UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
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CÁSSIO VÍCTORA RUAS

OS EFEITOS DE TRÊS DIFERENTES PROTOCOLOS DE TREINAMENTO ISOCINÉTICO NAS ADAPTAÇÕES NEUROMUSCULARES DE FLEXORES E EXTENSORES DO JOELHO

Porto Alegre
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CARTA DE APRESENTACAO DA DISSERTACAO

A presente dissertação teve o objetivo de investigar os efeitos de três diferentes protocolos de treinamento isocinético nas adaptações neuromusculares de flexores e extensores do joelho.

A dissertação está apresentada no seguinte formato: 1) Resumo, sumário, lista de tabelas/figuras, introdução, objetivos e revisão da literatura da dissertação (em português); 2) Artigo (em inglês), elaborado a partir dos resultados do estudo realizado, o qual será submetido a um periódico científico de nível internacional; 3) Conclusão da dissertação e referências bibliográficas para artigo e dissertação (em português).

O formato de apresentação está de acordo com a resolução N^{o} 114/2014 da Câmara de Pós-Graduação (CAMPG) (Anexo 1). A aprovação do estudo pelo comitê de ética da universidade em que os dados foram coletados está incluída no fim do documento (Anexo 2).

RESUMO

O treinamento isocinético é uma alternativa eficaz para incrementos neuromusculares e na *performance* de torque muscular dos flexores e extensores do joelho. No entanto, o treinamento mais efetivo para aumentar o equilíbrio de torque muscular entre isquiotibiais e quadríceps (I/Q) ainda parece desconhecido. Portanto, o objetivo deste estudo foi comparar os efeitos de três diferentes tipos de treinamentos isocinéticos nas razões I/Q convencional (R_{con}) e funcional (R_{fun}). Adicionalmente, foram avaliados os efeitos desses treinamentos nas variáveis de pico de torque (PT) concêntrico e excêntrico, pico de torque isométrico (PTI) taxa de produção de torque (TPT), ativação muscular (EMG), atraso eletromecânico (AE), espessura muscular (EM) e *echo-intensity* (EI) dos músculos flexores e extensores do joelho, bem como no desempenho funcional através dos testes *squat jump* (SJ), *counter movement jump* (CMJ), *drop jump* (DJ) e *sprint* 40m. Quarenta sujeitos homens destreinados (22,87 ± 2,28 anos, 70,66 ± 11,04 kg, 174,29 ± 6,9 cm) realizaram 6 semanas de treinamento para flexores e extensores do joelho em um dinamômetro isocinético Biodex. Eles foram selecionados de forma randomizada em 3 grupos de treinamento: modo concêntrico de extensão e concêntrico de flexão de joelhos (CON/CON); modo excêntrico de extensão e excêntrico de flexão de joelhos (EXC/EXC); modo concêntrico de extensão e excêntrico de flexão de joelhos (CON/EXC); e um grupo controle que não realizou nenhum treinamento (CNTRL). Todas as sessões de treinamento foram separadas por pelo menos 48h e as variáveis analisadas foram testadas em 2 dias, sendo realizadas 72h antes e depois da realização dos treinamentos. O grupo que treinou no modo EXC/EXC obteve maiores resultados na $R_{Fun,}$ assim como aumentos significativos em PT excêntrico, PTI, CMJ e DJ comparado aos demais grupos ($p<0,05$), enquanto o grupo que treinou no modo CON/CON aumentou TPF em relação aos demais ($p>0.05$). Todos os grupos aumentaram EM do quadríceps e isquiotibiais de forma similar ($p<0,05$). Não houve diferença entre os grupos para PT concêntrico, EMG, AE, EI, R_{Con}, SJ ou *Sprint* 40m ($p>0,05$). Portanto, o modo de treinamento EXC/EXC pode ser o mais efetivo para aumentar equilíbrio de torque muscular funcional I/Q. Treinamento excêntrico aumenta o torque excêntrico, influenciando nos aumentos na R_{Fun} e em saltos verticais que envolvem torque excêntrico (CMJ e DJ). O modo de treinamento CON/CON pode ser o mais efetivo em aumentos na potencia muscular.

Palavras-chave: Treinamento isocinético; Razões I/Q; Variáveis neuromusculares.

ABSTRACT

Isokinetic dynamometers may be a viable alternative for improvements in neuromuscular and strength performance of knee flexors and extensors. However, the most advantages training protocol to elicit the greatest increases in hamstrings to quadriceps (H/Q) muscle balance is unknown. Therefore, the aim of this study was to compare three different isokinetic training protocols on H/Q strength balance, calculated by conventional and functional ratios. A secondary aim was to compare the training protocols across varied quadriceps and hamstrings muscle actions on concentric and eccentric peak torque (PT), isometric peak torque (IPT), rate of torque development (RTD), muscle activation (EMG), electromechanical delay (EMD), muscle thickness (MT) and echo-intensity (EI), as well functional performance tested by squat jump (SJ), counter movement jump (CMJ), drop jump (DJ) and 40m sprint tests. Forty untrained male subjects (22.87 ± 2.28 yrs, 70.66 ± 11.04 kg, 174.29 ± 6.9 cm) performed 6 weeks of training of their dominant and non-dominant knees on a Biodex isokinetic dynamometer. They were randomly assigned to 3 training groups; concentric quadriceps and concentric hamstrings (CON/CON), eccentric quadriceps and eccentric hamstrings (ECC/ECC), concentric quadriceps and eccentric hamstrings (CON/ECC) or no training (CNTRL). All training sessions were separated by at least 48 hours, and all variables were tested in 2 days 72h before and after training. Results revealed that the ECC/ECC group showed significant increases in functional ratio, as well as hamstrings and quadriceps eccentric PT, IPT, CMJ and DJ, compared to all other groups while the CON/CON group increased RTD ($p<0.05$). In addition, all training groups increased MT of quadriceps and hamstrings similarly ($p<0.05$). There were no differences between groups for concentric PT, EMG, ED, EI, SJ, conventional ratio or 40m sprint ($p>0.05$). Our findings suggest that ECC/ECC training may be the most effective at increasing functional H/Q strength ratio. Eccentric training increases eccentric strength, thereby increasing the functional H/Q strength ratio. Eccentric training also improves vertical jumps involving eccentric strength. CON/CON training may be more effective at increasing muscle power.

Key-words: Isokinetic training; H:Q ratios; Neuromuscular variables.

SUMÁRIO

LISTA DE ABREVIATURAS EM PORTUGUÊS

PT	Pico de Torque
PTI	Pico de Torque Isométrico
TPT	Taxa de Produção de Torque
EMG	Eletromiografia / Ativação Muscular
AE	Atraso Eletromecânico
EM	Espessura Muscular
EI	*Echo-intensity*
SJ	*Squat Jump*
CMJ	*Counter Movement Jump*
DJ	*Drop Jump*
Razão I/Q	Razão isquiotibiais/quadriceps
R_{Con}	Razão Convencional
R_{Fun}	Razão Funcional
CON	Concêntrico
EXC	Excêntrico
CON/CON	Concêntrico de Extensores/Concêntrico de Flexores
EXC/EXC	Excêntrico de Extensores/Excêntrico de Flexores
CON/EXC	Concêntrico de Extensores/Excêntrico de Flexores
CNTRL	Controle (sem treinamento)
VM	Vasto Medial
VL	Vasto Lateral
VI	Vasto Intermédio
RF	Reto Femoral
BF_{cl}	Bíceps Femoral Cabeça Longa
ST	Semitendíneo
SM	Semimembráceo

LISTA DE ABREVIATURAS EM INGLÊS

PT	Peak Torque
IPT	Isometric Peak Torque
RTD	Rate of Torque Development
EMG	Electromyography / Muscle Activation
ED	Electromechanical Delay
MT	Muscle Thickness
EI	Echo-intensity
SJ	Squat Jump
CMJ	Counter Movement Jump
DJ	Drop Jump
H/Q ratio	Hamstrings/Quadríceps Ratio
CR	Conventional Ratio
FR	Functional Ratio
CON	Concentric
ECC	Eccentric
CON/CON	Concentric quadríceps/Concentric hamstrings
ECC/ECC	Eccentric quadriceps Eccentric hamstrings
CON/ECC	Concentric quadriceps/Eccentric hamstrings
CNTRL	Control (no training)
VM	Vastus medialis
VL	Vastus lateralis
VI	Vastus intermedius
RF	Rectus femoris
BF_{lh}	Bíceps femoris long head
ST	Semitendinosus
SM	Semimembranosus

LISTA DE TABELAS DO ARTIGO

LISTA DE FIGURAS DO ARTIGO

1. INTRODUÇÃO

1.1 Problema e Justificativa

Os dinamômetros isocinéticos são equipamentos utilizados para avaliação do torque muscular e têm sido utilizados para investigar as propriedades musculoarticulares em atividades de desempenho físico (ANDRADE MDOS *et al.*, 2012; ASKLING; KARLSSON; THORSTENSSON, 2003; BENNELL *et al.*, 1998; BRUKNER *et al.*, 2013; CHEUNG; SMITH; WONG DEL, 2012; COBURN *et al.*, 2006; CROISIER *et al.*, 2002; CROISIER *et al.*, 2008; ENISELER *et al.*, 2012; GOLIK-PERIC *et al.*, 2011; GRECO *et al.*, 2012;2013; GUR *et al.*, 1999; HENDERSON; BARNES; PORTAS, 2010; HOLCOMB *et al.*, 2007; IGA *et al.*, 2009; JENKINS *et al.*, 2013; LEHANCE *et al.*, 2009; MAGALHÃES *et al.*, 2001; PORTES *et al.*, 2007; ROSENE; FOGARTY; MAHAFFEY, 2001; ZEBIS *et al.*, 2011). Os testes e as avaliações realizados nestes equipamentos são considerados métodos consistentes para a predição da *performance*, padrão de lesões e diagnóstico de desequilíbrios musculares em adultos saudáveis e atletas (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; BROWN, LEE E., 2000; BROWN, L. E.; WEIR, 2001; BROWN, L. E. *et al.*, 1993; DVIR, 2004; ELLENBECKER; DAVIES, 2000; RUAS; BROWN; PINTO, 2015; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015; RUAS, CASSIO V. *et al.*, 2015; RUAS, C. V. *et al.*, 2014). Além disso, os protocolos de treinamentos no dinamômetro isocinético podem ser utilizados para incrementos neuromusculares e melhorias no desempenho físico, auxiliando na reabilitação e prevenção de lesões articulares (BROWN, LEE E., 2000; CABRI; CLARYS, 1991; CROISIER *et al.*, 2002; DVIR, 2004; GOLIK-PERIC *et al.*, 2011). No entanto, desde a introdução da dinamometria em protocolos modernos de reabilitação, pesquisadores e clínicos têm enfrentado dificuldades para selecionar protocolos isocínéticos específicos e associados aos objetivos estabelecidos para a rotina de treino a ser utilizada (CABRI; CLARYS, 1991; DVIR, 2004; GOLIK-PERIC *et al.*, 2011). Os efeitos relativos à estrutura dos protocolos, sobretudo associados ao controle da intensidade e do volume do treinamento, ainda não são suficientemente conhecidos e descritos de forma clara na literatura, considerando-se os diferentes objetivos possíveis de ser almejados com cada modelo de treino (CABRI; CLARYS, 1991; GOLIK-PERIC *et al.*, 2011).

As análises de pico de torque (PT) muscular obtidas pelos testes isocinéticos podem ser realizadas para avaliar a produção de torque voluntário máximo e para calcular as razões isocinéticas, que avaliam desequilíbrios entre o torque produzido pelos músculos agonistas e antagonistas de determinadas articulações. Este diagnóstico é importante para identificar desequilíbrios musculares e estimar riscos de futuras lesões (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; CROISIER *et al.*, 2002; DA SILVA *et al.*, 2013; ELLENBECKER; DAVIES, 2000; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015). Especificamente as razões isocinéticas dos isquiotibiais/quadríceps (I/Q) têm sido investigadas por uma variedade de estudos para descrever as propriedades de toque muscular em atividades que apresentam alta taxa de lesões de não-contato nos membros inferiores (ANDRADE MDOS *et al.*, 2012; ASKLING *et al.*, 2003; BENNELL *et al.*, 1998; BRUKNER *et al.*, 2013; CHEUNG *et al.*, 2012; COBURN *et al.*, 2006; CROISIER *et al.*, 2002; CROISIER *et al.*, 2008; ENISELER *et al.*, 2012; GRECO *et al.*, 2012;2013; GUR *et al.*, 1999; HENDERSON *et al.*, 2010; HOLCOMB *et al.*, 2007; IGA *et al.*, 2009; JENKINS *et al.*, 2013; LEHANCE *et al.*, 2009; MAGALHÃES *et al.*, 2001; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015; ZEBIS *et al.*, 2011). Estas lesões podem ocorrer quando os isquiotibiais não são capazes de gerar torque de oposição suficiente para desacelerar movimentos de translação anterior *(shear forces)* ou de rotação interna da tíbia, induzidas por contrações máximas de quadríceps em movimentos de extensão de joelho (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; CHEUNG *et al.*, 2012; COOMBS; GARBUTT, 2002; HOLCOMB *et al.*, 2007; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015), o que pode levar a lesões como rompimento do ligamento cruzado anterior (LCA) e distensão muscular dos isquiotibiais (COOMBS; GARBUTT, 2002; CROISIER *et al.*, 2002; CROISIER *et al.*, 2008; DALLINGA; BENJAMINSE; LEMMINK, 2012; HIEMSTRA *et al.*, 2004; HOLCOMB *et al.*, 2007). As razões isocinéticas podem ser classificadas em razão convencional (R_{Con}), que leva em consideração o PT concêntrico (CON) de isquiotibiais / PT CON de quadríceps, e razão funcional (R_{Fun}), que considera o PT excêntrico (EXC) de isquiotibiais / PT CON de quadríceps (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; COOMBS; GARBUTT, 2002; DVIR *et al.*, 1989; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015). Valores menores do que 0.6 para RC e 1.0 para RF tem sido sugeridos como indicadores de desequilíbrio muscular, o que pode levar a alto risco para lesões musculares e ligamentares envolvendo o complexo do joelho (AAGAARD *et al.*, 1998; ANDRADE MDOS *et al.*, 2012; COOMBS; GARBUTT, 2002; DVIR, 2004; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015; YEUNG; SUEN; YEUNG, 2009).

