also observed for fat-free mass and skeletal muscle mass, wherein the NT and NP group showed a higher increase than the advanced TT and TP group. There were no statistical significant effects for time vs. system interaction as well as time vs. training status vs. system interaction for muscular strength, fat-free mass and skeletal muscle mass.

Values at pre and post training for TBW, ICW, ECW, IGF-1 and testosterone are presented in Table 4.3. A significant time effect was observed for TBW and ICW, where all groups increased their scores after the intervention. There were significant time vs. training status interaction for testosterone levels, in which the TT and TP increased their values after the intervention, while the NT and NP did not change their scores. The covariate means as well as the adjusted post training scores are presented in Table 4.4. As a categorical indicator. Table 4.5 depicts the participants' responsiveness to RT according to system and training status.

Figure 4.3 depicts the weekly volume load. There was a significant time vs. system vs. training status interaction ($F = 4.90$, $P < 0.001$), in which NT presented higher increases (50.2%, ES = 4.05) compared to the other 3 groups (TT = 18.8%, ES = 1.32; TP = 20.1%, ES = 1.53; NP = 41.6, ES = 3.48).

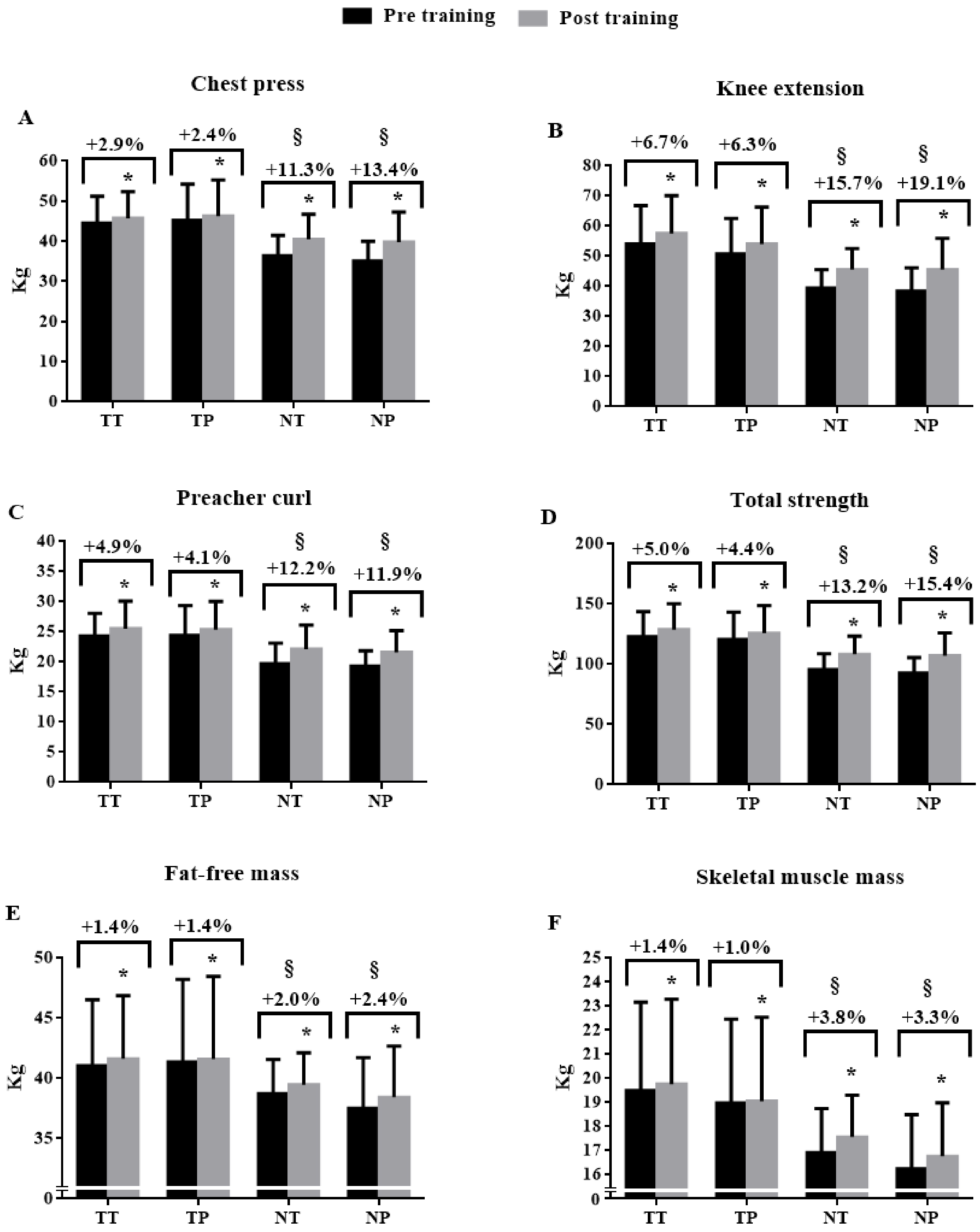

Figure 4.2 – Muscular strength, fat-free mass, and skeletal muscle mass at pre and post training according to training status and resistance training system. There is a significant ($P < 0.05$) training status by time interaction. * $P < 0.05$ vs. pre training. [§] $P < 0.05$ vs. trained traditional and trained pyramid. Data are expressed as mean and standard deviation. TT = trained traditional. TP = trained pyramid. NT = novice traditional. NP = novice pyramid.

Table 4.3 - Total body water and its intra and extracellular fractions, and anabolic hormones in older women at pre and post training according to resistance training system. Data are expressed as mean and standard deviation.

	TT (n = 16)	TP (n = 17)	NT (n = 17)	NP (n = 18)	Effects - ANCOVA	*P*
TBW (L)					Time	0.05
Pre training	31.2 ± 4.9	31.2 ± 6.8	29.1 ± 3.0	29.2 ± 3.6	Time x training status	0.08
Post training	32.1 ± 4.9	31.6 ± 6.6	29.6 ± 3.4	29.4 ± 3.4	Time x system	0.06
Δ%	2.9	1.0	1.5	0.7	Time x system x training status	0.10
Effect Size	0.18	0.05	0.14	0.06		
ICW (L)					Time	0.05
Pre training	17.4 ± 3.1	17.7 ± 4.6	16.1 ± 2.3	16.3 ± 2.4	Time x training status	0.10
Post training	18.4 ± 3.0*	18.0 ± 4.5*	16.5 ± 2.6*	16.6 ± 2.3*	Time x system	0.09
Δ%	5.9	1.7	2.3	1.6	Time x system x training status	0.07
Effect Size	0.33	0.07	0.14	0.11		
ECW (L)					Time	0.09
Pre training	13.8 ± 1.9	13.4 ± 2.3	13.0 ± 1.3	12.8 ± 1.4	Time x training status	0.64
Post training	13.7 ± 2.1	13.6 ± 2.2	13.1 ± 1.2	12.7 ± 1.3	Time x system	0.66
Δ%	-1.0	1.4	0.7	-0.6	Time x system x training status	0.11
Effect Size	-0.07	0.08	0.07	-0.05		
IGF-1 ($ng.mL^{-1}$)					Time	0.06
Pre training	114.8 ± 34.9	122.9 ± 50.7	142.1 ± 25.0	117.9 ± 52.7	Time x training status	0.73
Post training	118.9 ± 35.0	124.0 ± 54.4	142.7 ± 32.9	123.2 ± 39.3	Time x system	0.94
Δ%	3.6	0.9	0.4	4.5	Time x system x training status	0.82
Effect Size	0.12	0.02	0.02	0.12		
Testosterone ($ng.mL^{-1}$)					Time	< 0.01
Pre training	0.15 ± 0.09	0.17 ± 0.07	0.22 ± 0.24	0.12 ± 0.07	Time x training status	0.01
Post training	0.20 ± 0.10*	0.19 ± 0.09*	0.20 ± 0.11	0.13 ± 0.07	Time x system	0.54
Δ%	33.3	11.8	-9.1	8.3	Time x system x training status	0.20
Effect Size	0.53	0.25	-0.11	0.14		

Note: TBW = total body water. ICW = intracellular water. ECW = extracellular water. * $P < 0.05$ vs. pre training.TT = trained traditional. TP = trained pyramid. NT = novice traditional. NP = novice pyramid.

Table 4.4 – Adjusted mean by ANCOVA to post test.

	Covariate mean	**TT (n = 16)** Mean (95% CI)	**TP (n = 17)** Mean (95% CI)	**NT (n = 17)** Mean (95% CI)	**NP (n = 18)** Mean (95% CI)
Chest press (kg)	40.2	41.2 (39.9-42.6)	40.9 (39.6-42.3)	44.4 (43.2)	45.1 (43.8-46.6)
Knee extension (kg)	45.4	49.0 (46.9-57.1)	48.6 (46.7-50.6)	51.6 (49.6-53.6)	52.6 (50.6-54.5)
Preacher curl (kg)	21.8	23.0 (22.0-24.0)	22.9 (21.9-23.8)	24.2 (23.3-25.1)	24.2 (23.2-25.1)
Total strength (kg)	107.5	112.8 (109.5-116.1)	112.1 (109.9-115.3)	120.8 (117.6-123.9)	122.5 (119.4-125.6)
Fat-free mass (kg)	39.6	40.2 (39.8-40.7)	39.7 (39.3-40.2)	40.4 (39.9-40.8)	40.3 (39.9-40.8)
Skeletal muscle mass (kg)	17.8	18.1 (17.9-18.4)	18.0 (17.7-18.2)	18.4 (18.2-18.6)	18.3 (18.1-18.5)
Total body water (L)	30,1	30,9 (30,3-31,5)	30,8 (30,2-31,3)	30,7 (30,1-31,3)	30.5 (29,3-30.9)
Intracellular water (L)	16.8	17.9 (17.4-18.4)	17.1 (16.6-17.6)	17.1 (16.6-17.6)	17.0 (16.4-17.4)
Extracellular water (L)	13.2	13.2 (12.8-13.6)	13.4 (13.0-13.8)	13.4 (13.0-13.7)	13.2 (12.9-13.6)
IGF-1 ($ng.mL^{-1}$)	123.5	126.3 (115.4-137.1)	124.6 (114.1-135.1)	126.9 (114.2-139.7)	127.9 (115.9-139.9)
Testosterone ($ng.mL^{-1}$)	0.16	0.21 (0.18-0.25)	0.18 (0.15-0.21)	0.14 (0.10-0.18)	0.16 (0.12-0.19)

Note. TT = trained traditional. TP = trained pyramid. NT = novice traditional. NP = novice pyramid.

Table 4.5 – Participants responsiveness according to resistance training system and training status.