As sessões de treinamentos isocinéticos podem ser utilizadas para otimizar a interação de torque produzido entre isquiotibiais e quadríceps, aumentando as razões I/Q (CABRI; CLARYS, 1991; CROISIER *et al.*, 2002; CUNHA *et al.*, 2013; GIOFTSIDOU *et al.*, 2006). O fato dos dinamômetros isocinéticos permitirem a realização do torque máximo durante a amplitude total de movimento do exercício pode explicar os maiores efeitos encontrados por este treino quando comparado ao treino de força tradicional para este objetivo (GOLIK-PERIC *et al.*, 2011). Além disso, treinamentos isocinéticos podem ser efetivos em incrementos no torque, potência e ativação muscular (AKIMA *et al.*, 1999; BARONI, B. M. *et al.*, 2013; BROWN, L.; WHITEHURST, 2003; CADORE *et al.*, 2014; CUNHA *et al.*, 2013; EBID; OMAR; ABD EL BAKY, 2012; FABIS, 2007; GOLIK-PERIC *et al.*, 2011; GUILHEM; CORNU; GUEVEL, 2011; MILLER *et al.*, 2006; REMAUD; CORNU; GUEVEL, 2005; SYMONS *et al.*, 2005), espessura e qualidade muscular (BARONI, B. M. *et al.*, 2013; BLAZEVICH *et al.*, 2007; CADORE *et al.*, 2014; GUILHEM *et al.*, 2011) e desempenho em testes funcionais (CROISIER *et al.*, 2002; FABIS, 2007; GUR *et al.*, 2002; SANTOS *et al.*, 2010; SEKIR; GUR; AKOVA, 2010; SEKIR *et al.*, 2007; SYMONS *et al.*, 2005), fatores que também podem ter relação com diminuição de desequilíbrios musculares. Avaliações sobre qual protocolo resultará em maiores níveis de responsividade neuromuscular (menor atraso eletromecânico), rapidez em que essas ativações acontecem também poderiam auxiliar na elaboração destes treinamentos.

Nos dinamômetros isocinéticos é possível escolher o tipo de contração (modo) que irá ser utilizado durante o teste ou treino (BROWN, LEE E., 2000; DVIR, 2004). Os estudos também variam no uso de velocidades, séries, número de repetições, duração total e progressão do treino (BROWN, LEE E., 2000; CABRI; CLARYS, 1991; DVIR, 2004). Os estudos que realizaram treinamentos com protocolos específicos nos modos CON de extensores e CON de flexores do joelho (CON/CON) (BROWN, L.; WHITEHURST, 2003; CUNHA *et al.*, 2013; EBID *et al.*, 2012; GIOFTSIDOU *et al.*, 2006; GOLIK-PERIC *et al.*, 2011), CON de extensores do joelho e EXC de flexores (CON/EXC) (GUR *et al.*, 2002), EXC de flexores e EXC de extensores do joelho (EXC/EXC) (MILLER *et al.*, 2006), além de modos isolados EXC (BARAK; AYALON; DVIR, 2006; BARONI, BRUNO MANFREDINI *et al.*, 2013; BARONI, B. M. *et al.*, 2013; BLAZEVICH *et al.*, 2007; SANTOS *et al.*, 2010; SEGER; ARVIDSSON; THORSTENSSON, 1998; SYMONS *et al.*, 2005) e isolados CON (BARAK *et al.*, 2006; SEGER *et al.*, 1998; SYMONS *et al.*, 2005) de extensores do joelho já se mostraram eficientes para diversos incrementos neuromusculares. No entanto, o treinamento mais efetivo para aumentar o equilíbrio de torque muscular entre os flexores e extensores do joelho ainda parece desconhecido. Portanto, o objetivo deste estudo foi comparar os efeitos de três diferentes tipos de treinamentos isocinéticos nas razões I/Q (R_{con} e R_{fun}). Adicionalmente, foram avaliados os efeitos desses treinamentos nas variáveis neuromusculares de pico de torque (PT), pico de torque isométrico (PTI) taxa de produção de torque (TPT), ativação muscular (EMG), atraso eletromecânico (AE), espessura muscular (EM) e *echo-intensity* (EI) dos músculos flexores e extensores do joelho, bem como no desempenho funcional através dos testes *squat jump* (SJ), *counter movement jump* (CMJ), *drop jump* (DJ) e *sprint* 40m.

1.2. Objetivos:

1.2.1 Objetivo Geral

- Avaliar e comparar a diferença de três tipos de protocolos de treinamento isocinético nas adaptações neuromusculares nos flexores e extensores do joelho, com especial atenção à razão I/Q, bem como no desempenho funcional, em jovens destreinados.

1.2.2 Objetivos Específicos

- Avaliar e comparar as razões isquiotibiais/quadríceps (I/Q) (R_{Fun} e R_{Con}) entre 3 grupos de treinamento isocinético para flexores e extensores do joelho.

- Avaliar e comparar os picos de torque (PT) CON, EXC e isométrico (PTI) e a taxa de produção de torque (TPT) entre 3 grupos de treinamento isocinético para flexores e extensores do joelho.

- Avaliar e comparar a espessura (EM) e a qualidade muscular (*echo intensity* - EI) dos músculos reto femoral (RF), vasto lateral (VL), vasto medial (VM), vasto intermédio (VI), bíceps femoral cabeça longa (BF_{cl}), semitendíneo (ST) e semimembranáceo (SM) entre 3 grupos de treinamento isocinético para flexores e extensores do joelho.

- Avaliar e comparar o atraso eletromecânico (AE) do quadríceps e isquiotibiais, e a ativação neuromuscular (EMG) dos músculos RF, VL, VM e BF_{cl} entre 3 grupos de treinamento isocinético para flexores e extensores do joelho.

- Avaliar e comparar o desempenho em testes funcionais, representado por saltos (SJ, CMJ e DJ) e corrida *sprint* de 40m entre 3 grupos de treinamento isocinético para flexores e extensores do joelho.

2. REVISÃO DE LITERATURA

2.1. Dinamômetro Isocinético

A produção de torque muscular pode ser testada e avaliada para diagnóstico clínico, sendo utilizada para importantes intervenções terapêuticas e de reabilitação dos músculos e articulações (LAND; GORDON, 2011; RUAS, C. V. *et al.*, 2014). Dentre as avaliações de torque, o teste isocinético em dinamômetro computadorizado é utilizado para fornecer informações precisas e fidedignas que podem ser comparadas entre grupos musculares agonistas e antagonistas, membros lesionados e não-lesionados e atletas e não atletas, entre outros (CHANDLER; BROWN, 2009). Este teste envolve a programação de uma velocidade específica dentro uma amplitude de movimento preestabelecida para a avaliação do torque muscular em uma variedade de articulações (CHANDLER; BROWN, 2009; GOLIK-PERIC *et al.*, 2011). Sendo assim, durante um teste de torque isocinético, quanto maior o torque gerado pelo usuário, maior é o momento gerado pelos músculos, o que leva a uma tendência de aumento de velocidade angular (BROWN, LEE E., 2000; DVIR, 2004). No entanto, a máquina aumenta a sua resistência de forma compatível com o torque empregado e mantém o movimento dentro das margens da velocidade angular que foram estabelecidas (BROWN, LEE E., 2000; DVIR, 2004). O fato do torque ser expresso em dados numéricos permite treinadores e fisioterapeutas a avaliarem e compararem a produção de torque muscular de diferentes sujeitos e a acompanharem a progressão desta variável após treinos isocinéticos ou programas terapêuticos (CABRI; CLARYS, 1991). As características quantitativas objetivas do dinamômetro podem também ser utilizadas para fornecer dados normativos para avaliação de grupos de sujeitos, atletas e pacientes, podendo, portanto, serem utilizadas como referencia para populações investigadas (CABRI; CLARYS, 1991).

Muitos autores vêm utilizando a produção de torque isocinético para estimar padrões de lesões, *performance* e desequilíbrio muscular no joelho (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; COOMBS; GARBUTT, 2002; MAGALHÃES *et al.*, 2001; RUAS, C. *et al.*, 2015; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015; RUAS, CASSIO V. *et al.*, 2014). Uma das formas mais utilizadas para a avaliação deste desequilíbrio é através da obtenção da produção de torque muscular por dinamometria e cálculo de uma razão baseada no torque dos músculos antagonistas (flexores – isquiotibiais) dividido pelo torque dos músculos agonistas (extensores - quadríceps) do joelho. Esta razão é mais conhecida por razão isquiotibiais/quadríceps (I/Q) e tem sido utilizada para avaliação de desequilíbrio de torque muscular em torno da articulação do joelho por uma série de estudos (ANDRADE MDOS *et al.*, 2012; ASKLING *et al.*, 2003; BENNELL *et al.*, 1998; BRUKNER *et al.*, 2013; CHEUNG *et al.*, 2012; CROISIER *et al.*, 2008; ENISELER *et al.*, 2012; GRECO *et al.*, 2012;2013; GUR *et al.*, 1999; HENDERSON *et al.*, 2010; HOLCOMB *et al.*, 2007; IGA *et al.*, 2009; JENKINS *et al.*, 2013; LEHANCE *et al.*, 2009; MAGALHÃES *et al.*, 2001; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015; ZEBIS *et al.*, 2011).

2.2 Razões de Torque Muscular

As razões isocinéticas podem ser classificadas como razão convencional (R_{CON}) e razão funcional (R_{FUN}). A R_{CON} é a mais antiga descrita razão para a relação absoluta entre flexores e extensores do joelho (COOMBS; GARBUTT, 2002). Esta razão é calculada pelo PT concêntrico (CON) de isquiotibiais dividido pelo PT CON de quadríceps (PT CON I/PT CON Q) (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; GOLIK-PERIC *et al.*, 2011; HOLCOMB *et al.*, 2007; PORTES *et al.*, 2007; ROSENE *et al.*, 2001; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015). Embora esta relação possa variar de acordo com atividades funcionais específicas do esporte (ANDRADE MDOS *et al.*, 2012;

CHEUNG *et al.*, 2012; MAGALHÃES *et al.*, 2001; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015), valores de R_{CON} a partir de aproximadamente 0.6 na velocidade de teste de 60°·s^{-1} podem ser apropriadas para evitar riscos de lesões musculares e articulares no complexo do joelho (ANDRADE MDOS *et al.*, 2012; COOMBS; GARBUTT, 2002; DVIR, 2004; YEUNG *et al.*, 2009). Entretanto, esta razão não se aproxima da funcionalidade músculo-articular por não considerar os isquiotibiais trabalhando excentricamente para desacelerar ações musculares CON do quadríceps (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; COOMBS; GARBUTT, 2002; HOLCOMB *et al.*, 2007). Apesar desta grande limitação, a R_{CON} é considerada uma variável importante para a avaliação e monitoramento do equilíbrio de torque muscular e risco de lesões (ANDRADE MDOS *et al.*, 2012; CHEUNG *et al.*, 2012; DA SILVA *et al.*, 2013; GOLIK-PERIC *et al.*, 2011; LEHANCE *et al.*, 2009; MAGALHÃES *et al.*, 2001; PORTES *et al.*, 2007; ROSENE *et al.*, 2001). A R_{FUN} é considerada como a razão que mais se aproxima funcionalmente da interação dos músculos agonistas e antagonistas em movimentos funcionais e situações reais esportivas, por considerar os isquiotibiais trabalhando excentricamente (EXC) para "frear" as contrações CON do quadríceps (ex: corrida e chute) (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; COOMBS; GARBUTT, 2002; COSTA *et al.*, 2013; DE STE CROIX; DEIGHAN; ARMSTRONG, 2007; DVIR *et al.*, 1989; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015). Esta razão é calculada pelo PT EXC I/PT CON Q e uma R_{FUN} de valor aproximado a 1.0 pode indicar a capacidade dos isquiotibiais em oferecerem estabilidade articular durante movimentos de extensão do joelho (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; COOMBS; GARBUTT, 2002).

Ambas as razões (R_{CON} e R_{FUN}) foram investigadas por diversos estudos para descrever a relação existente entre isquiotibiais e quadríceps para funcionalidade da articulação do joelho e, principalmente, para diagnosticar riscos de lesões no ligamento cruzado anterior (LCA) e distensões musculares nos isquiotibiais (COOMBS; GARBUTT, 2002; CROISIER *et al.*, 2002; CROISIER *et al.*, 2008; DALLINGA *et al.*, 2012; HIEMSTRA *et al.*, 2004; HOLCOMB *et al.*, 2007; RUAS, C. *et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015). Estas lesões normalmente ocorrem quando os isquiotibiais apresentam um torque EXC insuficiente, tendo diminuída a sua capacidade de gerar forças de rotação e translação anterior da tíbia para desacelerar contrações CON do quadríceps (R_{CON} menor que 0.6 e R_{FUN} menor que 1.0). Os valores das razões I/Q podem ser aumentados através de sessões de treinamento isocinético, diminuindo o desequilíbrio muscular presente no complexo do joelho (CABRI; CLARYS, 1991; CROISIER *et al.*, 2002; CUNHA *et al.*, 2013).

2.3 Treinamento isocinético

Os protocolos de treinamento realizados no dinamômetro isocinético podem aumentar a produção de torque concêntrico, excêntrico e isométrico dos grupos musculares em torno da articulação escolhida. Diferentemente dos treinamentos de força tradicionais (isoinerciais), em que a tensão muscular máxima ocorre apenas nos ângulos onde há a vantagem mecânica mais favorável da amplitude de movimento trabalhada, os treinamentos isocinéticos permitem que o torque realizado pelo sujeito seja proporcionalmente retornado em forma de resistência pelo dinamômetro isocinético, o que permite a realização do nível máximo de produção de torque muscular durante toda a amplitude de movimento (CABRI; CLARYS, 1991; CUNHA *et al.*, 2013; GOLIK-PERIC *et al.*, 2011). Este fato pode explicar uma série de estudos que encontraram adaptações neuromusculares significativas após a realização deste tipo de treinamento na articulação do joelho (AKIMA *et al.*, 1999; BARONI, B. M. *et al.*, 2013; BLAZEVICH *et al.*, 2007; BROWN, L.; WHITEHURST, 2003; CADORE *et al.*, 2014; CROISIER *et al.*, 2002; CUNHA *et al.*, 2013; EBID *et al.*, 2012; FABIS, 2007; GOLIK-PERIC *et al.*, 2011; GUILHEM *et al.*, 2011; MILLER *et al.*, 2006; REMAUD *et al.*, 2005; SYMONS *et al.*, 2005).

Para mensurar as vantagens do treino isocinético como instrumento de incrementos de torque dos flexores e extensores do joelho e reabilitação de desequilíbrio muscular I/Q, alguns estudos demonstraram os efeitos de períodos curtos de treinamentos de força utilizando este tipo de treino (BARAK *et al.*, 2006; CROISIER *et al.*, 2002; CUNHA *et al.*, 2013; EBID *et al.*, 2012; GIOFTSIDOU *et al.*, 2006; GOLIK-PERIC *et al.*, 2011; MILLER *et al.*, 2006). Golik-Peric *et al.* (2011) avaliaram a diferença dos treinamentos isocinético e isoinercial após 4 semanas nos flexores e extensores do joelho de 38 atletas (divididos em dois grupos, cada um realizando um destes treinamentos). Para o treinamento isocinético foi utilizado um treinamento no modo CON/CON (5 vezes por semana), com diminuição da velocidade angular isocinética ao longo das semanas de treinamento, aumentando a capacidade de produção de torque em contrações máximas (relação torque x velocidade) (DVIR, 2004). Apesar dos dois grupos apresentarem incrementos nos torques de extensão e flexão concêntricos de joelho após os treinos, o grupo que treinou força isocinética não obteve valores significativamente diferentes nestas variáveis quando comparado ao grupo que treinou força isoinercial. Entretanto, os valores de razões I/Q do grupo que treinou utilizando o dinamômetro foram superiores ao grupo que treinou utilizando pesos livres e aparelhos, demonstrando ser mais eficaz na normalização de desequilíbrio muscular do joelho de indivíduos com baixas razões I/Q. Este estudo vai ao encontro de Croiser et al. (2002), que demonstraram que treinamento isocinético para flexores e extensores do joelho utilizando velocidades de 60˚/s e 240˚/s no modo concêntrico, com complemento de velocidades de 30˚/s e 120˚/s, 3 vezes por semana, aumentaram R_{CON} e R_{FUN} de jogadores de futebol e reduziram a incidência de lesões, a intensidade das dores e desconforto dos membros inferiores até 12 meses depois do treinamento. Da mesma forma, Giofsisdou *et al*. (2006) demonstraram que um treinamento isocinético com duração de 2 meses, 3 vezes por semana utilizando o espectro de velocidade angular com variação de 150˚/s-240˚/s resultou na restauração das razões I/Q de jogadores de futebol profissional. Variar velocidades durante o treinamento isocinético em ordem lógica de progressão de intensidade (ex: velocidades altas para baixas para contração CON, ou baixas para altas para contração EXC), tem sido sugerido como uma forma efetiva de respostas neuromusculares ótimas (GIOFTSIDOU *et al.*, 2006; KOVALESKJI; HEITMAN, 2000). Um outro estudo (Cunha *et al*. 2013) também demonstrou que treinamentos isocinéticos recíprocos (envolvendo flexão seguido de extensão de joelho CON/CON) em períodos curtos de apenas 3 semanas apresentaram maior eficiência em incrementos neuromusculares e performance muscular comparados a treinamentos envolvendo apenas contrações CON dos agonistas. Estes estudos corroboram com uma série de investigações que encontraram incrementos no torque muscular e/ou na relação I/Q após a utilização de treinamentos curtos em dinamômetros isocinéticos (BARAK *et al.*, 2006; COBURN *et al.*, 2006; EBID *et al.*, 2012; GIOFTSIDOU *et al.*, 2006; MILLER *et al.*, 2006), o que demonstra a eficácia de treinamentos em dinamometria na diminuição de desequilíbrio muscular. Os dinamômetros isocinéticos permitem a produção do torque máximo muscular durante a amplitude total de teste escolhida, o que pode explicar estas rápidas adaptações quando comparadas a outros treinos (GOLIK-PERIC *et al.*, 2011). Entretanto os estudos apresentados utilizaram protocolos diferentes uns dos outros quanto aos modos, velocidade angular, intensidade e volumes de treino, o que limita o conhecimento sobre a estruturação de protocolos visando à reabilitação neuromuscular em indivíduos com desequilíbrio muscular.

As adaptações relativas à ativação e volume muscular também têm sido variáveis investigadas após treinamentos isocinéticos e podem ser importantes para explicar os mecanismos envolvidos nos aumentos de torque muscular. Na literatura, treinamentos isocinéticos específicos de contrações CON e EXC foram investigados para determinar se as maiores adaptações na ativação (BARAK *et al.*, 2006; BARONI, B. M. *et al.*, 2013; CADORE *et al.*, 2014) e espessura muscular (CADORE *et al.*, 2014; SEGER *et al.*, 1998) são específicas do estímulo neuromuscular sofrido durante o treinamento. Barak et al. (2006) demonstraram que sujeitos que realizaram treinamentos isocinéticos EXC em alta velocidade para extensores do joelho (realizados 3 vezes por semana por 6 semanas) obtiveram maiores incrementos na ativação isométrica eletromiográfica do vasto medial (VM), quando comparados a sujeitos que treinaram apenas contrações CON e apenas EXC em menor velocidade. Baroni *et al*. (2013) encontraram incrementos no pico de torque isométrico (ISO), CON e EXC em diferentes magnitudes em sujeitos fisicamente ativos que realizaram 12 semanas de treinamento excêntrico isocinético nos extensores do joelho. No entanto a atividade EMG foi incrementada após 4 semanas para torque EXC, após 8 semanas para torque ISO e sem mudanças no decorrer do estudo para torque CON. Estas mudanças foram acompanhadas de adaptações morfológicas a partir da 4ª semana de treino, o que demonstrou que a produção de torque muscular concêntrico parece ser principalmente decorrente de incrementos na massa muscular e não resultado de uma maior ativação muscular quando apenas o torque excêntrico é treinado. Cadore *et al*. (2014), encontraram aumentos, mas não encontraram diferença para ativação isométrica eletromiográfica, ativação e volume muscular, PT CON, EXC, TPT, velocidade de condução muscular, espessura e qualidade muscular do músculo vasto lateral quando comparados grupos de indivíduos que treinaram apenas torque CON com sujeitos que treinaram apenas torque EXC de extensores do joelho durante um período de 6 semanas. Nesse estudo, o grupo que treinou torque EXC apresentou valores de PT isométrico maiores do que o grupo que treinou força de forma CON. Nesses 2 últimos estudos citados a velocidade de treinamento foi de 60˚/s e o volume de treino foi aumentado através da adição de séries e repetições por semana.

Para investigar especificamente as adaptações no volume muscular após diferentes contrações isocinéticas, Seger *et al*. (1998) compararam os incrementos de força e as adaptações na área de secção transversa (AST) muscular em sujeitos após 25 sessões de treinamentos concêntricos e excêntricos (em membros diferentes, respectivamente) nos extensores do joelho no dinamômetro isocinético. O fato das maiores adaptações nesse estudo terem sido encontradas após o treino excêntrico vai ao encontro de uma série de investigações que defendem que a especificidade do treino pode ser responsável por adaptações neuromusculares e morfológicas diferentes (BARONI, B. M. *et al.*, 2013; HIGBIE *et al.*, 1996; O'HAGAN *et al.*, 1995). A maioria dos estudos relata que adaptações musculares após treinos EXC tendem a ser maiores quando comparados a treinos CON, por um nível menor de unidades motoras serem ativadas durante contrações máximas e submáximas EXC, levando uma grande proporção da força a ser gerada através do alongamento passivo de elementos elásticos em série e pela produção aumentada de força por ponte cruzada, o que pode resultar em um maior dano muscular e consequente maior hipertrofia (HIGBIE *et al.*, 1996; O'HAGAN *et al.*, 1995). Além disso, treinamentos excêntricos apresentam um trabalho total maior do que treinamentos concêntricos, o que pode ser um estímulo adicional para maiores adaptações neuromusculares e morfológicas (CADORE *et al.*, 2014). No entanto, alguns estudos demonstram que ambos os treinamentos podem induzir a adaptações similares quando realizados em curtos períodos de tempo (CADORE *et al.*, 2014; VIKNE *et al.*, 2006).

Ainda há lacunas na literatura sobre qual treino isocinético poderá resultar em maiores níveis de ativação em diferentes modos de contração. Os níveis de ativação muscular podem variar de acordo com a especificidade da contração realizada e o entendimento sobre a interação entre unidades motoras, elementos contráteis e elementos elásticos pode ser importante para a estruturação de protocolos isocinéticos visando a reabilitação (BARAK *et al.*, 2006). Avaliações sobre qual protocolo resultará em maiores níveis de responsividade neuromuscular (menor atraso eletromecânico), rapidez em que essas ativações acontecem, taxa de produção de torque, capacidade de produção de potência muscular também poderiam auxiliar na elaboração destes treinamentos. Além disso, a investigação sobre diferentes protocolos de treinamento isocinético para maiores incrementos na espessura muscular e *echo intensity* podem ser interessantes, visto que essas variáveis podem demonstrar a força, qualidade e funcionalidade muscular (PINTO *et al.*, 2014; RECH *et al.*, 2014), que podem ter relação com um maior equilíbrio I/Q.

Os treinamentos isocinéticos também podem ser vantajosos para melhorias em testes funcionais (GUR *et al.*, 2002; SANTOS *et al.*, 2010; SEKIR *et al.*, 2010; SEKIR *et al.*, 2007; SYMONS *et al.*, 2005), apesar de nem sempre serem encontrados pela falta de especificidade do treinamento (CORDOVA *et al.*, 1995; KOVALESKJI; HEITMAN, 2000; SANTOS *et al.*, 2010; SMITH; MELTON, 1981; WHITE *et al.*, 2004). Santos *et al*. (2009) apesar de não terem encontrado correlação entre pico de torque dos extensores do joelho e testes de desempenho físico em jovens fisicamente ativos após treinamento isocinético excêntrico (2 vezes por semana por 6 semanas), encontraram melhorias nos resultados de testes de agilidade e saltos comparando pré e pós treinamento isocinético. Este estudo vai ao encontro do estudo de Symons *et al*. (2005), que investigaram os efeitos do treinamentos isocinéticos concêntricos, isométricos e excêntricos nos extensores do joelho (3 vezes por semana por 3 meses) e encontraram incrementos de torque isométrico e isocinético (CON e EXC) para todos os grupos avaliados, além de menores tempos no teste do degrau (*step test*), que indicou melhoria na funcionalidade em adultos saudáveis. Contrariamente, Smith e Melton (1981) encontraram ganhos similares para os flexores e extensores do joelho comparando grupos de treinamento isocinético em alta velocidade e baixa velocidade, mas o grupo que treinou em alta velocidade teve os maiores resultados nos testes de salto vertical, salto horizontal e *sprint* 40m, o que foi atribuído a especificidade da velocidade treinada, o que levou o grupo a conseguir produzir força em maiores velocidades, exigida nos testes funcionais realizados.

Esta melhoria nos testes funcionais demonstrada após treinos de força máxima em dinamômetros isocinéticos é também importante na reabilitação de lesões no complexo do joelho. Sekir *et al*. (2010) avaliaram os efeitos do treinamento isocinético na funcionalidade articular de sujeitos quando iniciados a 3 semanas (grupo 1) comparados a 9 semanas (grupo 2) pós operatório do LCA do joelho. Foi constatado que o grupo que treinou poucas semanas após a operação apresentou incrementos no torque isométrico e concêntrico maiores do que o grupo que demorou mais para começar o treinamento. Além disso, os resultados em testes de desempenho de caminhada, subir escada (*stair-climbing*) e agachamento foram também melhores para o grupo 1 comparado ao grupo 2. Entretanto, além de treinos isocinéticos, a reabilitação também incluiu treinamentos funcionais, o que pode ter influenciado nos resultados positivos das avaliações. Os efeitos do treinamento isocinético em testes funcionais também foram investigados em indivíduos com osteoartrite no joelho (GUR *et al.*, 2002) separados em dois grupos: um grupo de pacientes participou de treinamentos que incluíam apenas contrações CON e outro grupo treinou contrações CON seguidas de EXC dos flexores e extensores do joelho por um período de 2 meses. As sessões de treino incluíram velocidades de 30˚/s-180˚/s. Após os treinamentos, os dois grupos apresentaram diminuição das dores no joelho e aumentos na capacidade física (testes de levantar da cadeira, caminhar, subir escada e descer escalada), AST muscular (quadríceps e isquiotibiais) e pico de torque (predominantemente CON para grupo 1 e EXC para grupo 2). O grupo que treinou CON + EXC para os mesmos grupos musculares obteve os maiores resultados para torque excêntrico e teste de subir e descer escadas. Estes estudos demonstram a importância de treinos realizados no dinamômetro isocinético para melhorias na funcionalidade do joelho, principalmente na reabilitação pós-operatória e de lesões articulares e musculares no complexo do joelho.