	TT (n = 16)	PT (n = 17)	NT (n = 17)	NP (n =18)
	n (%)	n (%)	n (%)	n (%)
Chest press (kg)				
Non responder	6 (37.5)	9 (52.9)	0 (0)	2 (11.1)
Low responder	10 (62.5)	8 (47.1)	16 (94.1)	11 (61.7)
Moderate responder	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
High responder	0 (0.0)	0 (0.0)	1 (5.9)	5 (27.8)
Knee extension (kg)				
Non responder	2 (12.5)	4 (23.5)	1 (5.9)	0 (0.0)
Low responder	9 (56.3)	8 (47.1)	2 (17.6)	5 (27.8)
Moderate responder	5 (31.1)	4 (23.5)	8 (47.1)	6 (33.3)
High responder	0 (0.0)	1 (5.9)	5 (29.4)	7 (38.9)
Preacher curl (kg)				
Non responder	8 (50.0)	8 (47.1)	2 (11.8)	2 (11.1)
Low responder	5 (31.3)	4 (23.5)	5 (29.4)	5 (27.8)
Moderate responder	3 (18.8)	3 (17.6)	8 (47.1)	8 (44.4)
High responder	0 (0.0)	2 (11.8)	2 (11.8)	3 (16.7)
Fat-free mass (kg)				
Non responder	7 (43.8)	10 (58.8)	9 (52.9)	6 (33.3)
Low responder	9 (56.3)	7 (41.2)	8 (47.1)	12 (66.7)
Moderate responder	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
High responder	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Skeletal muscle mass (kg)				
Non responder	7 (43.8)	10 (58.8)	2 (11.8)	4 (22.2)
Low responder	9 (56.3)	7 (41.2)	13 (76.5)	14 (77.8)
Moderate responder	0 (0.0)	0 (0.0)	2 (11.8)	0 (0.0)
High responder	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total body water (kg)				
Non responder	9 (56.3)	9 (52.9)	8 (47.1)	9 (50.0)
Low responder	6 (37.5)	8 (47.1)	8 (47.1)	9 (50.0)
Moderate responder	1 (6.6)	0 (0.0)	1 (5.9)	0 (0.0)
High responder	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Intracellular water (L)				
Non responder	6 (35.7)	7 (41.2)	5 (29.4)	7 (38.9)
Low responder	6 (35.7)	9 (52.9)	9 (52.9)	10 (55.5)
Moderate responder	3 (18.8)	1 (5.9)	3 (17.9)	1 (5.6)
High responder	1 (6.3)	0 (0.0)	0 (0.0)	0 (0.0)
Extracellular water (L)				
Non responder	12 (75.0)	12 (70.6)	11 (64.7)	13 (72.2)
Low responder	3 (18.8)	3 (17.6)	5 (29.4)	4 (22.2)
Moderate responder	1 (6.3)	2 (11.8)	1 (5.9)	1 (5.6)
High responder	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
IGF-1 (ng.mL^{-1})				
Non responder	5 (31.3)	9 (52.9)	11 (64.7)	9 (50.0)
Low responder	4 (25.0)	2 (11.8)	1 (5.9)	2 (11.1)
Moderate responder	3 (18.8)	2 (11.8)	4 (23.5)	4 (22.2)
High responder	4 (25.0)	4 (23.5)	1 (5.9)	3 (16.7)
Testosterone (ng.mL^{-1})				
Non responder	4 (25.0)	9 (52.9)	12 (70.6)	11 (61.1)
Low responder	0 (0.0)	1 (5.9)	1 (5.9)	0 (0.0)
Moderate responder	1 (6.3)	1 (5.9)	0 (0.0)	1 (5.6)
High responder	11 (68.8)	6 (35.3)	4 (23.5)	6 (33.3)

Note: TT = trained traditional. TP = trained pyramid. NT = novice traditional. NP = novice pyramid.

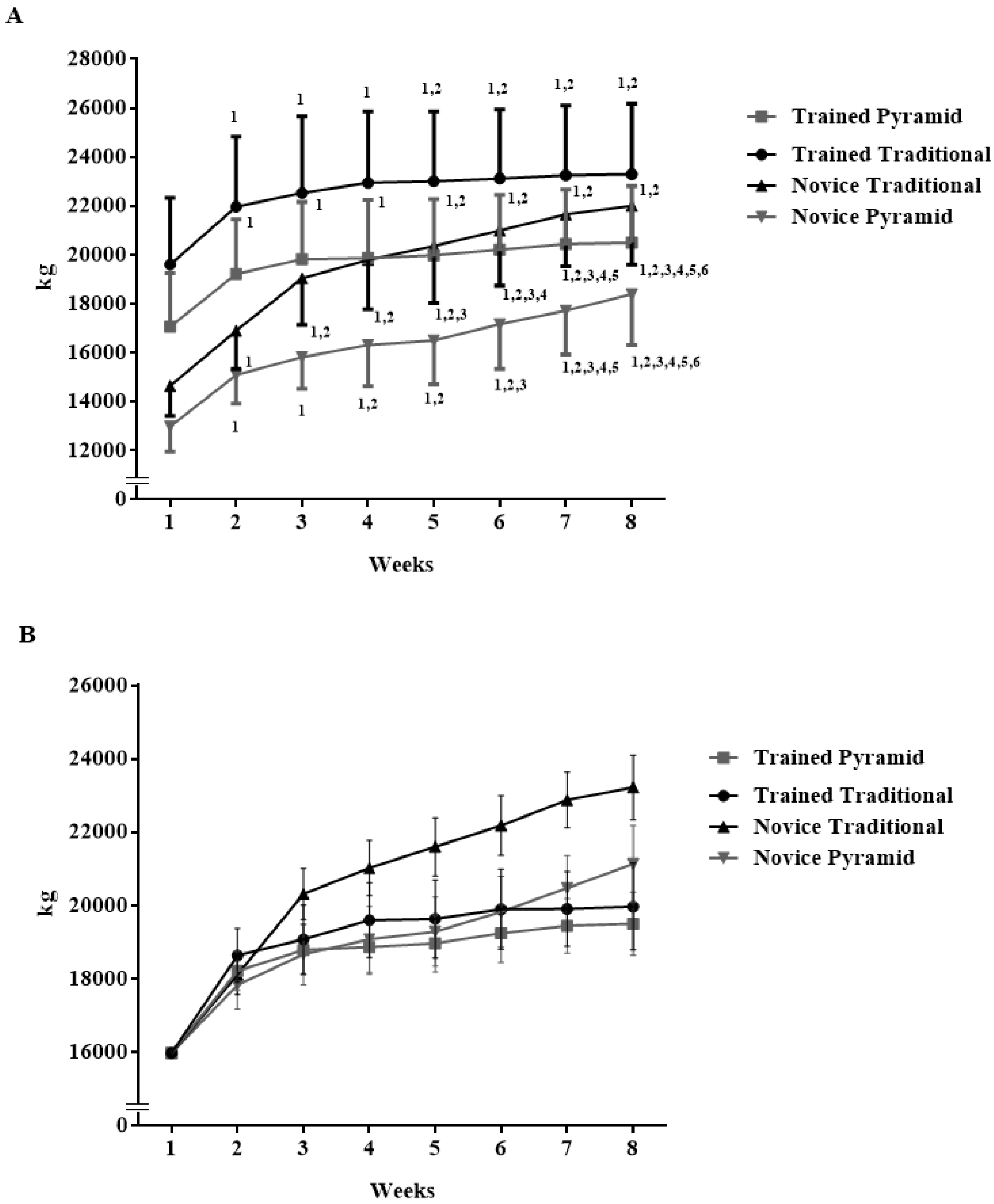

Figure 4.3 – Weekly volume of load during a resistance-training program in older women according to resistance-training system and status of training. The numbers indicate *P* < 0.05 vs. the week represented by the number. There is a significant statistical time vs. system vs. training stuatus interaction. In Panel A the data are presented as mean and standard deviation, and in Panel B as ANCOVA adjusted mean and 95% confidence interval.

4.4 Discussion

The main and novel finding of this study was that the RT performed in a pyramid system was equally as effective as a traditional system for promoting adaptations in muscular strength and hypertrophy in trained and untrained older women. We had hypothesized that the pyramid system would produce superior results. The rationale for such a hypothesis was based on the dose-response relationship between intensity and neuromuscular improvements that has been shown in older adults [(11-14)]. Since the pyramid system allows the use of higher intensities of load during the final sets of an exercise without impairing volume in the target repetition range (i.e. 8-12 repetition maximum), it was thought that the pyramid system would stimulate greater neuromuscular adaptations. However, contrary to our hypothesis, the results of this study failed to demonstrate a superiority of the pyramid over the traditional system.

To the best of authors' knowledge this is the first study comparing different RT systems in trained older women, which makes a detailed comparison with literature somewhat difficult. The limited number of studies that have investigated the effect of different intensities of RT in well-trained individuals demonstrate that greater loads are superior for maximizing strength development [(24, 25)]. There are several notable differences between these studies and ours. For one, both aforementioned studies investigated the adaptive response in well-trained young adult men, while we used older women. Moreover, Schoenfeld et al.[(25)] and Mangine et al [(24)] made a direct comparison of different training intensities where one group trained with higher intensity versus another with lower intensity, while we compared a system that allows higher intensity in the final sets by varying loads among sets versus the traditional system using constant loads throughout sets. Based on these findings, we can speculate that the repetition zone range applied in the pyramid training was not sufficient to elicit higher mechanical stress stimulus compared to the traditional system. Thus, further studies using the pyramid system with a wider repetitions zone range (e.g. 15, 10, 5 RM) producing a greater mechanical and metabolic stimulus are warranted.

An interesting finding of the present study was that the hypertrophy-oriented traditional RT system produced significant long-term increases on ICW in the trained participants. The increase in ICW content may be related to several factors, although a definitive mechanism to support such a contention is not clear at this time.

Regimented RT has been shown to enhance glycogen storage, with an increase in resting concentrations of 66% reported following 5 months of regimented RT [26]. These changes are seemingly mediated by a combination of enzymatic upregulation as well as a greater glycogen storage capacity of larger muscles. Since every gram of glycogen attracts three grams of water [27], this provides a basis whereby consistent RT can elicit chronic increases in cellular hydration [26]. Therefore, it would seem logical that the untrained groups would have experienced higher increases in ICW since their glycogen levels would have been lower at baseline. However, contrary to such speculation, all groups achieved increases in ICW. It is possible that this result may be related to the genetic intra-individual responsiveness of the participants who composed the trained group. Future studies are need to replicate this finding.

The metabolic stimulus from RT leads to a series of intracellular events that ultimately regulates the intracellular water status, and this increase in intracellular water content is a component of sarcoplasmic hypertrophy [28, 29]. Evidence shows that cellular hydration is correlated with both an increase in protein synthesis and a decrease in proteolysis [30-32]. In addition, it has been theorized that the stimulus associated with cell hydration status may trigger proliferation of satellite cells and facilitate their fusion to hypertrophying myofibers [33]. However, considering that the TT group showed greater ES in intracellular water without demonstrating superior changes in hypertrophy and strength, it can be inferred that the increase in intracellular water did not trigger enhance neuromuscular adaptations.