As vantagens do exercício isocinético incluem segurança, acomodação da resistência e facilidade na análise da produção de torque (CABRI; CLARYS, 1991). No entanto, ainda há dúvidas na literatura quanto à implementação de protocolos de avaliação relevantes para diferentes ocasiões e treinamentos mais vantajosos para diferentes programas de reabilitação, levando-se em conta modo, volume e intensidade (CABRI; CLARYS, 1991; DVIR, 2004; GOLIK-PERIC *et al.*, 2011). Uma série de fatores indica a necessidade de uma investigação sobre as adaptações neuromusculares e no equilíbrio de torque muscular I/Q resultantes de diferentes estímulos de treinamentos isocinéticos causado por diferentes protocolos. Os estudos variam no uso de velocidades, séries, número de repetições, modo de contração, duração total e progressão do treino, achando diferentes resultados (BROWN, LEE E., 2000; CABRI; CLARYS, 1991; DVIR, 2004). Esta lacuna na literatura pode acarretar em problemas e dificuldades na criação de protocolos visando aumentos de torque e equilíbrio dos flexores e extensores joelho. Resultados neste sentido podem possibilitar a troca de dados entre laboratório, hospitais e profissionais gerais para propósitos normativos e comparativos (CABRI; CLARYS, 1991).

3. ARTIGO

3.1. THE EFFECT OF THREE DIFFERENT PROTOCOLS ON KNEE STRENGTH RATIOS AND NEUROMUSCULAR ADAPTATIONS

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ABSTRACT

Isokinetic dynamometers may be a viable alternative for improvements in neuromuscular and strength performance due to advantages in safety, controlling speeds and ROM, velocity specificity, accommodating resistance, and objective quantitative data to facilitate strength analyses. However, the most advantages training protocol to elicit the greatest increases in hamstrings to quadriceps (H/Q) muscle balance is unknown. Therefore, the aim of this study was to compare three different isokinetic training protocols on H/Q strength balance, calculated by conventional and functional ratios. A secondary aim was to compare the training protocols across varied quadriceps and hamstrings muscle actions on concentric and eccentric peak torque (PT), isometric peak torque (IPT), rate of torque development (RTD), muscle activation (EMG), electromechanical delay (EMD), muscle thickness (MT) and echo-intensity (EI), as well functional performance tested by squat jump (SJ), counter movement jump (CMJ), drop jump (DJ) and 40m sprint tests. Forty untrained male subjects (22.87 ± 2.28 yrs, 70.66 ± 11.04 kg, 174.29 ± 6.9 cm) performed 6 weeks of training of their dominant and non-dominant knees on a Biodex isokinetic dynamometer. They were randomly assigned to 3 training groups; concentric quadriceps and concentric hamstrings (CON/CON), concentric quadriceps and eccentric hamstrings (CON/ECC) eccentric quadriceps and eccentric hamstrings (ECC/ECC), or no training (CNTRL). All training sessions were separated by at least 48 hours, and all variables were tested in 2 days 72h before and after training. Results revealed that the ECC/ECC group showed significant increases in H/Q functional ratio, as well as hamstrings and quadriceps eccentric PT, IPT, CMJ and DJ, compared to all other groups while the CON/CON group increased RTD ($p<0.05$). In addition, all training groups increased MT of quadriceps and hamstrings similarly ($p<0.05$). There were no differences between groups for concentric PT, EMG, ED, EI, SJ, conventional ratio or 40m sprint ($p>0.05$). Our findings suggest that ECC/ECC training may be the most effective at increasing functional H/Q strength ratio, as well as eccentric strength, isometric strength, CMJ and DJ performance. Eccentric training increases eccentric strength, thereby increasing the functional H/Q strength ratio. Eccentric training also improves vertical jumps involving eccentric strength. CON/CON training may be more effective at increasing muscle power.
Key-words: Isokinetic training; H:Q ratios; Neuromuscular variables.

INTRODUCTION

Isokinetic dynamometers are reliable tools for testing and training muscle strength and asymmetry across different sports, and joints (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; BROWN, LEE E., 2000; BROWN, L. E.; WEIR, 2001; BROWN, L. E. *et al.*, 1993; DVIR, 2004; ELLENBECKER; DAVIES, 2000; RUAS, C. *et al.*, 2015; RUAS, C. V. *et al.*, 2014; RUAS, CASSIO V. *et al.*, 2014). They provide objective quantitative data that can be used for reference and comparison (BROWN, LEE E., 2000; CABRI; CLARYS, 1991; DVIR, 2004), which is critical for accurate assessment (CABRI; CLARYS, 1991). This information can also be used for prescribing specific rehabilitation programs to improve performance, and prevent injuries (CROISIER *et al.*, 2002; CROISIER *et al.*, 2008). Isokinetic dynamometers have also been used for training (BROWN, LEE E., 2000; CABRI; CLARYS, 1991; DVIR, 2004), and may have advantages in terms of strength gains (GOLIK-PERIC *et al.*, 2011). While isoinertial machines allow muscles to produce the greatest tension at specific angles in the ROM, isokinetic machines provide resistance that is proportional to the torque produced by the subject, allowing maximal torque to be achieved through the entire pre-selected range of motion (CUNHA *et al.*, 2013; GOLIK-PERIC *et al.*, 2011).

Several studies have found that isokinetic training can be effective at increasing hamstrings and quadriceps concentric and/or eccentric peak torque (PT) (AKIMA *et al*., 1999; BROWN, L.; WHITEHURST, 2003; CADORE *et al*., 2014; COBURN *et al*., 2006; CUNHA *et al*., 2013; EBID; OMAR; ABD EL BAKY, 2012; FABIS, 2007; GOLIK-PERIC *et al*., 2011; GUILHEM; CORNU; GUEVEL, 2011; MILLER *et al*., 2006; REMAUD; CORNU; GUEVEL, 2005; SYMONS *et al*., 2005), which may increase hamstring to quadriceps (H/Q) strength ratios (CROISIER *et al*., 2002; GIOFTSIDOU *et al*., 2006; GOLIK-PERIC *et al*., 2011). H/Q strength ratios are often used to assess strength imbalances between these muscle groups, and can be classified as conventional ratio or functional ratio. Conventional and functional ratios less than normative values of 0.6 and 1.0, respectively, may indicate that hamstrings fail to produce enough torque to decelerate knee rotation or anterior tibial shear forces, which may be related to lower-extremity muscle and ligament injuries (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; CROISIER *et al.*, 2002; CROISIER *et al.*, 2008; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015). Besides increases in concentric and eccentric strength, isokinetic training can also improve isometric peak torque (IPT) (BARONI, B. M. *et al.*, 2013; CADORE *et al.*, 2014), rate of torque development (RTD) (BROWN, LEE E., 2000; CADORE *et al.*, 2014), and functional performance (CROISIER *et al.*, 2008; FABIS, 2007; GUR *et al.*, 1999; SANTOS *et al.*, 2010; SEKIR *et al.*, 2010; SMITH; MELTON, 1981; SYMONS *et al.*, 2005). Isokinetic dynamometers have also been used to investigate electromechanical delay (EMD), which is the time between the onset of electrical activity at the muscle and the onset of torque (CAVANAGH; KOMI, 1979; LACOURPAILLE; HUG; NORDEZ, 2013). The mechanisms underlying these strength increases have been investigated through muscle activation (EMG) and ultrasound measurements (BARONI, BRUNO MANFREDINI *et al.*, 2013; BARONI, B. M. *et al.*, 2013; CADORE *et al.*, 2014; HIGBIE *et al.*, 1996; SEGER *et al.*, 1998).

Isokinetic training may be a viable alternative for improvements in neuromuscular and strength performance due to advantages in safety, controlling speeds and ROM, velocity specificity, accommodating resistance, and objective quantitative data to facilitate strength analyses (BROWN, LEE E., 2000; CABRI; CLARYS, 1991; DVIR, 2004). However, studies have used a variety of speeds, sets, repetitions, length and progressions with different results (BROWN, LEE E., 2000; CABRI; CLARYS, 1991; DVIR, 2004). Also, specific neuromuscular adaptations have been found relative to muscular action (BARONI, B. M. *et al.*, 2013; HIGBIE *et al.*, 1996; O'HAGAN *et al.*, 1995). The most common actions used are concentric quadriceps and concentric hamstrings (CON/CON), concentric quadriceps and eccentric hamstrings (CON/ECC), and eccentric quadriceps and eccentric hamstrings (ECC/ECC) (BROWN, L.; WHITEHURST, 2003; CUNHA *et al.*, 2013; EBID *et al.*, 2012; GIOFTSIDOU *et al.*, 2006; GOLIK-PERIC *et al.*, 2011; GUR *et al.*, 2002; MILLER *et al.*, 2006). However, to our knowledge, the most advantages training protocol to elicit the greatest increases in H/Q muscle balance is unknown. Therefore, the aim of this study was to compare three different isokinetic training protocols on H/Q strength balance, calculated by conventional and functional ratios. A secondary aim was to compare the training protocols across varied quadriceps and hamstrings muscle actions on peak torque (PT), isometric peak torque (IPT), rate of torque development (RTD), muscle activation (EMG), electromechanical delay (EMD), muscle thickness (MT) and echo-intensity (EI), as well functional performance tested by squat jump (SJ), counter movement jump (CMJ), drop jump (DJ) and 40m sprint tests.

METHODS

Subjects

Forty male subjects (22.87 ± 2.28 years, 70.66 ± 11.04 kg, 174.29 ± 6.9 cm) volunteered to participate. They were free of any knee injuries, were not involved in any strength or endurance training program for the previous 3 months, and had refrained from physical activity 48 hours prior to the first testing session. All subjects had a functional ratio less than 1.0, thereby displaying functional H/Q muscle imbalance. Prior to participation, all subjects read and signed a University Institutional Review Boardapproved informed consent form based on the Declaration of Helsinki of ethical principles for medical research involving human subjects.

Experimental Design

Subjects were randomly assigned to one of 3 training groups; concentric quadriceps and concentric hamstrings (CON/CON), concentric quadriceps and eccentric hamstrings (CON/ECC) eccentric quadriceps and eccentric hamstrings (ECC/ECC), or no training (CNTRL). They performed 6 weeks of training of their dominant and non-dominant knees on a Biodex isokinetic dynamometer. Dominant leg concentric quadriceps and eccentric hamstrings PT, IPT, RTD, EMG, EMD, conventional and functional ratios, ultrasound and functional measurements were tested before and after training.

Procedures

Pre-training tests

Pre-training tests were performed on two separate days, separated by 48 hours.

On day 1, subjects were measured for mass on a digital scale (Model # ES200L, Ohaus, Pine Brook, NJ, USA), and height on a wall-mounted stadiometer (Seca Stadiometer, Ontario, Canada). Following this, they were measured by ultrasound; isometric peak torque (IPT), including rate of torque development (RTD), muscle activation (EMG) and electromechanical delay (EMD); and functional tests. Each test was separated by 10 minutes rest.

On day 2, subjects were tested for isokinetic concentric and eccentric quadriceps and hamstrings PT.

Training Sessions

Training sessions began 72 hours after day 2. They consisted of 2 visits a week for 6 weeks lasting about 20 minutes each. All training sessions were separated by at least 48 hours. Subjects comfortably sat on a Biodex System 3 isokinetic dynamometer using the same procedures of the isometric and isokinetic testing (description on IPT section). Group CON/CON began by performing 10 maximal repetitions at 210˚/s for quadriceps and hamstrings. Group ECC/ECC began by performing 10 maximal repetitions at 60˚/s for quadriceps and hamstrings. Group CON/ECC began by performing 10 maximal repetitions at 210˚/s for quadriceps concentric and at 60˚/s for hamstrings eccentric. The intensity of training was increased every week by decreasing isokinetic angular speed for concentric and increasing angular speed for eccentric in 30˚/s increments (GIOFTSIDOU *et al.*, 2006; GOLIK-PERIC *et al.*, 2011; GUR *et al.*, 1999; KOVALESKJI; HEITMAN, 2000). The volume of training was increased by one set every week (BARONI, B. M. *et al.*, 2013; CADORE *et al.*, 2014) (table 1). Group CNTRL did not do any training, but returned to the lab to be tested after 6 weeks.

Table 1: Training sessions design.

Weeks	Sessions	Sets	Repetitions	CON/CON speed	ECC/ECC speed	CON/ECC speed
1	2	1	10	210˚/s	60˚/s	210˚/s - 60˚/s
2	2	2	10	180˚/s	90˚/s	180˚/s - 90˚/s
3	2	3	10	150˚/s	120˚/s	150˚/s - 120˚/s
4	2	4	10	120˚/s	150˚/s	120˚/s - 150˚/s
5	2	5	10	90˚/s	180˚/s	90˚/s - 180˚/s
6	2	6	10	60˚/s	210˚/s	60˚/s - 210˚/s

Post-training tests

Post tests began 72 hours after the last training session. Participants performed the same tests as pre-training in the same order. Tests were performed on 2 days separated by 48 hours.

Ultrasound Measurements

Subjects laid in a supine position with both arms and legs extended and relaxed for 10 minutes for stabilization of normal body fluids (Pinto *et al*, 2014; Rech *et al*, 2014). Muscle thickness (MT) and echo-intensity (EI) measurements were then made by three consecutive images in the transverse plan of the quadriceps rectus femoris (RF), vastus intermedius (VI), vastus lateralis (VL) and vastus medialis (VM), and hamstrings biceps femoris long head (BF_{lh}), semitendinosus (ST) and semimembranosus (SM) muscles of the dominant leg of each subject (40 legs) using a real-time portable B-mode ultrasound device (GE LOGIQTM e, GE Healthcare, WI, USA) with linear-array transducer (code 12L-RS, variable frequency band 4.2-13.0 Mhz). Quadriceps images were measured first followed by hamstrings in a prone position. These positions were to ensure they maintained their legs extended and muscles relaxed during all measurements (CARESIO *et al.*, 2015). A water-based gel was used between the skin and transducer in order to ensure acoustic contact and reduce risk of misinterpretation of images due to pressure of the transducer (CARESIO *et al.*, 2015; PINTO *et al.*, 2014). The anatomical site for all measurements was at 50% of the distance between the lateral condyle and greater trochanter of the femur, except for the VM which was at 30% (PINTO *et al.*, 2014; RECH *et al.*, 2014). The transducer was placed perpendicular to the leg at the largest diameter of the muscles (CARESIO *et al.*, 2015). Transparency film was used to map the skin to ensure measurements matched between days (RADAELLI *et al.*, 2013). Settings for gain (52 dB), depth (9 cm), and frequency (12 MHz) were maintained for all images. These were optimized for quality (PALMER *et al.*, 2015).

MT values were measured as the widest distance between the adipose muscle upper interface and the lower interface for all quadriceps and hamstrings muscles, except for VI, which was measured as the widest distance between the adipose-muscle upper interface and the bone (PALMER *et al.*, 2015; RECH *et al.*, 2014). Distances were measured using the straight-line function of the ImageJ software. The average of three MT measurements was calculated for each muscle.

Muscle EI values of each muscle were measured by grayscale analyses using the histogram function of the ImageJ software by using the polygon function, surrounding the muscles without including fascia or bone. EI values were expressed in values between 0 and 255, where black = 0 and white = 255 (CARESIO *et al.*, 2015). The average of three EI measurements was calculated for each muscle.

All images were saved and exported to ImageJ software (Version 1.48v, National Institutes of Health, Bethesda, MD, USA) for analyses. An experienced researcher in ultrasound assessments performed all measurements. The first ten subjects were required to visit the lab one day before commencement of the study. They performed ultrasound measurements on two consecutive days to calculate test-retest reliability for MT and EI. Intraclass correlation coefficients (ICC, 1,1) were between 0.92-0.99 (MT) and 0.74-0.93 (EI) for quadriceps muscles, and 0.81-0.99 (MT) and 0.82-0.93 (EI) for hamstrings muscles.

IPT, EMG, ED, and RTD

Maximal quadriceps and hamstrings IPT were tested on the Biodex isokinetic dynamometer. Subjects sat on the machine and had straps applied across their thighs and chest in order to avoid superfluous movement (BROWN, L. E.; WEIR, 2001). The dynamometer's axis of rotation was aligned with the lateral condyle of their test knee (BROWN, L.; WHITEHURST, 2003; BROWN, L. E.; WEIR, 2001; BROWN, L. E. *et al.*, 1993). The lower leg of the subjects was attached to the machine's lever arm 2 cm above the medial malleolus. Before testing, subjects performed an isokinetic concentric extension-flexion warm-up of 10 repetitions at 180˚/s through 90˚ of range of motion. Their leg was then positioned at 60˚of knee extension. Testing began with quadriceps isometric strength, followed by hamstrings. Both tests consisted of 3 repetitions of 5 seconds, and were separated by 5 minutes rest. They were asked to push for the quadriceps test and to pull for the hamstrings test as hard and fast as possible (SAHALY *et al.*, 2001). Subjects performed 1 submaximal preliminary repetition before each test for familiarization purposes. Instructions and verbal encouragement were given during the test. The average of three IPTs was considered for further analyses

During the IPT test, subjects were fitted with electrodes in order to measure quadriceps RF, VL and VM, and hamstrings BF_{lh} muscle activation. The same anatomical sites used for ultrasound measurements were used to place the electrodes on the skin. The electrodes were connected to an EMG device (Run Technologies Myopac). Muscle activation was calculated by a 1 second plateau of the curve during each knee extension and flexion IPT (KLASS; BAUDRY; DUCHATEAU, 2008). The average of three values was considered for further analyses.

RTD was calculated during IPT (IPT / time to reach IPT) (GRUBER; GOLLHOFER, 2004).

EMD was calculated by the delta between EMG start and torque start (CAVANAGH; KOMI, 1979; LACOURPAILLE *et al.*, 2013) by a LabVIEW (version 2014 National Instruments Corporation, Austin, TX, USA) software. The muscle representing quadriceps was VL, while the muscle representing hamstrings was BF_{lh}. The average of three RTD and three ED values of each muscle were considered for further analyses.

Isokinetic PT

Maximal quadriceps and hamstrings concentric and eccentric PT were tested on a Biodex System 3 (Biodex Medical System, Shirley, NY, USA). Subjects sat comfortably on the machine using the same procedures as the IPT test. Before testing, subjects performed a specific isokinetic warm-up of 10 repetitions at 180°/s and a specific warm-up of 3 concentric extension-flexion repetitions at 60°/s. Upon completing the warm up, testing started with concentric, followed by eccentric. Testing was performed at 60°/s through a 90° range of motion. Both concentric and eccentric tests consisted of 5 repetitions separated by 2 minutes rest. Subjects were asked to push the lever arm as hard and fast as possible. Verbal encouragement was given during the test.

The highest peak torque values across all repetitions and tests were used for further analysis. The conventional ratio was calculated by dividing hamstrings concentric peak torque by quadriceps concentric peak torque, whereas the functional ratio was calculated by dividing hamstrings eccentric peak torque by quadriceps concentric peak torque (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015).

Functional Tests

Functional tests consisted of 3 different types of vertical jumps, and a 40m sprint test.

Vertical jumps were counter movement jump (CMJ), squat jump (SJ), and drop jump (DJ), which were performed on an AMTI force plate (Advanced Mechanical

Technology, Inc., Watertown, MA, USA) with an EPIC device positioned next to the force plate. For CMJ, subjects started in a standing position, dropped to a squatting position, and jumped up as high and fast as possible with arm swing, with no pause (BROWN, L. E.; WEIR, 2001). For DJ, subjects stepped off a 40cm box and upon landing, jumped up as high and fast as possible with arm swing (MARKWICK *et al.*, 2015). For SJ, subjects hands were placed on their hips then they lowered to a squat position, remained still for 2 seconds, then jumped up as high and fast as possible (BROWN, L. E.; WEIR, 2001). Three attempts were allowed for familiarization of each test, and 5 minutes rest was given between tests. SJ height was measured by a LabVIEW (version 2014 National Instruments Corporation, Austin, TX, USA) software on a desktop computer connected to the force plate. The average of 3 reps of each vertical jump test was considered for further analyses.

Forty-meter sprint was performed on a grass field measured by a tape device. An electronic timing system (Speedtrap II, Brower, Salt Lake City, UT, USA) using infrared beams, recorded all times. In addition, ten-meter split times (0-10, 10-20, 20-30, 30-40) were recorded by separate timing lights (BARTOLINI *et al.*, 2011). Before testing, subjects warmed up by jogging 40m. Subjects then performed 3 maximal sprints, separated by 5 minutes rest. The starting position was immediately behind the starting line using a staggered stance with the nondominant foot in front and the dominant foot in back (JOHNSON *et al.*, 2010). The average of three max sprints was considered for analyses.

STATISTICAL ANALYSES

The normality of all values was verified by the Shapiro-Wilk test. A 2 x 2 x 4 (ratio x time x group) mixed factor ANOVA was used to compare conventional and functional ratios. A 2 x 2 x 2 x 4 (muscle x action x time x group) ANOVA was used to compare quadriceps and hamstrings concentric and eccentric isokinetic PT. Six 2 x 2 x 4 (muscle x time x group) ANOVAs were used to compare IPT, EMG, ED, RTD, MT and EI. Three 2 x 4 (time x group) ANOVAs were used to compare CMJ, DJ, and SJ. A 2 x 4 (time x group) ANOVA was used to compare total 40m sprint and a 2 x 4 x 4 (time x split x group) ANOVA was used to compare splits. All data were expressed as mean and SD, and all analyses were performed with SPSS 21.0 (Statistical Package for Social Sciences, Chicago, IL, USA). The effect size for each significant difference between pre and post tests comparisons between groups was calculated by using means (M) and standard deviations (SD) between variables to identify the magnitude and direction of the differences (d = Post test mean – Pre test mean/Pre test mean), in which values <0.50 were considered trivial, 0.50–1.25 small, 1.25–1.9 moderate, and >2.0 large for untrained subjects (RHEA, 2004; RUAS, CASSIO V. *et al.*, 2015). An a priori alpha level of 0.05 was used to determine statistical significance.

RESULTS

For conventional and functional ratios there was an interaction of ratio x time x group (p<0.05). This was followed up with four 2 x 2 ANOVAs, one for each group. Group CON/CON demonstrated a main effect for ratio, where functional ratio was greater than conventional ratio (p<0.05). Group ECC/ECC demonstrated an interaction of ratio x time (p<0.05). This was followed up with two paired t-tests, where functional ratio post was greater than pre (p<0.05), but conventional ratio post was not different than pre (p>0.05). Group CON/ECC demonstrated a main effect for ratio, where functional ratio was greater than conventional ratio (p<0.05). Group CNTRL demonstrated no interactions or main effects (p>0.05). (Figure 1).

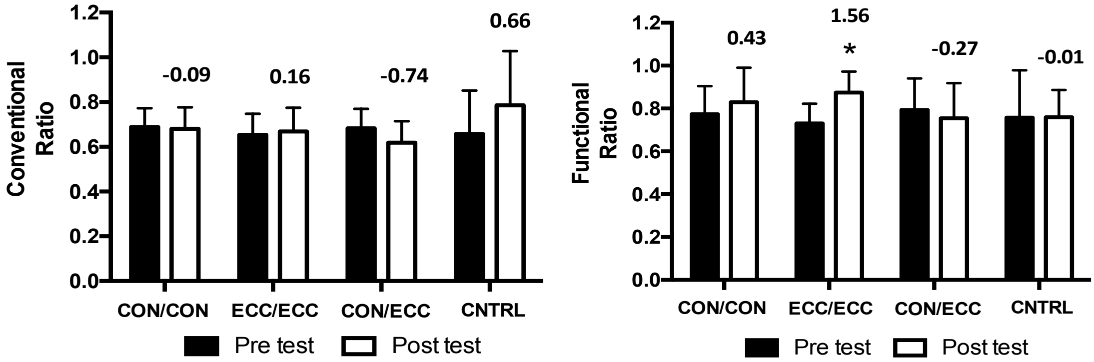

Figure 1. Means and SD of conventional and functional hamstrings-to-quadriceps (H:Q) ratios between pre and post tests for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups.
*Significantly greater than pre test ($p<0.05$). Effect sizes are presented for pre and post test comparisons.

For isokinetic PT, there was an interaction of muscle x action x time x group ($p<0.05$). This was followed up with four 2x2x2 ANOVAs, one for each group. Group CON/CON demonstrated a main effect for muscle, where quadriceps was greater than hamstrings, and a main effect for action, where eccentric was greater than concentric ($p<0.05$). Group ECC/ECC demonstrated an interaction of muscle x action x time ($p<0.05$). This was followed up with 2x2 ANOVAs, one for each muscle. Quadriceps presented an interaction of action x time ($p<0.05$). This was followed up with two paired t-tests, which demonstrated that quadriceps eccentric post was greater than quadriceps eccentric pre ($p<0.05$), but quadriceps concentric post was not different than quadriceps concentric pre ($p>0.05$). Hamstrings presented an interaction of action x time ($p<0.05$). This was followed up with two paired t-tests, which demonstrated that hamstrings eccentric post was greater than hamstrings eccentric pre ($p<0.05$), but hamstrings concentric post was not different than hamstrings concentric pre ($p>0.05$). Group CON/ECC demonstrated an interaction of muscle x action ($p<0.05$). This was followed up with two paired t-tests, which demonstrated that quadriceps eccentric was greater than quadriceps concentric ($p<0.05$), and that hamstrings eccentric was greater than hamstrings concentric ($p<0.05$). Group CNTRL demonstrated an interaction of muscle x action ($p<0.05$). This was followed up with two paired t-tests, which demonstrated that quadriceps eccentric was greater than quadriceps concentric ($p<0.05$), but hamstrings eccentric was not different than hamstrings concentric ($p>0.05$) (Figure 2).

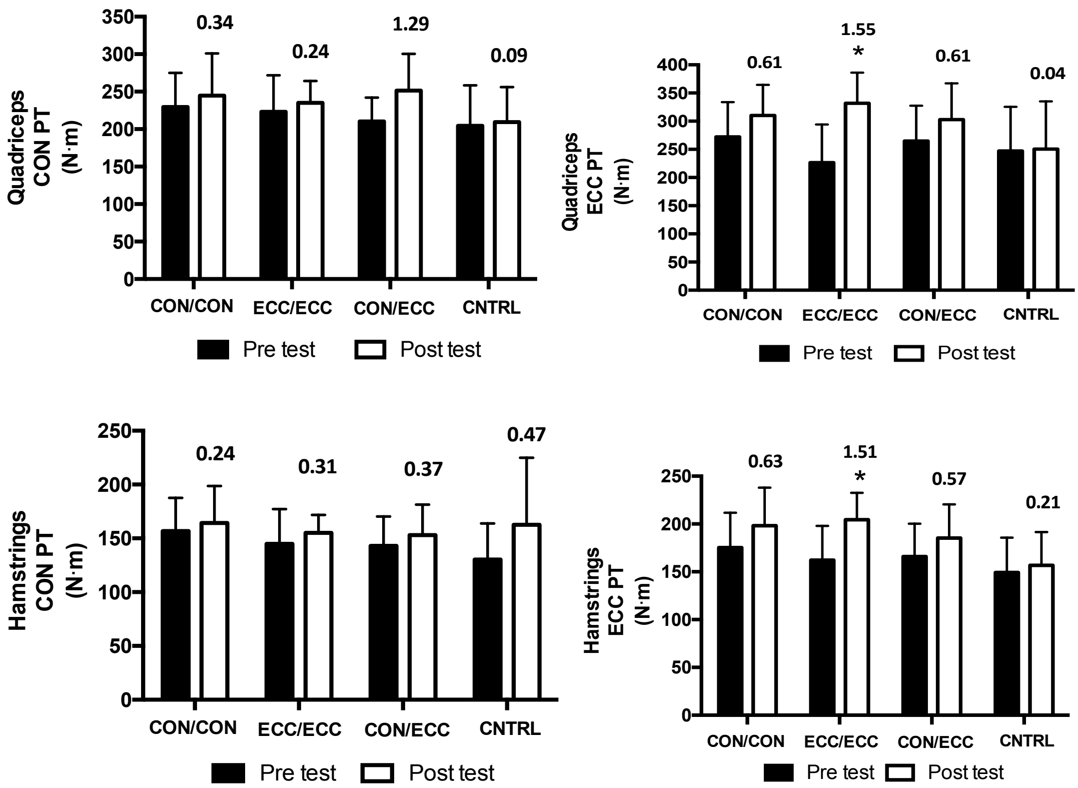

Figure 2. Means and SD of quadriceps and hamstrings concentric (CON) and eccentric (ECC) peak torque (PT) during pre and post tests on concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups. Effect sizes are presented for pre and post test comparisons.
*Significantly greater than pre test ($p<0.05$).