The main anabolic hormones involved in muscle growth and remodeling are testosterone and IFG-1. Therefore, these hormones have been proposed as a physiological marker for evaluating the anabolic state of the organism. With respect to testosterone, our results indicate that a certain level of experience seems to be necessary to optimize the chronic response of testosterone. Kraemer et al. [34] observed that acute elevations in testosterone of young weightlifters (14 to 18 years old) were influenced by age and experience where the elevations did not occur if the experience with training is equal to or greater than two years. In another experiment Kraemer et al. [35] did not observe acute increases during strength training until previously sedentary individuals reached six weeks of training. Collectively, these data suggest that training experience seems to influence the acute and chronic testosterone responses where it may possible that a longer period of training is needed to stimulate chronic adaptations. Considering that well-trained subjects have less potential for hypertrophy, the changes in testosterone kinetics observed in trained participants could be an important element to induce further muscle growth. The mechanism underlying the changes in testosterone are not clear to date; however, testosterone actions are magnified by mechanical loading [7, 10] and thus the absolute workload that can be achieve by trained participants may be related to chronic testosterone adaptations. Despite the absence of chronic hormonal changes in untrained subjects, it is important to mention that RT has been shown to upregulate androgen receptor content in humans [7], which may enhance the potential for testosterone binding at the cellular level, and thus facilitate its uptake into target tissues. It remains unclear if alterations in chronic testosterone levels within a normal physiological range have an appreciable impact on muscle growth; further study is warranted in this regard.

IGF-1 is often referred to as the most important mammalian anabolic hormone and shows enhanced effects in response to mechanical loading [7, 10]. IGF-1 induces hypertrophy in both an autocrine and paracrine manner, mainly by increasing the rate of protein synthesis by downregulating catabolic signaling process involved in protein degradation as well as mediating compensatory hypertrophy by regulating satellite cell activity [7, 10]. Three distinct isoforms have been identified, the systemic isoforms IGF-1Ea and IFG-1Eb, and a splice variant IFG-1Ec. Although each of these isoforms are expressed in muscle tissue, only IGF-1Ec appears to be locally activated by mechanical signals and thus it has been termed mechano-growth factor (MGF) [7, 10]. The anabolic effects of IGF-1 appear to be magnified in response to mechanical loading [7, 8, 10]. However, our study did not find any changes in IGF-1 basal concentrations after 8 weeks of RT. These results are in line with previous studies that investigated the effects of RT on testosterone and IGF-1 in older women [36, 37]. Despite low levels of anabolic hormones, older women nevertheless are able to reach significant increases in muscular hypertrophy following regimented RT. Importantly, our analysis only measured serum hormonal values; it remains possible the RT program induced changes at the hormone receptor level that enhanced anabolic processes [38].

Our results showed that muscular strength and hypertrophy adaptations from a RT program are greater in novice lifters compared with those who have training experience. Research indicates that the acute increase in muscular protein synthesis after a RT bout is modulated by an individual's training status [39], with evidence showing untrained subjects have higher mixed muscular protein synthetic rates compared to trained subjects [39, 40] resulting in greater overall muscular protein synthesis. Thus, a heightened anabolic environment seemingly enhances the ability for novice RT participants to achieve greater net protein accretion compared to trained individuals. In support of this hypothesis, Ahtiainen et al. [17] compared the quadriceps femoris cross-sectional area following 21 weeks of heavy RT in untrained and trained subjects. At the end of the study period, only the untrained group demonstrated significant hypertrophy; the trained group had reached a plateau in muscular adaptations. It is reasonable to speculate that the systematic manipulation of RT program variables in the present study helped to promote significant increases in muscle mass in the trained subjects albeit to a lower degree in comparison to the novice. With respect to muscular strength, the greater increases observed in beginners may be a result of neural adaptations that occur along the training continuum such as increased motor recruitment and decreased co-activation of antagonist muscles [41].

An important aspect of our experiment was the analysis of the participants' responsiveness. Although it is generally accepted that the group average represents a typical response for most individuals, muscular adaptations to RT programs are not uniform and a wide-ranging inter-individual variability is consistently noted following long-term training [42-44]. We stratified data into high, moderate-, low- and non-responders. The presentation of data in this regard seemingly provides greater insight into the varying response to RT, and may help the practitioner to draw conclusions with respect to individual program design.

Finally, it is important to note that findings here are specific to the intervention period, to older women and cannot necessarily be extrapolated to other populations. Whether results would differ for younger individuals, men, or those with previous resistance training experience remains to be determined. Further research is needed in these areas to replicate these findings.

4.5 Conclusion

We conclude that RT performed in pyramid system is an effective method to promote positive adaptations on muscular strength and hypertrophy in untrained and previously trained older women. However, the pyramid system does not provide any inherent advantages over a traditional RT system. Thus, the practitioner can seemingly decide which system to use based on personal preference.

4.6 References

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CAPÍTULO 5

Artigo original 4

Pyramidal and traditional hypertrophy-type resistance training systems improves muscular quality and metabolic biomarkers in untrained and trained older women

Abstract

The purpose of this study was to investigate the effect of resistance training (RT) performed in a pyramid versus traditional system on muscular quality and metabolic biomarkers in trained and untrained older women. Sixty-eight older women (68.9 ± 5.9 years, 67.0 ± 13.0 kg, 155.3 ± 6.1 cm, and 27.6 ± 4.9 kg.m^{-2}) were separated into 4 groups based on combinations of RT experience and training protocol: trained traditional (TT, n = 16), trained pyramid (TP, n = 17), novice traditional (NT, n = 17), and novice pyramid (NP, n = 18). At the beginning and the end of each RT phase, measurements of body fat, muscular quality, serum levels of C-reactive protein (CRP), glucose (GLU), total cholesterol (TC), high-density lipoprotein (HDL-C), low-density lipoprotein (LDL-C), and triglycerides (TG) were conducted. The RT program was carried out 3 days-per-week for 8 weeks, where the traditional RT consisted of 3 sets of 8-12 RM with constant load for the 3 sets, whereas the pyramid RT consisted of 3 sets of 12/10/8 RM with incremental loads for each set. Significant ($P < 0.05$) reductions on body fat was observed only on novice groups (NT = -2.5%, NP = -2.8%). A significant time by training status interaction ($P < 0.05$) for the CRP (TT = -60.2%, TP = -47.1%, NT = 25.5%, NP = -13.1%), and muscular quality (TT = 3.3%, TP = 3.7%, NT = 9.3%, NP = 11.0%) were observed. A main effect of time ($P < 0.05$) was identified for the GLU (TT = -7.6%, TP = -5.7%, NT = -5.6%, NP = -0.5%), TG (TT = -15.8%, TP = -5.3%, NT = -26.8%, NP = -4.7%), HDL-C (TT = 10.7%, TP = 4.7%, NT = 11.6%, NP =2.7 %), and LDL-C (TT = -23.8%, TP = -26.8%, NT = -34.7%, NP = -27.9%). These results suggest that RT improves muscular quality, metabolic biomarkers of older women with differing levels of training status independently of the system.

Keywords: aging, C-reactive protein, lipoproteins, muscular quality, strength training.

5.1 Introduction

Biological aging is associated with morphological and biochemical alterations that ultimately increase the risk of developing cardiovascular disease. Reduction of muscular quality is a significant change that occur with aging that ultimately affect health and quality of life in older individuals [(1)]. The muscular quality reflects the strength produced by a specific muscular volume [(1)]. This approach can therefore be considered a more valuable measure of muscle function than the isolated analysis of strength and/or muscle mass alone [(1)]. Aging is also associated with biochemical alterations that increase the risk of developing cardiovascular disease, which is the major cause of morbidity and mortality in the older ages [(2)]. Among the risk factors, serum blood levels of glucose and lipids profile have been shown to have a greater impact on cardiovascular disease risk in women compared to men [(3, 4)]. Chronic inflammation has also been implicated as playing a role in cardiovascular disease [(5)]. To this end, elevations in C-reactive protein (CRP), an inflammation biomarker, may be considered an important independent indicator of mortality for cardiovascular and metabolic diseases [(6, 7)].

Resistance training (RT) is an intervention that has been promoted as a means to attenuate the deleterious effects of aging [(8, 9)]. In addition to its effects on enhancing muscular strength and muscle mass, RT provides numerous additional benefits to older adults' health that may directly impact cardiovascular disease risk including positive changes in body fat [(10-12)], improvements in metabolic profile [(13-16)], and a reduction in inflammatory biomarkers [(17-20)]. The principal guidelines to RT prescription [(8, 9, 21)] recommend the use of same loads related to a given repetitions zone, a system known as traditional training. Such recommendations are based on abundant evidence about the effectiveness of this training system. However, other training systems have been developed over time by instructors, athletes, and practitioners in an attempt to maximize benefits. Among the different RT systems, the pyramid system is very popular and frequently used by athletes and non-athletes in order to improve the adaptations induced by RT. The pyramid system is characterized by increasing the load with a parallel decrease in repetitions across sets. Hypothetically, these alterations in two important variables may optimize the metabolic and mechanical stimuli necessary for muscle protein accretion [(8, 22)]. Additionally, manipulation of volume and intensity can also promote other important metabolic responses, with a positive impact on the lipids profile [(23, 24)] and in inflammation biomarker [(25)], since metabolic and inflammatory changes induced by RT may be dependent on the specific characteristics of the program [23-25].

In addition, training status may play an important role in neuromuscular [26-28] and metabolic adaptations induced by RT [25, 29]. Compared to novice trainees, subjects previously exposed to RT have a greater skeletal muscle mass, which is the primary metabolic target tissue for glucose and triglyceride metabolism [30], acts as an endocrine organ releasing myokines with anti-inflammatory properties [29], and is a substantial contributor to resting metabolic rate [31]. Although previous research has investigated the effects of RT on muscular strength and metabolic biomarker changes in older women, it remains undetermined whether these changes are influenced by different system and by distinct levels of RT experience. Therefore, the purpose of this study was to analyze the effects of a comprehensive RT program on muscular quality and the metabolic biomarkers of older women differing levels of RT experience. We hypothesized that the pyramid system would provide superior improvements in the outcomes induced by RT. A secondary hypothesis was that older women with previous experience in RT would present different adaptations on muscular quality and on metabolic biomarkers.

5.2 Methods

5.2.1 Participants

Sixty-eight older women (≥ 60 years old) volunteered to participate in this study. Participant recruitment was carried out through newspaper and radio advertisings, and home delivery of leaflets in the central area and residential neighborhoods. Participants were assigned to one of four groups according to RT experience and training system: trained traditional (TT, n = 16), trained pyramid (TP, n = 17), novice traditional (NT, n = 17), and novice pyramid (NP, n = 18). The participants in the advanced groups had previously carried out 24 weeks of RT. All participants completed health history and physical activity questionnaires and met the following inclusion criteria: 60 years old or more, physically independent, free from cardiac or orthopedic dysfunction, not receiving hormonal replacement therapy, and not performing any regular physical exercise more than once a week over the six months preceding the beginning of the study. Participants passed a diagnostic, graded exercise stress test with 12-lead electrocardiogram reviewed by a cardiologist and were released with no restrictions for participation in this study. Adherence to the program was satisfactory, with all subjects participating in >85% of the total sessions. Written informed consent was obtained from all subjects after a detailed description of study procedures was provided. This investigation was conducted according to the Declaration of Helsinki, and was approved by the local University Ethics Committee.

5.2.2 Participants' responsiveness

The determination of participants' responsiveness was based on their relative changes. Subjects were classified as high responder with improvements ≥ 20.0%, moderate responders with improvements from 10.0% to 19.9%, low responders with improvements from 1.0 to 9.9%, non responders with improvements ≤ 0.99%, or no changes, or impairment in the outcomes.

5.2.3 Experimental design

The study was carried out over a period of 40 weeks that were divided into 3 phases. The first two phases consisted of 12-week periods where participants who were ultimately placed in the advanced group underwent a RT program for 24 weeks (weeks 3-14 and 17-28). In the third phase of the experiment, new participants were recruited to form the group comprised of novices, and all participants then performed 8-weeks of RT (weeks 31-38). At the beginning of phase 1 and 3, and at the end of the third phase, 2 weeks were used for evaluations consisting of anthropometric measures, tests of one repetition maximum (1RM), body composition analysis by dual energy X-ray absorptiometry (DXA), and blood work for biochemical analysis. The experimental design is displayed in Figure 5.1.

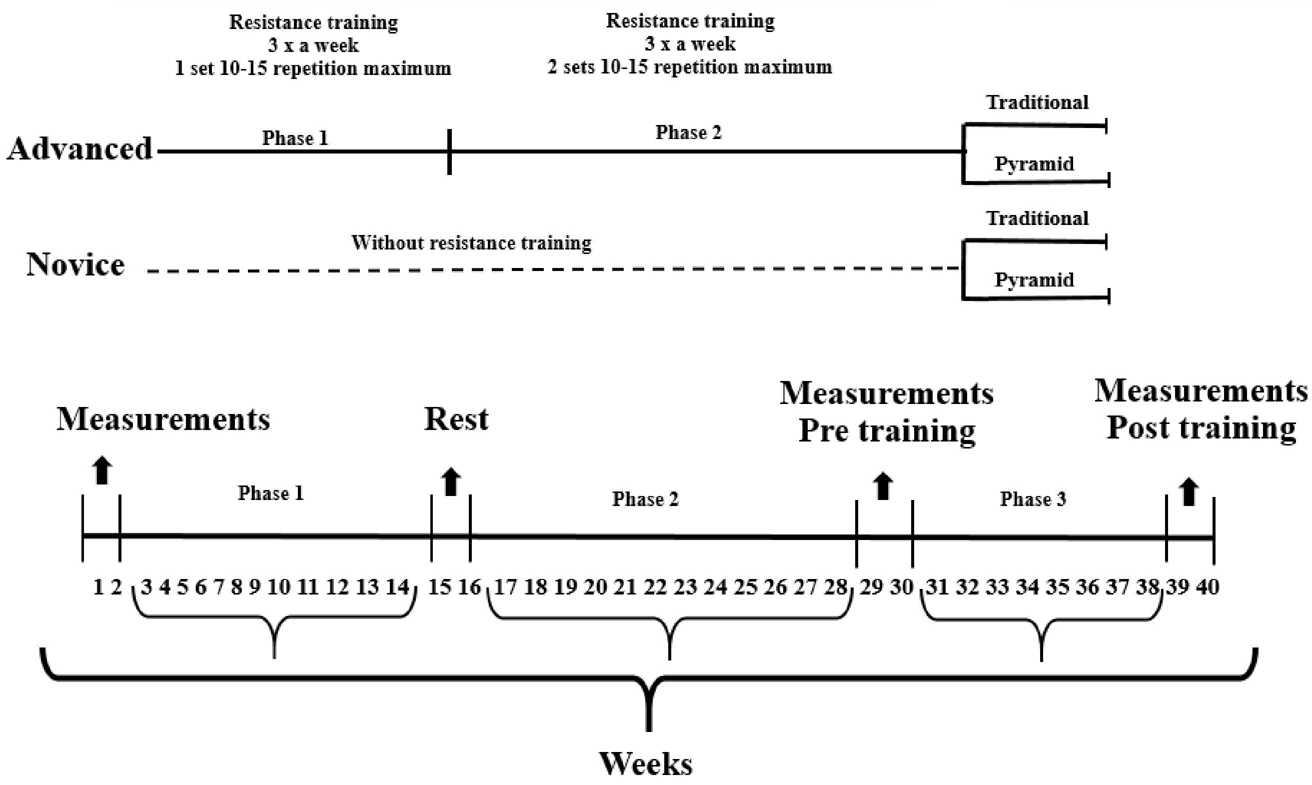

Figure 5.1 – Experimental design.

5.2.4 Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Balmak, Laboratory Equipment Labstore, Curitiba, Paraná, Brazil), with the participants wearing light workout clothing and no shoes. Height was measured with a stadiometer attached on the scale to the nearest 0.1 cm with subjects standing sans shoes. Body mass index was calculated as body mass in kilograms divided by the square root of height in meters.

5.2.5 Body composition

Whole body DXA scans (Lunar Prodigy, model NRL 41990, GE Lunar, Madison, WI) were used to asses body fat and appendicular lean soft tissue. The skeletal muscle mass was estimated by the predictive equation proposed by Kim et al. [32]. Prior to scanning, participants were instructed to remove all objects containing metal. Scans were performed with the subjects lying in the supine position along the table's longitudinal centerline axis. Feet were taped together at the toes to immobilize the legs while the hands were maintained in a pronated position within the scanning region.

Subjects remained motionless during the entire scanning procedure. Both calibration and analysis were carried out by a skilled laboratory technician. The equipment calibration followed the manufacturer's recommendations. The software generated standard lines that set apart the limbs from the trunk and head. These lines were adjusted by the same technician using specific anatomical points determined by the manufacturer. Analyses during the intervention were performed by the same technician who was blinded to intervention time point. Previous test-retest scans of 10 older women measured 24-48 h apart resulted in a standard error of measurement of 0.29 kg 0.90 kg for skeletal muscle mass and percentage of body fat, respectively, and intraclass correlation coefficient of >0.990 and >0.980 for skeletal muscle mass and percentage of body fat, respectively.

5.2.6 Muscular strength

Maximal dynamic strength was evaluated using the 1RM test assessed on chest press, knee extension, and preacher curl performed in this exact order. Testing for each exercise was preceded by a warm-up set (6-10 repetitions), with approximately 50% of the estimated load used in the first attempt of the 1RM. This warm-up was also used to familiarize the subjects with the testing equipment and lifting technique. The testing procedure was initiated 2 minutes after the warm-up. The subjects were instructed to try to accomplish two repetitions with the imposed load in three attempts in both exercises. The rest period was 3 to 5 min between each attempt, and 5 min between exercises. The 1RM was recorded as the last resistance lifted in which the subject was able to complete only one single maximal execution [(33)]. Execution technique for each exercise was standardized and continuously monitored to ensure reliability. All 1RM testing sessions were supervised by 2 researchers for greater safety and integrity of the subjects. Verbal encouragement was given throughout each test. Three 1RM sessions were performed separated by 48 hours (ICC ≥ 0.96). The highest load achieved among the 3 sessions was used for analysis in each exercise. Total strength was determined by the sum of the 3 exercises.

5.2.7 Muscular quality

The total muscle quality index was determined by dividing the total strength that was determined by the sum of the 3 exercises by the total skeletal muscle mass. Upper limb muscle quality was determined from division of the load mobilized in the preacher curl exercise by the arms lean soft tissue, while the lower limb muscle quality was be determined from division of the load mobilized in knee extension exercise by the legs lean soft tissue [1].

5.2.8 Biochemical analysis

Serum levels of high-sensitivity CRP, glucose (GLU), total cholesterol (TC), high-density lipoprotein (HDL-C), low-density lipoprotein (LDL-C), and triglycerides (TG) were measured after 12 h fasting by a laboratory technician. The blood was taken from the antecubital vein. The subjects were instructed not to perform vigorous exercise for the preceding 24 h and to avoid alcohol or caffeinated beverages 72 h before collection. Measurements were performed by standard methods in a specialized laboratory at University Hospital. Samples were deposited in vacuum tubes with a gel separator without anticoagulant and were centrifuged for 10 min at 3000 rpm for serum separation. Thereafter, the PCR, TG, and HDL-C concentrations were determined. The LDL-C was calculated using the Friedewald, Levy, & Fredrickson [34] equation, where LDL-C = TC - (HDL-C + TGL/5). The analyses were carried out using a biochemical auto-analyzer system (Dimension RxL Max - Siemens Dade Behring) according to established methods in the literature consistent with the manufacturer’s recommendations.

5.2.9 Resistance training program

Supervised RT was performed during the morning hours in the State University facilities. The protocol was based on recommendations for RT in an older population to improve muscular strength and hypertrophy [8, 9]. Physical education professionals to ensure consistent and safe performance personally supervised all participants. Subjects performed RT using a combination of free weights and machines.

The sessions were performed 3 times per week on Mondays, Wednesdays, and Fridays. The RT program was a whole body program with 8 exercises comprising one exercise with free weights and seven with machines performed in the following order: chest press, horizontal leg press, seated row, knee extension, preacher curl (free weights), leg curl, triceps pushdown, and seated calf raise.

Participants of the advanced group performed 1 set of 10-15 repetitions maximum during the first 12-week phase, and then 2 sets of 10-15 repetitions maximum in the second 12-weeks phase. Afterwards, participants of the TT and NT groups performed 3 sets of 8-12 repetitions maximum with the same load in the 3 sets. While the participants of the TP and NP groups performed 3 sets with the load increasing and number of repetitions simultaneously decreasing for each set, thus, the number of repetitions used in each set was 12/10/8/ repetition maximum, respectively, with variable resistance. For both systems, the participants carried out exercises until muscle failure or an inability to sustain exercise performance with proper form.

Participants were instructed to inhale during the eccentric phase and exhale during the concentric phase while maintaining a constant velocity of movement at a ratio of approximately 1:2 seconds (concentric and eccentric phases, respectively). Participants were afforded 1 to 2 min of rest interval between sets and 2 to 3 min between each exercise. Instructors adjusted the loads of each exercise according to the subject's abilities and improvements in exercise capacity throughout the study in order ensure that the subjects were exercising with as much resistance as possible while maintaining proper exercise technique. Progression for the traditional training was planned when the upper limits of the repetitions-zone were completed for two consecutive training sessions and for pyramid training when the participant was able to perform two more repetitions in the last set. For both systems weight was increased 2-5% for the upper limb exercises and 5-10% for the lower limb exercises to the next session [8].