For IPT there was an interaction of time x group ($p<0.05$). This was followed up with four paired t-tests, one for each group. For group ECC/ECC post was greater than pre ($p<0.05$). For groups CON/CON, CON/ECC and CNTRL post was not different than pre ($p>0.05$) (table 2).

Table 2: Means and SD of hamstrings and quadriceps isometric peak torque (IPT) between pre and post tests for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups. Data collapsed across muscle. Effect sizes (ES) are presented for pre and post test comparisons.

	IPT (N·m)						
	Quadriceps		Hamstrings		Collapsed across muscle		
	Pre	Post	Pre	Post	Pre	Post	ES
CON/CON	248.37 ± 66.14	257.36 ± 62.99	143.74 ± 34.71	145.38 ± 30.73	196.06 ± 48.72	201.37 ± 45.70	0.11
ECC/ECC	225.62 ± 56.88	261.39 ± 45.56	121.77 ± 28.87	144.79 ± 25.92	173.7 ± 41.41	203.09 ± 30.83*	0.71
CON/ECC	223.93 ± 38.87	239.71 ± 45.73	141.06 ± 25.99	140.4 ± 29.30	182.49 ± 27.95	190.05 ± 29.25	0.27
CNTRL	230.86 ± 56.49	230.56 ± 58.73	117.67 ± 29.46	116.07 ± 28.73	174.27 ± 37.79	174.32 ± 40.56	0.03

*Significantly greater than pre test ($p<0.05$).

For RTD, there was an interaction of time x group ($p<0.05$). This was followed up with four paired t-tests, one for each group. For group CON/CON post was greater than pre. For group ECC/ECC and CON/ECC post was not different than pre ($p<0.05$). For group CNTRL pre was greater than post ($p>0.05$) (Table 3).

Table 3: Means and SD of hamstrings and quadriceps total rate of torque development (RTD) between pre and post tests for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups. Data collapsed across muscle. Effect sizes are presented for pre and post test comparisons.

	RTD (Nm s^{1})						
	Quadriceps		Hamstrings		Collapsed across muscle		
	Pre	Post	Pre	Post	Pre	Post	ES
CON/CON	155.45 ± 84.27	258.68 ± 121.57	148.93 ± 74.07	191.85 ± 103.92	152.19 ± 65.01	225.27 ± 88.8*	1.12
ECC/ECC	248.35 ± 175.5	220.14 ± 89.02	168.31 ± 135.83	169.16 ± 108.66	208.33 ± 141.21	194.65 ± 67.43	-0.07
CON/ECC	234.6 ± 100.35	258.57 ± 164.33	183.76 ± 105.72	161.62 ± 108.66	209.17 ± 92.24	210.1 ± 132.93	0.01
CNTRL	266.41 ± 191.5	168.04 ± 109.49	200.7 ± 135.89	160.00 ± 89.71	233.56 ± 141.93	164.02 ± 69.63	-0.49

*Significantly greater than pre test ($p<0.05$).

For EMG, there was a main effect for time, where post was greater than pre ($p<0.05$), and a main effect for muscle, where RF was greater than VM, VL, and BF_{lh} ($p<0.05$) (Table 4).

Table 4: Means and SD of rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), and biceps femoris long head (BF_{lh}) muscle activation (EMG) between pre and post tests for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups. Data collapsed across muscle and group, and across time and group.

	EMG (RMS)									
	RF		VL		VM		BFlh			
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
CON/CON	0.53 ± 0.20	0.61 ± 0.32	0.40 ± 0.18	0.47 ± 0.16	0.43 ± 0.15	0.49 ± 0.13	0.38 ± 0.13	0.54 ± 0.37	-	-
ECC/ECC	0.46 ± 0.12	0.48 ± 0.19	0.37 ± 0.17	0.35 ± 0.17	0.36 ± 0.15	0.41 ± 0.2	0.43 ± 0.16	0.44 ± 0.22	-	-
CON/ECC	0.48 ± 0.19	0,5 ± 0.22	0.45 ± 0.23	0.44 ± 0.23	0.33 ± 0.13	0.36 ± 0.14	0.44 ± 0.21	0.48 ± 0.25	-	-
CNTRL	0.47 ± 0.26	0,53 ± 0.29	0.34 ± 0.16	0.42 ± 0.18	0.34 ± 0.16	0.45 ± 0.28	0.36 ± 0.11	0.41 ± 0.09	-	-
Collapsed (muscle and group)	-	-	-	-	-	-	-	-	0.41 ± 0.14	0.46 ± 0.18*
Collapsed (time and group)	0.50 ± 0.35#		0.40 ± 0.03		0.39 ± 0.02		0.43 ± 0.03		-	

*Significantly greater than pre test (p<0.05).
significantly greater than VM, VL, and BF (p<0.05)

For ED, there was an interaction of muscle x time ($p<0.05$). This was followed up with two paired t-tests, one for each muscle. Quadriceps pre was greater than post ($p<0.05$). Hamstrings pre was not different than post ($p>0.05$) (Table 5).

Table 5: Means and SD of hamstrings and quadriceps electromechanical delay (EMD) between pre and post tests for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups. Data collapsed across group.

	EMD (ms)			
	Quadriceps		Hamstrings	
	Pre	Post	Pre	Post
CON/CON	0.32 ± 0.07	0.2 ± 0.08	0.30 ± 0.08	0.31 ± 0.07
ECC/ECC	0.29 ± 0.09	0.21 ± 0.10	0.25 ± 0.05	0.26 ± 0.8
CON/ECC	0.22 ± 0.07	0.19 ± 0.10	0.26 ± 0.07	0.26 ± 0.8
CNTRL	0.26 ± 0.05	0.25 ± 0.08	0.36 ± 0.12	0.3 ± 0.14
Collapsed across group	0.27 ± 0.08*	0.21 ± 0.09	0.29 ± 0.09*	0.28 ± 0.12

*Significantly greater than post test (p<0.05).

For ultrasound MT there was an interaction of muscle x time and of time x group ($p<0.05$). They were followed up with seven paired t-tests, one for each muscle, and two paired t-tests, one for each group. VL, VM, ST and SM post were greater than pre ($p<0.05$) while RF and VI post were not different than pre ($p>0.05$). For groups CON/CON, ECC/ECC and CON/ECC post was greater than pre ($p<0.05$). For group CNTRL post was not different than pre ($p>0.05$) (Table 6).

Table 6: Means and SD of rectus femoris (RF), vastus intermedius (VI), vastus lateralis (VL), vastus medialis (VM), biceps femoris long head (BF_{lh}), semitendinosus (ST) and semimembranosus (SM) muscle thickness (MT) between pre and post tests for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups. Data collapsed across muscle, and across group. Effect sizes are presented for pre and post test comparisons.

	MT (mm)									
	CON/CON		ECC/ECC		CON/ECC		CNTRL		Collapsed (group)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
RF	26.86 ± 3.70	27.28 ± 5.3	24.6 ± 4.36	26.2 ± 3.54	23.06 ± 3.66	24.10 ± 3.30	23.3 ± 2.92	23.23 ± 3.52	24.45 ± 3.86	25.20 ± 4.17
VI	19.71 ± 6.21	20.06 ± 5.2	20.1 ± 5.23	24.23 ± 4.32	21.01 ± 6.84	21.43 ± 5.44	21.54 ± 3.30	20.26 ± 3.53	20.58 ± 5.39	21.49 ± 4.80
VL	31.77 ± 6.27	35.15 ± 5.21	27.04 ± 8.37	31.25 ± 6.25	27.58 ± 5.04	30.46 ± 5.16	27.47 ± 4.41	26.87 ± 4.82	28.46 ± 6.27	30.95 ± 5.97*
VM	60.63 ± 14.37	68.87 ± 6.70	66.53 ± 4.32	71.52 ± 3.00	60.77 ± 5.45	64.14 ± 4.30	65.02 ± 4.56	63.74 ± 4.75	63.23 ± 8.40	67.06 ± 5.73*
BFlh	39.26 ± 3.72	42.04 ± 3.93	39.67 ± 0.04	46.4 ± 7.96	37.14 ± 5.50	41.72 ± 4.58	39.05 ± 2.54	38.37 ± 3.86	38.78 ± 5.25	42.12 ± 5.89*
ST	33.44 ± 5.58	35.55 ± 6.08	33.44 ± 5.68	40.91 ± 2.99	31.2 ± 5.51	34.91 ± 7.06	32.36 ± 5.17	31.94 ± 5.74	32.6 ± 5.35	35.82 ± 6.36*
SM	37.2 ± 6.97	40.83 ± 6.06	35.35 ± 5.20	39.2 ± 10.20	33.35 ± 8.47	34.13 ± 4.68	35.48 ± 4.27	36.39 ± 3.80	35.34 ± 6.40	37.63 ± 6.93*
Collapsed (muscle)	35.55 ± 4.19	38.54 ± 3.82*	35.25 ± 3.64	39.97 ± 3.61*	33.45 ± 1.21	35.84 ± 1.19*	34.89 ± 2.19	34.4 ± 2.58	-	-
ES	0.71		1.30		1.98		-0.22		-	

*significantly greater than pre test ($p<0.05$)

For ultrasound EI, there was a main effect for time, where pre was greater than post ($p<0.05$). There was also a main effect for muscle where RF was greater than VI and VM ($p<0.05$). VL was greater than VI and VM ($p<0.05$). VM was greater than VI ($p<0.05$). BF_{lh} was greater than RF, VI, VL, VM and BF_{lh} ($p<0.05$). SM was greater than RF, VI, VL, VM ($p<0.05$). ST was greater than RF, VI, VL, VM and BF_{lh} ($p<0.05$) (table 7).

Table 7: Means and SD of rectus femoris (RF), vastus intermedius (VI), vastus lateralis (VL), vastus medialis (VM), biceps femoris long head (BF_{lh}), semitendinosus (ST) and semimembranosus (SM) echo-intensity (EI) between pre and post tests for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups. Data collapsed across muscle and group, and across time and group.

	EI (AU)										
	CON/CON		ECC/ECC		CON/ECC		CNTRL		-		-
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Collapsed (time and group)
RF	36.20 ± 6.40	36.96 ± 6.55	38.75 ± 4.90	36.69 ± 3.86	35.82 ± 7.40	36.82 ± 6.87	37.60 ± 6.89	35.96 ± 7.03	-	-	36.84 ± 0.91#
VI	33.14 ± 5.32	30.74 ± 4.93	31,3 ± 6.28	28.21 ± 4.70	32.05 ± 6.28	32.94 ± 5.70	29.56 ± 4.08	31.05 ± 5.30	-	-	33.31 ± 0.73
VL	37.43 ± 3.17	35.94 ± 4.05	35.7 ± 4.38	32.53 ± 6.51	37.14 ± 8.49	38.02 ± 4.04	37.59 ± 4.13	36.03 ± 6.04	-	-	31.12 ± 0.73#
VM	37.59 ± 4.13	36.03 ± 6.04	34.79 ± 4.02	31.58 ± 3.20	34.23 ± 5.05	33.45 ± 6.65	32.6 ± 5.44	32.41 ± 6.64	-	-	36.29 ± 0.71†
BF_{lh}	42.83 ± 7.39	39.50 ± 7.06	39.76 ± 5.83	37.79 ± 5.78	41.65 ± 7.54	39.05 ± 5.16	42.13 ± 6.07	40.51 ± 9.20	-	-	40.4 ± 1.03‡
ST	42.09 ± 8.31	40.8 ± 8.30	41.62 ± 8.05	39,02 ± 6.26	42.79 ± 7.09	41.43 ± 9.41	44.4 ± 8.58	43.89 ± 9.42	-	-	42 ± 1.23¶
SM	44.91 ± 8.22	39.94 ± 3.40	42.24 ± 5.74	42.05 ± 3.52	45.51 ± 8.14	41.66 ± 6.26	40.3 ± 4.67	40.32 ± 9.94	-	-	42.11 ± 0.93§
Collapsed (muscle and group)	-	-	-	-	-	-	-	-	38.26 ± 4.2*	36.72 ± 4.64	

*significantly greater than post test ($p<0.05$)
significantly greater than VI and VM($p<0.05$)
† significantly greater than VI ($p<0.05$)
‡ significantly greater than RF, VI, VL, VM and BF_{lh} ($p<0.05$)
¶ significantly greater than RF, VI, VL and VM ($p<0.05$)
§ significantly greater than RF, VI, VL, VM and BF_{lh} ($p<0.05$)

For CMJ there was an interaction of time x group ($p<0.05$). This was followed up with four paired t-tests, one for each group. For group ECC/ECC, post was greater than pre ($p<0.05$). For groups CON/CON, CON/ECC and CNTRL post was not different than pre ($p>0.05$) (Figure 3).