5.2.10 Statistical analyses

One-way analysis of variance (ANOVA) was applied for anthropometric baseline comparisons. Three-way analysis of covariance (ANCOVA) for repeated measures was applied for comparisons between groups and moments, with baseline scores used as covariates. When F-ratio was significant, Bonferroni's post hoc test was employed to identify the mean differences. The effect size was calculated as post training mean minus pre training mean divided by pooled standard deviation of pre and post training [35]. For all statistical analyses, significance was accepted at $P < 0.05$. The data were analyzed using STATISTICA software version 10.0 (STATSOFT INC., TULSA, OK, USA).

5.3 Results

The anthropometric characteristics of participants according to groups are presented in Table 5.1. No differences between groups were observed for age, body mass, stature, and body mass index at baseline. The changes from pre to post training in body fat, appendicular muscle mass and muscle quality are displayed in Table 5.2. Statistical significance for time vs. training status interaction were observed for body fat, lower limb skeletal muscle mass, total muscle quality, and lower limb muscle quality, in which for body fat only the novice groups altered the scores after 8 weeks of RT, while the novice groups showed a higher increase in lower limb skeletal muscle mass, total muscle quality, and lower limb muscle quality than the advanced groups.. A significant main effect of time was observed for upper limb skeletal muscle mass and upper limb muscle quality with groups showing similar improvements.

Table 5.3 displays the metabolic parameters at pre and post training. A significant time vs. training status interaction was observed for CRP with the advanced groups showing higher decrease in their scores after the intervention period in comparison with the novice groups. There were no significant interaction for any other variables. Main effects of time were observed for GLU, TG, HDL-C and LDL-C, with all groups showing similar improvements.

The covariate means as well as the adjusted post training scores are presented in Table 5.4. As a categorical indicator, Table 5.5 depicts the participants' responsiveness to RT according to system and training status.

Table 5.1 – Anthropometric characteristics of the sample at baseline. Data are expressed as mean and standard deviation.

	TT (n = 16)	TP (n = 17)	NT (n = 17)	NP (n = 18)	*P*
Age (years)	69.1 ± 6.1	70.4 ± 5.9	69.2 ± 6.2	66.9 ± 5.2	0.22
Body mass (kg)	67.9 ± 14.2	70.3 ± 16.1	63.3 ± 9.2	66.3 ± 11.9	0.92
Height (cm)	158.2 ± 5.8	155.1 ± 6.4	154.5 ± 5.2	153.5 ± 6.3	0.45
Body mass index ($kg.m^{-2}$)	27.0 ± 5.2	29.0 ± 5.4	26.5 ± 3.5	28.1 ± 5.1	0.88

Note: TT = trained traditional. TP = trained pyramid. NT = novice traditional. NP = novice pyramid.

Table 5.2 - Body fat, appendicular skeletal muscle mass and muscle quality in older women according to resistance training system. Data are expressed as mean and standard deviation.

	TT (n = 16)	TP (n = 17)	NT (n = 17)	NP (n = 18)	Effects - ANCOVA	*P*
Body fat (%)					Time	0.14
Pre training	36.3 ± 10.6	38.4 ± 6.8	36.5 ± 7.5	44.1 ± 7.5	Time x training status	< 0.01
Post training	35.9 ± 10.7	38.6 ± 7.5	35.6 ± 7.6*	39.9 ± 7.7*	Time x system	0.78
Δ%	-1.0	0.4	-2.5	-2.8	Time x system x training status	0.24
Effect size	-0.03	0.02	-0.12	-0.15		
ULSMM (kg)					Time	0.05
Pre training	4.1 ± 0.7	4.0 ± 0.9	3.7 ± 0.5	3.6 ± 0.6	Time x training status	0.33
Post training	4.2 ± 0.7*	4.1 ± 0.9*	3.8 ± 0.5*	3.7 ± 0.6*	Time x system	0.17
Δ%	2.4	2.5	2.7	2.8	Time x system x training status	0.48
Effect size	0.14	0.11	0.20	0.17		
LLSMM (kg)					Time	< 0.01
Pre training	13.3 ± 2.7	12.9 ± 2.2	11.6 ± 1.2	11.1 ± 1.7	Time x training status	< 0.01
Post training	13.5 ± 2.2*	13.1 ± 2.3*	12.1 ± 1.1*	11.5 ± 1.7*	Time x system	0.12
Δ%	1.2	1.6	4.3	4.1	Time x system x training status	0.41
Effect size	0.06	0.09	0.42	0.27		
TMQ					Time	0.01
Pre training	6.3 ± 0.9	6.4 ± 1.1	5.6 ± 0.6	5.7 ± 0.7	Time x training status	< 0.01
Post training	6.5 ± 1.0*	6.6 ± 0.9*	6.1 ± 0.7*	6.4 ± 0.8*	Time x system	0.42
Δ%	3.3	3.7	9.3	11.0	Time x system x training status	0.63
Effect size	0.21	0.22	0.76	0.80		
ULMQ					Time	< 0.001
Pre training	5.8 ± 0.6	5.9 ± 1.0	5.3 ± 0.7	5.3 ± 0.5	Time x training status	0.34
Post training	6.1 ± 0.7*	6.3 ± 0.8*	5.8 ± 0.9*	6.0 ± 0.5*	Time x system	0.46
Δ%	6.0	6.0	10.1	12.2	Time x system x training status	0.75
Effect size	0.51	0.37	0.65	1.11		
LLMQ					Time	< 0.01
Pre training	4.1 ± 1.0	3.9 ± 0.9	3.3 ± 0.4	3.4 ± 0.7	Time x training status	0.05
Post training	4.3 ± 0.9*	4.2 ± 0.9*	3.7 ± 0.5*	3.9 ± 0.7*	Time x system	0.40
Δ%	5.5	7.4	11.6	13.3	Time x system x training status	0.88
Effect size	0.23	0.31	0.79	0.64		0.12

Note: ULSMM = upper limb skeletal muscle mass. LLSMM = lower limb skeletal muscle mass. TMQ = total muscle quality. ULMQ = upper limb muscle quality. LLMQ = lower limb muscle quality. * $P < 0.05$ vs. pre training.TT = trained traditional. TP = trained pyramid. NT = novice traditional. NP = novice pyramid.

Table 5.3 – Metabolic profile of older women at pre and post training according to resistance training experience. Data are expressed as mean and standard deviation.

	TT (n = 16)	TP (n = 17)	NT (n = 17)	NP (n = 18)	Effects - ANCOVA	*P*
Glucose (mg.dL^{-1})					Time	< 0.001
Pre training	100.0 ± 28.5	99.8 ± 14.6	95.4 ± 11.2	98.0 ± 10.8	Time x training status	0.46
Post training	92.4 ± 12.8*	94.1 ± 15.9*	90.1 ± 10.1*	97.5 ± 15.8*	Time x system	0.14
Δ%	-7.6	-5.7	-5.6	-0.5	Time x system x training status	0.42
Effect size	-0.37	-0.37	-0.50	-0.03		
TC (mg.dL^{-1})					Time	0.07
Pre training	190.3 ± 32.1	192.3 ± 25.9	210.8 ± 43.4	210.2 ± 32.7	Time x training status	0.08
Post training	190.5 ± 29.3	186.2 ± 17.3	204.7 ± 32.7	209.5 ± 36.8	Time x system	0.93
Δ%	0.1	-3.2	-2.9	-0.4	Time x system x training status	0.49
Effect size	0.01	-028	-0.16	-0.02		
Triglycerides (mg.dL^{-1})					Time	< 0.001
Pre training	111.8 ± 56.3	108.5 ± 51.2	150.8 ± 85.9	116.1 ± 47.4	Time x training status	0.45
Post training	94.2 ± 19.3*	102.8 ± 57.8*	110.4 ± 49.5*	110.6 ± 46.1*	Time x system	0.14
Δ%	-15.8	-5.3	-26.8	-4.7	Time x system x training status	0.82
Effect size	-0.47	-0.11	-0.60	-0.12		
HDL-C (mg.dL^{-1})					Time	< 0.001
Pre training	54.3 ± 19.5	57.7 ± 15.5	48.2 ± 13.1	56.3 ± 12.0	Time x training status	0.64
Post training	60.1 ± 17.8*	60.4 ± 15.1*	53.8 ± 14.8*	57.8 ± 13.9*	Time x system	0.78
Δ%	10.7	4.7	11.6	2.7	Time x system x training status	0.42
Effect size	0.31	0.18	0.40	0.12		
LDL-C (mg.dL^{-1})					Time	< 0.001
Pre training	103.6 ± 28.3	110.1 ± 17.0	132.4 ± 40.6	130.6 ± 32.8	Time x training status	0.18
Post training	78.9 ± 17.4*	80.5 ± 12.8*	86.5 ± 27.2*	94.1 ± 23.8*	Time x system	0.39
Δ%	-23.8	-26.8	-34.7	-27.9	Time x system x training status	0.48
Effect size	-1.08	-1.98	-1.35	-1.29		
CRP (mg.L^{-1})					Time	< 0.01
Pre training	2.6 ± 1.4	2.8 ± 2.2	3.0 ± 1.8	3.4 ± 3.0	Time x training status	< 0.01
Post training	1.0 ± 1.2*	1.5 ± 1.3*	2.2 ± 2.2*	2.9 ± 1.9*	Time x system	0.21
Δ%	-60.2	-47.1	-25.5	-13.1	Time x system x training status	0.79
Effect size	-1.19	-0.74	-0.37	-0.18		

Note: TC = total cholesterol. TT = trained traditional. TP = trained pyramid. NT = novice traditional. NP = novice pyramid. HDL-C = high-density lipoprotein. LDL-C = low-density lipoprotein. CRP = C-reactive protein. * $P < 0.05$ vs. pre training.

Table 5.4 – Adjusted mean by ANCOVA to post test.

	Covariate mean	**TT (n = 16)**	**TP (n = 17)**	**NT (n = 17)**	**NP (n = 18)**
		Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)
Body fat (%)	38.1	37.7 (37.0-38.5)	38.2 (37.4-38.9)	37.3 (36.5-38.0)	36.8 (36.1-37.6)
Upper limb muscle mass (kg)	3.90	3.98 (3.82-4.14)	3.90 (3.65-3.98)	4.0 (3.88-4.20)	3.90 (3.64-3.96)
Lower limb muscle mass (kg)	12.2	12.4 (12.1-12.6)	12.3 (11.8-12.4)	12.7 (12.4-12.9)	12.5 (12.3-12.7)
Total muscle quality	6.05	6.28 (6.09-6.46)	6.30 (6.13-6.48)	6.55 (6.37-6.73)	6.66 (6.49-6.83)
Upper limb muscle quality	5.62	6.01 (5.75-6.27)	6.06 (5.80-6.32)	6.10 (5.84-6.36)	6.23 (5.98-6.48)
Lower limb muscle quality	3.72	3.98 (3.81-4.16)	4.04 (3.87-4.20)	4.09 (3.92-4.26)	4.17 (4.01-4.33)
Glucose ($mg.dL^{-1}$)	98.3	91.6 (85.9-97.3)	93.4 (87.9-98.9)	91.4 (85.9-96.9)	97.2 (92.3-103.0)
Total cholesterol ($mg.dL^{-1}$)	198.8	193.3 (176.5-210.3)	187.2 (171.3-203.2)	202.2 (186.7-218.9)	202.6 (192.0-218.3)
Triglycerides ($mg.dL^{-1}$)	121.9	95.3 (72.4-118.2)	114.2 (91.6-136.5)	107.2 (84.5-130.0)	120.3 (99.7-142.8)
High-density lipoprotein ($mg.dL^{-1}$)	54.8	60.2 (52.7-67.7)	56.2 (48.8-63.7)	55.5 (48.1-63.0)	57.4 (50.3-64.4)
Low-density lipoprotein ($mg.dL^{-1}$)	119.6	81.0 (70.2-91.8)	81.8 (71.5-92.1)	84.9 (74.5-95.3)	92.7 (82.7-102.7)
C-reactive protein ($mg.L^{-1}$)	3.00	1.06 (0.18-1.94)	1.59 (0.77-2.44)	2.07 (1.22-2.93)	2.75 (2.25-2.82)

Note. TT = trained traditional. TP = trained pyramid. NT = novice traditional. NP = novice pyramid.

Table 5.5 – Participants responsiveness according to resistance training system and training status.

	TT (n = 16)	PT (n = 17)	NT (n = 17)	NP (n =18)
	n (%)	n (%)	n (%)	n (%)
Body fat				
Non responder	7 (43.8)	11 (64.7)	6 (35.3)	5 (27.8)
Low responder	9 (56.3)	6 (35.3)	10 (58.8)	12 (66.7)
Moderate responder	0 (0.0)	0 (0.0)	1 (5.9)	1 (5.6)
High responder	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Upper limb muscle mass				
Non responder	8 (50.0)	11 (64.7)	6 (35.3)	10 (55.6)
Low responder	8 (50.0)	5 (29.4)	11 (64.7)	7 (38.9)
Moderate responder	0 (0.0)	1 (5.9)	0 (0.0)	1 (5.6)
High responder	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Lower limb muscle mass				
Non responder	6 (37.5)	9 (52.9)	1 (5.9)	1 (5.6)
Low responder	10 (62.5)	8 (47.1)	12 (70.6)	17 (94.4)
Moderate responder	0 (0.0)	0 (0.0)	4 (23.5)	0 (0.0)
High responder	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total muscle quality				
Non responder	3 (18.8)	2 (11.8)	2 (11.8)	1 (5.6)
Low responder	13 (81.3)	14 (82.4)	8 (47.1)	7 (38.9)
Moderate responder	0 (0.0)	1 (5.9)	6 (35.3)	8 (44.4)
High responder	0 (0.0)	0 (0.0)	1 (5.9)	2 (11.1)
Upper limb muscle quality				
Non responder	5 (31.3)	4 (23.5)	4 (23.5)	3 (16.7)
Low responder	5 (31.3)	8 (47.1)	3 (17.6)	4 (22.2)
Moderate responder	6 (37.5)	0 (0.0)	7 (41.2)	7 (38.9)
High responder	0 (0.0)	5 (29.4)	3 (17.6)	4 (22.2)
Lower limb muscle quality				
Non responder	4 (25.0)	2 (11.8)	1 (5.9)	1 (5.6)
Low responder	6 (37.5)	10 (58.8)	6 (35.3)	6 (33.3)
Moderate responder	5 (31.3)	4 (23.5)	5 (29.4)	6 (33.3)
High responder	1 (6.3)	1 (5.9)	5 (29.4)	5 (29.4)
Glucose				
Non responder	4 (25.0)	2 (11.8)	4 (23.5)	8 (44.4)
Low responder	9 (56.3)	11 (64.7)	6 (35.3)	6 (33.3)
Moderate responder	2 (12.5)	4 (23.5)	6 (35.3)	3 (16.7)
High responder	1 (6.3)	0 (0.0)	1 (5.9)	1 (5.6)
Total cholesterol				
Non responder	7 (43.8)	8 (47.1)	10 (58.8)	8 (44.4)
Low responder	6 (37.5)	2 (11.8)	4 (23.5)	4 (22.2)
Moderate responder	2 (12.5)	5 (29.4)	1 (5.9)	4 (22.2)
High responder	1 (6.3)	2 (11.8)	2 (11.8)	2 (11.1)
Triglycerides				
Non responder	5 (31.3)	10 (58.8)	3 (17.6)	9 (50.0)
Low responder	2 (12.5)	1 (5.9)	2 (11.8)	4 (22.2)
Moderate responder	3 (18.8)	1 (5.9)	4 (23.5)	2 (11.1)
High responder	6 (37.5)	5 (29.4)	8 (47.1)	3 (16.7)
High-density lipoprotein				
Non responder	4 (25.0)	8 (47.1)	4 (23.5)	9 (50.0)
Low responder	2 (12.5)	4 (23.5)	6 (35.3)	4 (22.2)
Moderate responder	4 (25.0)	2 (11.8)	1 (5.9)	2 (11.1)
High responder	6 (37.5)	3 (17.6)	6 (35.3)	3 (16.7)
Low-density lipoprotein				
Non responder	3 (18.8)	1 (5.9)	4 (23.5)	2 (11.1)
Low responder	1 (6.3)	2 (11.8)	1 (5.9)	3 (16.7)
Moderate responder	2 (12.5)	3 (17.6)	0 (0.0)	3 (16.7)
High responder	10 (62.5)	11 (64.7)	12 (70.6)	10 (55.6)
C-reactive protein				
Non responder	1 (6.3)	6 (35.3)	8 (47.1)	9 (50.0)
Low responder	1 (6.3)	0 (0.0)	0 (0.0)	0 (0.0)
Moderate responder	1 (6.3)	0 (0.0)	0 (0.0)	0 (0.0)
High responder	13 (81.3)	11 (64.7)	9 (52.9)	9 (50.0)

Note: TT = trained traditional. TP = trained pyramid. NT = novice traditional. NP = novice pyramid.

5.4 Discussion

The main and novel finding were twofold: 1) RT performed in either traditional or pyramidal system improves muscular quality as well as metabolic biomarkers in older women. 2) Longer experience in RT may influences CRP, body fat, and muscle quality responses. To the authors' knowledge, this is the first study to compare the adaptive responses from different RT systems on muscular quality, metabolic biomarkers in older women with differing levels of RT.

Our results showed that muscle quality increased after training regardless of the system used, indicating that more strength can be produced per unit of muscle mass in the women's arms and legs. These results corroborate previous studies that reported an increase in muscle quality after a RT period [36-40]. Our study expands on previous findings by comparing muscle quality in two different RT systems. Another important feature of our study is that we examined changes in muscle quality on a regional basis which is especially important in the older individuals because the age-related decline in muscle quality observed in women are different between limbs, with a greater age-related decline has been seen in legs than in arms [41]. Moreover, we observed that the improvements in total muscle quality and lower limb muscle quality were higher in untrained than trained older women. It has been speculated that improvements on muscular quality from RT may be related to factors such as neural adaptations (increased motor recruitment and decreased co-activation of antagonist muscles) and a reduction in intramuscular fat [1]. Thus, given that these adaptive responses are dependent on an individual's training experience with RT [26-28], in which further neuromuscular adaptations become progressively more difficult as one gains training experience because the so-called "window of adaptation" decreases during long-term RT [42], it would be expected a higher response in untrained participants.

Regarding to the inflammatory biomarker, we observed that both RT systems are effective for reducing blood levels of CRP. Previous studies have found reductions in CRP after a RT program in novice subjects [17, 18, 25, 43-46]. Although the exact mechanisms by which RT leads to CRP reduction are not fully understood, we can speculate on several possibilities. Muscle contraction produces myokines that have anti-inflammatory effects antagonizing the pro-inflammatory cytokines, thus favoring the inflammation reduction as well as in the CRP [29]. Moreover, changes in some body composition components such as body fat and skeletal muscle mass may play an important role on inflammatory levels [25, 43-47], and RT has a positive impact on both of these outcomes. On the other hand, some investigations observed that the reductions in CRP are independent of body composition changes (17, 18). While the novice group in the present study displayed greater improvements in body composition, the advanced groups had a better response in CRP profile. These findings suggest that factors other than body composition changes are responsible for CRP decreases in those with RT experience. The greater reductions in CRP observed in advanced group may be related to the amount of muscle mass involved in the contractile activity (29). Moreover, myokines are sensitive to intensity of exercise (29), and although trained and novice performed the exercise at the same relative intensity, the advanced subjects achieved higher absolute workloads.

Another risk factor for cardiovascular disease studied was the lipid profile. No reductions in TC were noted for any groups at post-intervention. However, it is noteworthy that the TC includes both LDL-C and HDL-C, and given the antagonistic differences between these two lipoproteins on health, analysis of TC alone can be misleading. With respect to specific lipoproteins fractions and TG, we observed beneficial changes to both HDL-C and LDL-C as well as to the TG irrespective of the training system and level of training status. There is evidence suggesting that the manipulation of RT variables can influence the alterations in lipid profile (23, 24), but our study failed to demonstrate a disparate response in this regard. Therefore, the information regarding optimal intensity, volume and type of training to promote significant changes in blood lipids are still incipient. Our results are in line with previous studies that found positive effects of RT on lipoprotein fractions in older women (14-16, 48). The mechanisms of the RT effect on lipid profile have yet to be fully elucidated, and this study does not present mechanistic insight. That said, it is reasonable to speculate that lipid-lowering benefits of RT may lie in an increased ability of skeletal muscle to use fat (49). This effect is conceivably due to enzymatic changes that regulate the metabolism of lipoproteins, which includes an increase in lipoprotein lipase that mediates LDL plasma removal and lipid oxidation, and an increase in lecithin-cholesterol acyltransferase, an enzyme responsible for HDL-C transfer (49).

With respect to fasting blood glucose, our experiment noted significant reductions after participation in the RT program for both systems in novice and advance participants. This reduction is logical given that RT primarily relies on the glycolytic pathway for energy (50) and thus the immediate effects from the exercise bout alone helps to improve glucose homeostasis. Moreover, RT enhances insulin sensitivity via multiple mechanisms including an increase in skeletal muscle mass and qualitative improvement in muscle metabolic properties such as increased density of GLUT-4 transporters and an increase in the content/activity of the enzyme glycogen synthase [(51)]. As with other health-related markers, however, no differences were found between conditions, suggesting both approaches are equally effective in improving glucose homeostasis.