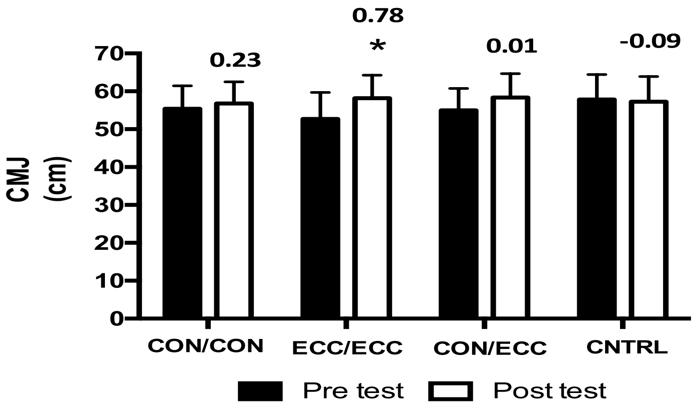

Figure 3. Means and SD of counter movement jump (CMJ) between pre and post tests for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups. Effect sizes are presented for pre and post test comparisons.
*Significantly greater than pre test ($p<0.05$).

For DJ there was an interaction of time x group ($p<0.05$). This was followed up with four paired t-tests, one for each group. For group ECC/ECC, post was greater than pre ($p<0.05$). For groups CON/CON, CON/ECC and CNTRL post was not different than pre ($p>0.05$) (Figure 4).

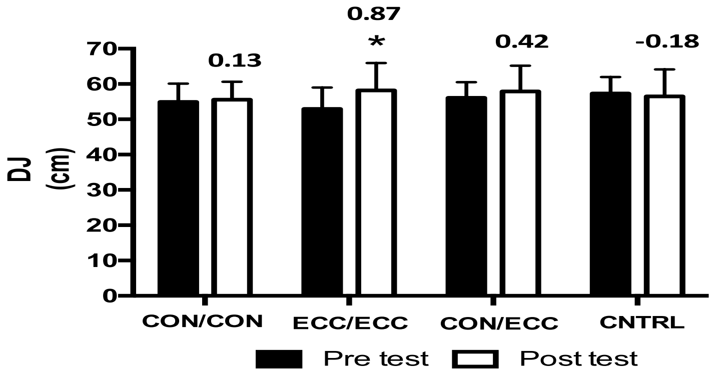

Figure 4. Means and SD of drop jump (DJ) between pre and post tests for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups. Effect sizes are presented for pre and post test comparisons.
*Significantly greater than pre test (p<0.05).

For SJ, there were no interactions or main effects (p>0.05) (Table 8).

Table 8: Means and SD of squat jump (SJ) between pre and post tests for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups.

	SJ (cm)	
	Pre	Post
CON/CON	21.76 ± 3.83	23.43 ± 3.38
ECC/ECC	21.45 ± 2.31	24.38 ± 3.11
CON/ECC	22.10 ± 4.36	22.16 ± 5.53
CNTRL	21.39 ± 3.05	20.50 ± 4.45

For 40m sprint splits there was an interaction of split x time (p<0.05). This was followed up with four paired t-tests. The 20-30m pre split was greater than post (p<0.05). No other splits were different (p>0.05).

For full 40m sprint there were no interactions or main effects (p>0.05) (table 9).

Table 9: Means and SD of full forty-meter (40m) sprint time and ten-meter split times (0-10, 10-20, 20-30, 30-40) between pre and post for concentric/concentric (CON/CON), eccentric/eccentric (ECC/ECC), concentric/eccentric (CON/ECC), and control (CNTRL) groups. Data collapsed across group.

	40m Sprint									
	0-10		10-20		20-30		30-40		Full	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
CON/CON	1.92 ± 0.13	1.90 ± 0.09	1.40 ± 0.08	1.39 ± 0.07	1.33 ± 0.09	1.30 ± 0.84	1.34 ± 0.1	1.31 ± 0.1	5.99 ± 0.4	5.90 ± 0.4
ECC/ECC	1.95 ± 0.13	1.94 ± 0.07	1.45 ± 0.07	1.41 ± 0.07	1.37 ± 0.07	1.33 ± 0.06	1.39 ± 0.08	1.35 ± 0.07	6.18 ± 0.32	6.05 ± 0.33
CON/ECC	1.93 ± 0.11	1.95 ± 0.08	1.41 ± 0.1	1.41 ± 0.1	1.35 ± 0.11	1.33 ± 0.11	1.38 ± 0.14	1.35 ± 0.14	6.10 ± 0.44	6.05 ± 0.43
CNTRL	1.92 ± 0.9	1.95 ± 0.08	1.40 ± 0.08	1.41 ± 0.08	1.34 ± 0.09	1.35 ± 0.11	1.37 ± 0.12	1.38 ± 0.12	6.04 ± 0.36	6.08 ± 0.38
Collapsed across group	1.93 ± 0.11	1.93 ± 0.08	1.41 ± 0.08	1.41 ± 0.08	1.35 ± 0.09*	1.33 ± 0.09	1.37 ± 0.09	1.35 ± 0.09	-	-

*Significantly greater than post test (p<0.05).

DISCUSSION

The aim of this study was to compare three different isokinetic training protocols on dominant leg H/Q strength balance, calculated by conventional and functional ratios. A secondary aim was to compare the training protocols across varied quadriceps and hamstrings muscle actions on concentric and eccentric peak torque (PT), isometric peak torque (IPT), rate of torque development (RTD), muscle activation (EMG), electromechanical delay (EMD), muscle thickness (MT) and echo-intensity (EI), as well as functional performance tested by squat jump (SJ), counter movement jump (CMJ), drop jump (DJ) and 40m sprint tests. Our results revealed that the ECC/ECC group showed significant increases in H/Q functional ratio, as well as hamstrings and quadriceps eccentric PT, IPT, CMJ and DJ, compared to all other groups while the CON/CON group increased RTD. In addition, all training groups increased MT of quadriceps and hamstrings similarly. There were no differences between groups for concentric PT, EMG, ED, conventional ratio, ultrasound EI, or 40m sprint. This demonstrates that ECC/ECC training was most effective overall at increasing functional H/Q strength ratio, as well as eccentric strength, isometric strength, CMJ and DJ performance. Eccentric training increased eccentric strength, which increased the functional H/Q strength ratio, and improved vertical jumps involving eccentric strength. CON/CON training was only effective at increasing muscle power.

Only a few studies have tested the effectiveness of isokinetic training to increase H:Q muscle balance (CROISIER *et al*., 2002; GIOFTSIDOU *et al*., 2006; GOLIK-PERIC *et al*., 2011). However, to our knowledge we are the first study to compare different modes of training on both functional and conventional ratios. Golik-Peric *et al*. (2011) found that isokinetic CON/CON training 5 times a week with speeds decreasing from 300-60°/s was more effective at increasing conventional ratio compared to isotonic training in athletes, although no other isokinetic training or functional ratio was tested. Gioftsisdou *et al.* (2006) found that a 2 month/3 times a week specific isokinetic training program using velocity spectrum exercise from 150°-240°/s resulted in restoration of muscular H:Q balance and strength of professional soccer players. Croiser *et al.* (2002) found that isokinetic training of concentric knee flexors and extensors across speeds of 60°/s to 240°/s, and eccentric knee flexor training across speeds of 30°/s to 120°/s 3 times a week, increased conventional and functional ratios of soccer players with muscle imbalances, and reduced injury or reinjury, intensity of lower-limb pain and discomfort up to 12 months after training. They concluded that rehabilitation isokinetic programs focused on eccentric training are effective at increasing H:Q muscle balance and reducing strength deficits upon return to play. Although we did not find differences between groups for conventional ratio, our results are in agreement with these findings since ECC/ECC progressive speed training increased the functional ratio. This ratio is considered as realistic to actual game performance and its use is more acceptable for knee imbalance and injury risk assessments as it considers deceleration performed by hamstrings eccentric actions during quadriceps concentric actions (e.g running and kicking) (AAGAARD *et al.*, 1998; AAGAARD *et al.*, 1995; RUAS, C. V.; MINOZZO, F.*; et al.*, 2015; RUAS, C. V.; PINTO, M. D.*; et al.*, 2015). Since the CON/ECC and CON/CON groups did not demonstrate quadriceps and hamstrings concentric or hamstrings eccentric strength increases, the conventional and functional ratios were unchanged.

Several studies have investigated the effect of isokinetic training on quadriceps and hamstrings concentric, eccentric and isometric strength (AKIMA *et al.*, 1999; BROWN, L.; WHITEHURST, 2003; CADORE *et al.*, 2014; CUNHA *et al.*, 2013; EBID; OMAR; ABD EL BAKY, 2012; FABIS, 2007; GOLIK-PERIC *et al.*, 2011; GUILHEM; CORNU; GUEVEL, 2011; MILLER *et al.*, 2006; REMAUD; CORNU; GUEVEL, 2005; SYMONS *et al.*, 2005; BARONI, B. M. *et al*., 2013; CADORE *et al*., 2014; HIGBIE *et al*., 1996; SEGER *et al*., 1998). However, different protocols, modes, volume and speeds have been used (BROWN, LEE E., 2000; CABRI; CLARYS, 1991; DVIR, 2004). Cadore *et al*. (2014) found that 6 weeks of CON and ECC training at 60˚/s performed twice a week, with progression of sets and repetitions per week, resulted in similar increases in knee extensor concentric and eccentric strength, but IPT was greater for ECC training. Baroni *et al*. (2013) found that 4 weeks of ECC training consisting of 3 sets of 10 repetitions resulted in increases in knee extensor eccentric and isometric strength, which continued to increase throughout 12 weeks of training, when volume of sets and repetitions were increased. They also found that concentric strength progressively increased to a lesser extent, but only until the eighth week. Although these studies did not train knee flexors, our results partly agree with them as we also found eccentric and IPT strength increases for the ECC/ECC group. However, we did not find significant concentric increases for any group, nor increases in eccentric strength for the CON/CON or CON/ECC groups. This may be because our training differed from prior studies in progression of volume and intensity, as well as sets per week and/or length of training. Higbie *et al*. (1996) compared knee extensor CON and ECC training for 10 weeks, 3 days a week and CNTRL, and found that only the ECC group increased eccentric strength, and only the CON group increased concentric strength. Miller *et al*. (2006) also found that 20 weeks of knee extension and flexion ECC/ECC training lead to greater eccentric gains compared to CON/CON. We also found ECC/ECC training was the most effective at increasing eccentric strength. Eccentric strength has been reported to have unique neuromuscular characteristics compared to concentric strength, generating the highest forces with the lowest energy cost (LASTAYO *et al.*, 2014; ROIG; SHADGAN; REID, 2008) and neuromuscular activity (CADORE *et al.*, 2014; ENOKA, 1996; ROIG *et al.*, 2008), therefore demonstrating the ideal characteristics for general strength increases following training (LASTAYO *et al.*, 2014; ROIG *et al.*, 2008). Also, eccentric strength is often less trained than concentric strength, which may lead to greater eccentric gains in less time (HORTOBAGYI *et al.*, 1996; ROIG *et al.*, 2008). Although no significant changes were found for concentric strength in the concentrically trained groups, it is possible that longer training could lead to greater gains, due to the greater knee extensors concentric PT effect sizes we found in the CON/ECC and CON/CON groups post tests. However, differently than eccentric, concentric strength may have to be trained in a test speed specific manner for greatest concentric strength improvements (COBURN *et al.*, 2006).

We found that ECC/ECC was the only group to increase hamstrings and quadriceps IPT. This is in accordance with previous studies investigating eccentric isokinetic training (BARONI, B. M. *et al.*, 2013; CADORE *et al.*, 2014; DOS SANTOS ROCHA *et al.*, 2011). In the ECC muscle action, torque is greater per cross bridge and/or passive stretch of series elastic elements (HIGBIE *et al.*, 1996; LASTAYO *et al.*, 2014). Although we did not find differences between groups for muscle activation, all training groups had greater post MT compared to control. Cadore et al. (2014) found that CON and ECC training showed similar improvements in MT after 6 weeks of training. Higbie et al. (1996) found that CON and ECC training resulted in increases in cross sectional area (CSA) of the quadriceps compared to control, while ECC increases were greater than CON after 10 weeks of isokinetic training. Previous studies have shown that eccentric intensive training can lead to changes in the morphology and force per unit of muscle CSA (HIGBIE *et al.*, 1996; REEVES *et al.*, 2009; ROIG *et al.*, 2008). Since we found no differences between groups for muscle activation or between training groups for MT, the greater eccentric and isometric strength by the ECC/ECC group may be predominantly due to greater strength per unit of CSA compared to CON/ECC and CON/CON (HIGBIE *et al.*, 1996; ROIG *et al.*, 2008). Also, eccentric exercise has been associated with a high reduction in muscular co-contraction (REID *et al.*, 2010; ROIG *et al.*, 2008). This may explain why the ECC/ECC group showed greater improvements in hamstrings eccentric strength than the CON/ECC group. However, we did not directly measure muscle co-contraction.

Coburn *et al*. (2006) found that very short-term 3 session isokinetic training of concentric knee extension consisting of 4 sets of 10 repetitions at 60°/s led to increases in concentric PT at slow (60°/s) and fast (120°/s) speeds, while training at 120°/s increased concentric PT only at the fastest speed. In contrast, Brown and Whitehurst (2003) found that slow or fast speed short-term session isokinetic concentric knee extension training consisting of 3 sets of 8 repetitions did not result in PT increases, but increased rate of velocity development in a speed specific manner. This is in accordance with our findings as we found that CON/CON training did not result in significant improvement in concentric strength, but did increase RTD. The CON/CON group had speeds changed from fast to slow throughout training, which may have improved their capacity to move their leg quickly, even in slow-velocity movements (KOVALESKJI; HEITMAN, 2000). Since power is associated with fast isokinetic speeds, these have been suggested to be performed earlier prior to using slow speeds for optimum power development in isokinetic training (KOVALESKJI; HEITMAN, 2000). This is in accordance with our results as the CON/CON group moved from 210 to 60°/s throughout training.