An important aspect of our experiment was the analysis of the participants' responsiveness. Although it is generally accepted that the group average represents a typical response for most individuals, muscular adaptations to RT programs are not uniform and a wide-ranging inter-individual variability is consistently noted following long-term training [(52-54)]. We stratified data into high, moderate-, low- and non-responders. The presentation of data in this regard seemingly provides greater insight into the varying response to RT, and may help the practitioner to draw conclusions with respect to individual program design.

Finally, the results presented here are specific to older women and cannot necessarily be extrapolated to other populations. Moreover, we were not able to monitor physical activity levels outside of the study environment, which may have confounded results. On the other hand, to our knowledge the present study is the first to investigate the effect of different RT systems on muscle quality, metabolic biomarkers in older women differing levels status, thus representing an important contribution to the current body of literature.

5.5 Conclusion

The results suggest that RT is an effective strategy to reduce CRP levels as well as to improve blood GLU and lipid profile of older women and that these adaptations are not dependent on the training system. In addition, the magnitude of the changes in CRP concentration, body fat and muscular quality are dependent on individual training status.

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CAPÍTULO 6

Considerações finais

6.1 Conclusões da tese

O presente trabalho comparou dois sistemas de TP sobre indicadores de saúde e desempenho motor de mulheres idosas com diferente experiência em TP. A análise conjunta dos artigos originais sugerem que os ganhos de força, a hipertrofia muscular, a redução de gordura corporal, bem como a melhora nos parametros bioquimicos ocorrerem igualmente em ambos os sistemas. Entretanto, experiência prévia com o TP exerce importante influência sobre as respostas induzidas pelo TP.

No contexto desta investigação, vale destacar alguns aspectos importantes que devem ser considerados na extrapolação dos achados. O modelo de progressão de carga adotado, cujas cargas são aumentadas somente quando um determinado número alvo de repetições é atingido, pode favorecer aqueles indivíduos que são motivados pelo desafio do aumento de cargas. A atividade física não foi controlada ou monitorada durante o período de intervenção, assim algumas adaptações positivas observadas podem ter ocorrido forma indireta, ou seja, o TP estimulando o aumento da atividade física cotidiana. O presente trabalho não utilizou um grupo controle. Embora para responder a principal questão do experimento (comparação de sistemas de treinamento) o grupo controle não seja essencial, a sua ausência impede analisar o efeito do treinamento de forma isolada.

Por outro lado, vale destacar alguns pontos fortes da presente investigação como a utilização do modelo *crossover*, um procedimento experimental que reduz o viés da variação interindividual, assim fortalecendo os achados. A utilização de protocolos com a aplicação de sobrecargas progressivas ao longo de todo o experimento. A equiparação dos níveis de treinamento das participantes que compuseram o grupo de idosas treinadas. Por fim, o monitoramento do consumo energético e de macronutrientes ao proporcionou informações que demonstraram uma manutenção relativa dos hábitos alimentares dos sujeitos ao longo do período de intervenção. Esse fato permitiu uma análise mais consistente dos efeitos do TP.

6.2 Aplicações práticas

Os resultados observados no presente trabalho, indicando que ambos os sistemas piramidal e tradicional são igualmente eficazes para promover adaptações positivas em mulheres idosas têm implicações importantes para os treinadores e profissionais da área de prescrição de programas de TP. Haja vista a flexibilidade de poder escolher o sistema de TP a ser utilizado, tomando como base na preferência individual. Este é um benefício relevante dada a importância da adesão na obtenção de resultados a longo prazo, especialmente em uma população de idosos. Além disso, os praticantes também têm a opção de utilizar uma combinação de diferentes sistemas TP ao longo do tempo, pois isso pode ajudar a manter o interesse pela adição de variedade para um programa TP.

Do ponto de vista clinico, os achados reportados nesta investigação indicam que o TP pode ser aplicado como uma medida terapêutica e preventiva para atenuar os processos deletérios que ocorrem no sistema funcional, na composição corporal e parâmetros bioquímicos associados ao processo natural do envelhecimento.

6.3 Perspectivas

A prática de TP tem suas origens na Grécia antiga, e durante o período no qual não haviam divulgação de estudos sobre os benefícios do TP, o preconceito predominava, sendo recomendado exclusivamente para atletas de força e culturismo e entusiastas destas modalidades esportivas e contraindicada para as demais populações, dentre estas, incluindo idosos. Porém, recentemente, graças a evidências científicas, o TP tem sido recomendado como a principal estratégia para manutenção e aumento de força e massa muscular em indivíduos de várias idades, saudáveis e não saudáveis. Ainda, devido ao grande número de estudos científicos é reconhecida como uma modalidade de exercício físico completa, sendo recomendada pelos principais posicionamentos como exercício como uma das formas de exercício sistemático para promoção da saúde e aptidão física geral.

Portanto, diante deste cenário evolutivo, das informações produzidas na presente investigação e das evidências científicas disponíveis na literatura sobre eficiência e segurança do TP, existe a perspectiva de que o TP seja a principal prática de exercício recomendada no futuro, complementada por outras formas de exercício. Portanto, estudos futuros devem produzir informações sobre as melhores estratégias de manipulação de TP são fundamentais para auxiliar na prescrição do treinamento e tomada de decisão.

ANEXOS

ANEXO A

Universidade Estadual de Londrina

PARANÁ
GOVERNO DO ESTADO

COMITÊ DE ÉTICA EM PESQUISA ENVOLVENDO SERES HUMANOS
Universidade Estadual de Londrina
Registro CONEP 5231

Parecer CEP/UEL:	048/2012
CAAE:	01893712.5.0000.5231
Processo:	10656/2012
Pesquisador(a):	Edilson Serpeloni Cyrino
Unidade/Órgão:	CEFE – Departamento de Educação Física

Prezado(a) Senhor(a):

O "**Comitê de Ética em Pesquisa Envolvendo Seres Humanos da Universidade Estadual de Londrina**" (Registro CONEP 5231) – de acordo com as orientações da Resolução 196/96 do Conselho Nacional de Saúde/MS e Resoluções Complementares, avaliou o projeto:

"IMPACTO DE DIFERENTES FREQUÊNCIAS SEMANAIS AO TREINAMENTO COM PESOS EM MULHERES IDOSAS"

Situação do Projeto: **Aprovado**

Informamos que deverá ser comunicada, por escrito, qualquer modificação que ocorra no desenvolvimento da pesquisa, bem como deverá ser encaminhado ao CEP/UEL relatório final da pesquisa, conforme prevê a Resolução 196/96 do Conselho Nacional de Saúde/MS e Resoluções Complementares.

Londrina, 23 de agosto de 2012.

Profa. Dra. Alexandrina Aparecida Maciel Cardelli
Coordenadora do Comitê de Ética em Pesquisa Envolvendo Seres Humanos
Universidade Estadual de Londrina

Campus Universitário: Rodovia Celso Garcia Cid (PR 445), Km 380 - Fone (43) 3371-4000 - PABX - Fax 3328-4440 - Caixa Postal 6001 - CEP 86051-990 - Internet http://www.uel.br
LONDRINA - PARANÁ - BRASIL

Form. Código 11.764 - Formato A4 (210x297)

APÊNDICES

APÊNDICE A

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Título da pesquisa:
“EFEITO DE SISTEMAS DE TREINAMENTO COM PESOS COM CARGAS FIXAS E VARIÁVEIS SOBRE INDICADORES DE SAÚDE E DE DESEMPENHO FÍSICO EM MULHERES IDOSAS”

Prezada Senhora:

Gostaríamos de convidá-la para participar da pesquisa **“Efeito de sistemas de treinamento com pesos com cargas fixas e variáveis sobre indicadores de saúde e de desempenho físico em mulheres idosas”**, a ser realizada no município de Londrina/PR. O objetivo desta pesquisa é analisar os efeitos de diferentes sistemas de treinamento com pesos sobre indicadores metabólicos, fisiológicos, neuromusculares e morfológicos em mulheres idosas.

Todas as avaliações serão realizadas por profissionais previamente treinados para tal finalidade. A assinatura deste termo permitirá que você participe das seguintes atividades: (1) Programa de treinamento com pesos com duração de 64 semanas que será acompanhado por profissionais e estudantes de Educação Física; (2) Preenchimento de questionários sobre histórico de saúde e atividade física habitual; (3) Medidas de peso, altura, pressão arterial, frequência cardíaca em repouso e atividade física habitual; (4) Avaliação da composição corporal pelos métodos de impedância bioelétrica (teste com duração de ~30 s: deitado em um colchonete, dois pequenos eletrodos serão colocados na mão e pé direito e transmitirão uma pequena corrente elétrica que indicará a quantidade de água [procedimento indolor e sem qualquer tipo de risco]), DEXA (teste com duração de aproximadamente sete minutos: deitada em uma mesa no próprio equipamento, sem portar qualquer tipo de objeto metálico, vestindo apenas roupas leves [shorts e top]. O equipamento fará um escaneamento do corpo todo para determinação da massa livre de gordura, massa gorda e massa óssea [procedimento indolor e sem qualquer tipo de risco]); (5) Coleta de sangue venoso em jejum de 12 h feita por um técnico capacitado e habilitado para a avaliação de indicadores metabólicos; (6) Avaliação nutricional por meio da aplicação de registros alimentares de três dias; (7) Avaliação da aptidão neuromuscular por meio de testes de uma repetição máxima (teste realizado em três exercícios para os segmentos de membros superiores, inferiores e tronco, que consiste na realização de três tentativas com o objetivo de levantar a maior quantidade de peso possível em apenas uma repetição para determinação da força muscular máxima).

Gostaríamos de esclarecer que a participação é totalmente voluntária. A participante pode recusar-se a participar/desistir a qualquer momento sem sofrer prejuízo algum. As informações serão utilizadas somente para fins de pesquisa e todos os documentos e amostras utilizados serão identificados por um código numérico sem identificação nominal para preservar a identidade da participante. Lembramos que não será cobrada taxa alguma por estas avaliações. Da mesma forma, não será paga quantia alguma as participantes.

Ao final do estudo, comprometemo-nos a retornar com os resultados de todas as avaliações, que serão entregues as participantes. Espera-se com essa pesquisa, proporcionar informações que possam favorecer a melhoria da saúde e qualidade de vida de mulheres idosas por meio da prática de treinamento e associação com aspectos nutricionais, além de possibilitar a melhoria de parâmetros morfológicos, fisiológicos, neuromusculares e metabólicos das participantes. Apesar de considerados mínimos, os possíveis riscos são: desconfortos na coleta sanguínea e cansaço durante os testes físicos. É possível também que alguns grupamentos musculares exigidos nos testes de esforço fiquem doloridos entre 24 e 48 horas após a realização dos mesmos.

Caso você tenha dúvidas ou necessite de maiores esclarecimentos pode contatar o Prof. Dr. Edilson Serpeloni Cyrino, no Laboratório de Metabolismo, Nutrição e Exercício, localizado no Centro de Educação Física e Esporte, da Universidade Estadual de Londrina, pelo telefone (43) 3371-4772 / 9139-4509 ou procurar o Comitê de Ética em Pesquisa Envolvendo Seres Humanos da Universidade Estadual de Londrina, na Avenida Robert Kock, 60 ou no telefone (43) 3371-2490. Este termo deverá ser preenchido em duas vias de igual teor, sendo uma delas, devidamente preenchida, assinada e entregue a você.

Londrina,____ de_____________de 2015.

____

Pesquisador Responsável

RG::__________________________

Eu,____ (**nome por extenso do sujeito de pesquisa**), tendo sido devidamente esclarecido sobre os procedimentos da pesquisa, concordo em participar **voluntariamente** da pesquisa descrita acima.

Assinatura (ou impressão dactiloscópica):____________________________

Data:___________________

APÊNDICE B
FICHA DE REGISTRO ALIMENTAR

Data ___/___/___ Mom._________

DESJEJUM ____h____min

ALIMENTO	TIPO	QUANTIDADE			Outros alimentos - qtde
Pão/bolacha	______	○ unidade______	○ fatia: □f □m □g ______		
Leite/ iogurte	______	○ copo gde(req.)______	○ copo americano______	○ xic □p □m □g ______	
Marg./Mant./Req.	______	○ ptade faca______	○ colher de chá______		
Café	______	○ copo americano______	○ Xícara □p □m □g______	○ copo café ______	
Açúcar	______	○ colher de sopa______	○ colher de sob.______	○ colher chá ______	
Queijo/ presunto	______	○ fatia fina______	○ fatia média______	○ fatia grossa______	
Cereal	______	○ colher de sopa______	○ colher de sob______	○ xic □p □m □g ______	
Fruta/suco	______	○ unidade______	○ fatia □p □m □g______	○ Copo. □p □m □g ______	
Achocolatado	______	○ colher de sopa______	○ colher de sob______	○ colher de chá______	

Lanche da manhã ____h____min

ALIMENTO	TIPO	QUANTIDADE			Outros alimentos - qtde
Pão/bolacha/bolo	______	○ unidade______	○ fatia: □f □m □g ______		
Leite/ iogurte/vitamina	______	○ copo gde(req.)______	○ copo americano______	○ xic □p □m □g ______	
Café	______	○ copo americano______	○ Xícara □p □m □g______	○ copo café ______	
Salgado	______	○ unidade______	□peq □méd □gde		
Açúcar	______	○ colher de sopa______	○ colher de sob.______	○ colher chá ______	
Queijo/ presunto	______	○ fatia fina______	○ fatia média______	○ fatia grossa______	
Fruta / suco	______	○ unidade______	○ fatia: □f □m □g ______	○ copo □amer. □requ.______	
Marg./Mant./Req	______	○ pta. de faca______	○ col □sopa □sob □chá______		

Almoço ____h____min

ALIMENTO	TIPO	QUANTIDADE			Outros alimentos - qtde
Arroz	______	○ escumadeira______	○ colher de sopa______	○ colher de servir______	
Feijão	______	○ concha □p □m □g______	○ colher de sopa______	○ colher de servir______	
Salada	______	○ folha □p □m □g ______	○ prato □p □m □g______	○ colher de sopa/servir______	
Legumes	______	○ colher de sopa/servir______	○ legumes ______	○ xic □p □m □g ______	
Carne	______	○ pdç □p □m □g______	○ colher de sopa______	○ colher de servir______	
Massa	______	○ pegador de macarrão______	○ colher de sopa______	○ colher de servir______	
Molho	______	○ colher de sopa______	○ colher de servir______	○ concha □p □m □g______	
Sobremesa	______	○ unidade______	○ outro______	○ col □sopa □sob □chá______	
Fruta/suco	______	○ unidade______	○ fatia □p □m □g ______	○ copo □amer. □requ.______	
Sal	______			Óleo:	

Lanche da Tarde____h____min

ALIMENTO	TIPO	QUANTIDADE			Outros alimentos - qtde
Pão/bolacha/bolo	______	○ unidade______	○ fatia: □f □m □g ______		
Leite/ iogurte/vitamina	______	○ copo gde(req.)______	○ copo americano______	○ xic □p □m □g ______	
Café	______	○ copo americano______	○ Xícara □p □m □g______	○ copo café ______	
Salgado	______	○ unidade______	□peq □méd □gde		
Açúcar	______	○ colher de sopa______	○ colher de sob.______	○ colher chá ______	
Queijo/ presunto	______	○ fatia fina______	○ fatia média______	○ fatia grossa______	
Fruta / suco	______	○ unidade______	○ fatia: □f □m □g ______	○ copo □amer. □requ.______	
Marg./Mant./Req	______	○ pta. de faca______	○ col □sopa □sob □chá______		

ALIMENTO TIPO QUANTIDADE Outros alimentos - qtde

Jantar ____h____min

□Repetiu almoço.

ALIMENTO	TIPO	QUANTIDADE			Outros alimentos - qtde
Arroz	______	○ escumadeira______	○ colher de sopa______	○ colher de servir______	
Feijão	______	○ concha □p □m □g______	○ colher de sopa______	○ colher de servir______	
Salada	______	○ folha □p □m □g ______	○ prato □p □m □g______	○ colher de sopa/servir______	
Legumes	______	○ colher de sopa/servir______	○ legumes ______	○ xic □p □m □g ______	
Carne	______	○ pdç □p □m □g______	○ colher de sopa______	○ colher de servir______	
Massa	______	○ pegador de macarrão______	○ colher de sopa______	○ colher de servir______	
Molho	______	○ colher de sopa______	○ colher de servir______	○ concha □p □m □g______	
Sobremesa	______	○ unidade______	○ outro______	○ col □sopa □sob □chá______	
Fruta/suco	______	○ unidade______	○ fatia □p □m □g ______	○ copo □amer. □requ.______	
Sal	______			Óleo:	

Ceia ____h____min

ALIMENTO	TIPO	QUANTIDADE			Outros alimentos - qtde
Pão/bolacha/bolo	______	○ unidade______	○ fatia: □f □m □g ______		
Leite/ iogurte/vitamina	______	○ copo gde (req.)______	○ copo americano______	○ xic □p □m □g ______	
Açúcar	______	○ colher de sopa______	○ colher de sobremesa______	○ colher chá______	
Queijo/ presunto	______	○ fatia fina______	○ fatia média______	○ fatia grossa______	
Fruta / suco/vitamina	______	○ unidade______	○ fatia □peq □méd □gde______	○ copo □amer. □requ.______	
margarina		○ pta. de faca	○ colher de chá		

Consumo de água no dia

Litros: __________ Copo: ○ americano ○ requeijão ○ outros __________

APÊNDICE C
FICHA DE TREINO ETAPA 1

PROJETO IDOSAS – TREINAMENTO DE MUSCULAÇÃO **TRADICIONAL**

NOME: ____

		__/__		__/__		__/__		__/__		__/__		__/__	
		Sessão 1		Sessão 2		Sessão 3		Sessão 4		Sessão 5		Sessão 6	
ORDEM EXERCÍCIO	SÉRIES/ REPETIÇÕES	CARGA	REP	CARGA	REP	CARGA	REP	CARGA	REP	CARGA	REP	CARGA	REP
Supino Vertical	1 X 10-15 RM												
Leg Press	1 X 10-15 RM												
Remada Sentada	1 X 10-15 RM												
Cadeira Extensora	1 X 10-15 RM												
Rosca Scott	1 X 10-15 RM												
Mesa flexora	1 X 10-15 RM												
Tríceps Pulley	1 X 10-15 RM												
Panturrilha Sentada	1 X 10-15 RM												

TREINADOR						
Observações						

APÊNDICE D
FICHA DE TREINO ETAPA 2

PROJETO IDOSAS – TREINAMENTO DE MUSCULAÇÃO **TRADICIONAL**

NOME: ____

		__/__		__/__		__/__		__/__		__/__		__/__	
		Sessão 1		**Sessão 2**		**Sessão 3**		**Sessão 4**		**Sessão 5**		**Sessão 6**	
ORDEM EXERCÍCIO	**SÉRIES/ REPETIÇÕES**	**CARGA**	**REP**	**CARGA**	**REP**	**CARGA**	**REP**	**CARGA**	**REP**	**CARGA**	**REP**	**CARGA**	**REP**
Supino Vertical	2 X 10-15 RM												
Leg Press	2 X 10-15 RM												
Remada Sentada	2 X 10-15 RM												
Cadeira Extensora	2 X 10-15 RM												
Rosca Scott	2 X 10-15 RM												
Mesa flexora	2 X 10-15 RM												
Tríceps Pulley	2 X 10-15 RM												
Panturrilha Sentada	2 X 10-15 RM												
TREINADOR													
Observações													

APÊNDICE E
FICHA DE TREINO TRADICIONAL ETAPAS 3 E 5

PROJETO IDOSAS – TREINAMENTO DE MUSCULAÇÃO **TRADICIONAL**

NOME: ____

		__/__		__/__		__/__		__/__		__/__		__/__	
		Sessão 1		Sessão 2		Sessão 3		Sessão 4		Sessão 5		Sessão 6	
ORDEM EXERCÍCIO	SÉRIES/ REPETIÇÕES	CARGA	REP	CARGA	REP	CARGA	REP	CARGA	REP	CARGA	REP	CARGA	REP
Supino Vertical	3 X 8-12 RM												
Leg Press	3 X 8-12 RM												
Remada Sentada	3 X 8-12 RM												
Cadeira Extensora	3 X 8-12 RM												
Rosca Scott	3 X 8-12 RM												
Mesa flexora	3 X 8-12 RM												
Tríceps Pulley	3 X 8-12 RM												
Panturrilha Sentada	3 X 8-12 RM												
TREINADOR													
Observações													

APÊNDICE F
FICHA DE TREINO PIRÂMIDE ETAPAS 3 E 5

PROJETO IDOSAS – TREINAMENTO DE MUSCULAÇÃO **½ PIRAMIDE**

NOME: ____

		__/__		__/__		__/__		__/__		__/__		__/__	
		Sessão 1		**Sessão 2**		**Sessão 3**		**Sessão 4**		**Sessão 5**		**Sessão 6**	
ORDEM EXERCÍCIO	**SÉRIES/ REPETIÇÕES**	**CARGA**	**REP**	**CARGA**	**REP**	**CARGA**	**REP**	**CARGA**	**REP**	**CARGA**	**REP**	**CARGA**	**REP**
Supino Vertical	12/10/8 RM												
Leg Press	12/10/8 RM												
Remada Sentada	12/10/8 RM												
Cadeira Extensora	12/10/8 RM												
Rosca Scott	12/10/8 RM												
Mesa flexora	12/10/8 RM												
Tríceps Pulley	12/10/8 RM												
Panturrilha Sentada	12/10/8 RM												

TREINADOR						
Observações						