Although isokinetic training has been related to functional tests improvements during knee injury rehabilitation (CROISIER *et al*., 2008; FABIS, 2007; GUR *et al*., 1999; SEKIR *et al*., 2010; SMITH; MELTON, 1981; SYMONS *et al*., 2005), several studies have found that these strength improvements may not be transferred to more complex activities due to a lack of specificity (CORDOVA *et al.*, 1995; KOVALESKJI; HEITMAN, 2000; SANTOS *et al.*, 2010; SMITH; MELTON, 1981; WHITE *et al.*, 2004). However, a few studies have shown that velocity spectrum exercise protocols, in which the velocity is varied from slow to fast during the course of training, may promote force and power development at high speeds that are transferable to functional activities (KOVALESKJI; HEITMAN, 2000). Smith and Melton (1981) found that similar gains in strength in the knee flexors and extensors were found for groups that trained with high isokinetic speeds, low isokinetic speeds and isotonic variable-resistance. However high speeds had the greatest increases in vertical jump, standing long jump and 40m sprint. Gur *et al*. (1999) found that a knee extension and flexion protocol that included both concentric and eccentric compared to concentric alone from 30°/s-180°/s resulted in greater eccentric strength and in functional stair climb and descend tests. Our results are in agreement with these results in that the ECC/ECC group which trained at velocities from slow to fast had the greatest increases for CMJ and DJ. The lack of concentric strength improvements may explain the lack of squat jump improvements we found between groups, since this jump requires only a concentric action without an eccentric (BROWN, L. E.; WEIR, 2001). The 40m sprint is a very complex test that involves coordinated movements of the arms and legs at high intensities (BARTOLINI *et al.*, 2011; JOHNSON *et al.*, 2010). This may explain why no difference was found for this functional test.

We did not find differences between groups for muscle EI or EMD. We are only aware of one study that has investigated muscle EI after isokinetic training (CADORE *et al.*, 2014), which also did not find difference between CON vs ECC training groups, although training increased EI in both groups. We are not aware of any studies investigating electromechanical delay after isokinetic training. In the current study since there were time effect and muscle x time interaction for these variables, longer isokinetic training with a greater number of sets per week might have elicited differences between training groups. Interestingly, the CON/ECC group was the only training group to not differ from the others in any variable. For this group, speed was increased for eccentric and decreased for concentric, which may not have been optimal for neuromuscular adaptation related to velocity specificity (GIOFTSIDOU *et al.*, 2006; KOVALESKJI; HEITMAN, 2000). Variation of velocity spectrum may have to follow a progression of speeds from slow to fast for eccentric strength or from fast to slow for concentric strength for agonist and antagonist muscles for greater increases in strength, functional activities and power.

CONCLUSION

Our findings suggest that ECC/ECC training may be the most effective at increasing functional H/Q strength ratio. Additionally, ECC/ECC training may be the most effective at increasing eccentric strength, isometric strength, CMJ and DJ performance. Eccentric training increases eccentric strength, thereby increasing the functional H/Q strength ratio. Eccentric training also improves vertical jumps involving eccentric strength. CON/CON training may be more effective at increasing muscle power.

4. CONCLUSAO DA DISSERTACAO

Os achados desta dissertação sugerem que o protocolo de treinamento totalmente excêntrico (ECC/ECC) utilizado no presente estudo pode ser o mais efetivo em aumentar o equilíbrio de torque muscular funcional I/Q. Adicionalmente, este protocolo pode ser o mais efetivo em aumentos no torque excêntrico, isométrico e no desempenho nos saltos CMJ e DJ em jovens destreinados em força. Os aumentos no torque excêntrico de isquiotibiais, sem aumentos de torque concêntrico de quadríceps, advindos deste modelo de treinamento, podem ter influenciado nos aumentos no equilíbrio de torque muscular funcional I/Q. Os saltos CMJ e DJ também apresentam alto componente excêntrico, o que pode explicar os aumentos observados nesses saltos. O treinamento CON/CON utilizado pode ser o mais efetivo para aumentos na potência muscular. Futuros estudos que possam replicar estes protocolos, com estes objetivos, poderão investigar a efetividade desses achados na prática esportiva, para aumento do torque muscular, equilíbrio de torque e funcionalidade de atletas. No presente estudo escolheu-se utilizar variação de velocidade e número de séries para progressão de intensidade e volume de treinamento isocinético, tendo como base racional para esta estratégia o fato de que a intensidade de contração é incrementada com a redução da velocidade em contrações isocinéticas realizadas no modo concêntrico, o contrário ocorrendo no modo excêntrico (BROWN, LEE E., 2000; DVIR, 2004). Além disso, optou-se por incrementar o volume de ação muscular ao longo dos microciclos do programa de treino pelo fato desta variável também afetar positivamente os incrementos na força desejados e constituir-se numa importante variável controlada num programa de treino (KRAEMER; RATAMESS, 2004). No entanto, futuros estudos são necessários para comparar os efeitos de diferentes formas de manipulação destas variáveis no controle da intensidade e do volume no treinamento isocinético. Além disso, no presente estudo só foi utilizada uma velocidade para teste de torque isocinético (60°/s), por conta desta ser a velocidade mais utilizada para o principal objetivo do estudo que foi avaliar as razões I/Q. Ainda assim, para futuras investigações pode ser interessante que este teste seja realizado em mais de uma velocidade isocinética para investigar adaptações neuromusculares e equilíbrio de torque muscular I/Q.

5. REFERÊNCIAS BIBLIOGRÁFICAS

AAGAARD, P. *et al.* A new concept for isokinetic hamstring: quadriceps muscle strength ratio. **Am J Sports Med,** v. 26, n. 2, p. 231-7, 1998.

AAGAARD, P. *et al.* Isokinetic hamstring/quadriceps strength ratio: influence from joint angular velocity, gravity correction and contraction mode. **Acta Physiol Scand,** v. 154, n. 4, p. 421-7, 1995.

AKIMA, H. *et al.* Early phase adaptations of muscle use and strength to isokinetic training. **Med Sci Sports Exerc,** v. 31, n. 4, p. 588-94, 1999.

ANDRADE MDOS, S. *et al.* Isokinetic hamstrings-to-quadriceps peak torque ratio: the influence of sport modality, gender, and angular velocity. **J Sports Sci,** v. 30, n. 6, p. 547-53, 2012.

ASKLING, C.; KARLSSON, J.; THORSTENSSON, A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. **Scand J Med Sci Sports,** v. 13, n. 4, p. 244-50, 2003.

BARAK, Y.; AYALON, M.; DVIR, Z. Spectral EMG changes in vastus medialis muscle following short range of motion isokinetic training. **J Electromyogr Kinesiol,** v. 16, n. 5, p. 403-12, 2006.

BARONI, B. M. *et al.* Muscle architecture adaptations to knee extensor eccentric training: rectus femoris vs. vastus lateralis. **Muscle Nerve,** v. 48, n. 4, p. 498-506, 2013.

BARONI, B. M. *et al.* Time course of neuromuscular adaptations to knee extensor eccentric training. **Int J Sports Med,** v. 34, n. 10, p. 904-11, 2013.

BARTOLINI, J. A. *et al.* Optimal elastic cord assistance for sprinting in collegiate women soccer players. **J Strength Cond Res,** v. 25, n. 5, p. 1263-1270, 2011.

BENNELL, K. *et al.* Isokinetic strength testing does not predict hamstring injury in Australian Rules footballers. **Br J Sports Med,** v. 32, n. 4, p. 309-14, 1998.

BLAZEVICH, A. J. *et al.* Influence of concentric and eccentric resistance training on architectural adaptation in human quadriceps muscles. **J Appl Physiol,** v. 103, n. 5, p. 1565-75, 2007.

BROWN, L.; WHITEHURST, M. The effect of short-term isokinetic training on force and rate of velocity development. **J Strength Cond Res,** v. 17, n. 1, p. 88-94, 2003.

BROWN, L. E. **Isokinetics in human performance**. Champaign, IL: Human Kinetics, 2000.

BROWN, L. E.; WEIR, J. P. ASEP Procedures Recommendation I: Accurate Assessment Of Muscular Strength And Power. **J Exerc Physiol Online,** v. 4, n. 3, p. 1-21, 2001.

BROWN, L. E. *et al.* Reliability of the Biodex System 2 Isokinetic Dynamometer Concentric Mode. **Isokinet Exerc Sci,** v. 3, n. 3, p. 160-163, 1993.

BRUKNER, P. *et al.* Recurrent hamstring muscle injury: applying the limited evidence in the professional football setting with a seven-point programme. **Br J Sports Med**, 2013.

CABRI, J. M.; CLARYS, J. P. Isokinetic exercise in rehabilitation. **Appl Ergon,** v. 22, n. 5, p. 295-8, 1991.

CADORE, E. L. *et al.* Muscle conduction velocity, strength, neural activity, and morphological changes after eccentric and concentric training. **Scand J Med Sci Sports,** v. 24, n. 5, p. 343-352, 2014.

CARESIO, C. *et al.* Muscle echo intensity: reliability and conditioning factors. **Clin Physiol Funct Imaging,** v. 35, n. 5, p. 393-403, 2015.

CAVANAGH, P. R.; KOMI, P. V. Electromechanical delay in human skeletal muscle under concentric and eccentric contractions. **Eur J Appl Physiol Occup Physiol,** v. 42, n. 3, p. 159-163, 1979.

CHANDLER, T. J.; BROWN, L. E. **Treinamento de Força para o Desempenho Humano**. 1st. Artmed, 2009.

CHEUNG, R. T.; SMITH, A. W.; WONG DEL, P. H:q ratios and bilateral leg strength in college field and court sports players. **J Hum Kinet,** v. 33, p. 63-71, 2012.

COBURN, J. W. *et al.* Neuromuscular responses to three days of velocity-specific isokinetic training. **J Strength Cond Res,** v. 20, n. 4, p. 892-898, 2006.

COOMBS, R.; GARBUTT, G. Development in the use of the hamstring/quadriceps ratio for the assessment of muscle balance. **J Sports Sci and Med,** v. 1, p. 56-62, 2002.

CORDOVA, M. L. *et al.* A comparison of isokinetic and isotonic predictions of a functional task. **J Athl Train,** v. 30, n. 4, p. 319, 1995.

COSTA, P. B. *et al.* Acute effects of static stretching on peak torque and the hamstrings-to-quadriceps conventional and functional ratios. **Scand J Med Sci Sports,** v. 23, n. 1, p. 38-45, 2013.

CROISIER, J. L. *et al.* Hamstring muscle strain recurrence and strength performance disorders. **Am J Sports Med.,** v. 30, n. 2, p. 199-203, 2002.

CROISIER, J. L. *et al.* Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. **Am J Sports Med,** v. 36, n. 8, p. 1469-75, 2008.

CUNHA, R. *et al.* Effects of short-term isokinetic training with reciprocal knee extensors agonist and antagonist muscle actions: a controlled and randomized trial. **Braz J Phys Ther,** v. 17, n. 2, p. 137-45, 2013.

DA SILVA, B. G. C. *et al.* Comparison of hamstring/quadriceps ratio between isoinertial and isokinetic measurements. **Isokinet Exerc Sci,** v. 21, n. 2, p. 107-112, 2013.

DALLINGA, J. M.; BENJAMINSE, A.; LEMMINK, K. A. Which screening tools can predict injury to the lower extremities in team sports?: a systematic review. **Sports Med,** v. 42, n. 9, p. 791-815, 2012.

DE STE CROIX, M.; DEIGHAN, M.; ARMSTRONG, N. Functional eccentric-concentric ratio of knee extensors and flexors in pre-pubertal children, teenagers and adult males and females. **Int J Sports Med,** v. 28, n. 9, p. 768-72, 2007.

DOS SANTOS ROCHA, C. S. *et al.* Specificity of strength gains after 12 weeks of isokinetic eccentric training in healthy men. **Isokinet Exerc Sci,** v. 19, n. 3, p. 221-226, 2011.

DVIR, Z. **Isokinetics: Muscle Testing, Interpretation, and Clinical Applications**. Churchill Livingstone, 2004.

DVIR, Z. *et al.* Thigh muscle activity and anterior cruciate ligament insufficiency. **Clin Biomech,** v. 4, n. 2, p. 87–91, 1989.

EBID, A. A.; OMAR, M. T.; ABD EL BAKY, A. M. Effect of 12-week isokinetic training on muscle strength in adult with healed thermal burn. **Burns,** v. 38, n. 1, p. 61-8, 2012.

ELLENBECKER, T. S.; DAVIES, G. J. The application of isokinetics in testing and rehabilitation of the shoulder complex. **J Athl Train,** v. 35, n. 3, p. 338-50, 2000.

ENISELER, N. *et al.* Isokinetic Strength Responses to Season-long Training and Competition in Turkish Elite Soccer Players. **J Hum Kinet,** v. 31, p. 159-68, 2012.

ENOKA, R. M. Eccentric contractions require unique activation strategies by the nervous system. **J Appl Physio,** v. 81, n. 6, p. 2339-2346, 1996.

FABIS, J. The impact of a isokinetic training program on the peak torque of the quadriceps and knee flexors after anterior cruciate ligament reconstruction with hamstrings. **Ortop Traumatol Rehabil,** v. 9, n. 5, p. 527-31, 2007.

GIOFTSIDOU, A. *et al.* Soccer players' muscular imbalances: restoration with an isokinetic strength training program. **Percept Mot Skills,** v. 103, n. 1, p. 151-9, 2006.

GOLIK-PERIC, D. *et al.* Short-term isokinetic training versus isotonic training: effects on asymmetry in strength of thigh muscles. **J Hum Kinet,** v. 30, p. 29-35, 2011.

GRECO, C. C. *et al.* Rapid hamstrings/quadriceps strength capacity in professional soccer players with different conventional isokinetic muscle strength ratios. **J Sports Sci Med,** v. 11, n. 3, p. 418-22, 2012.

GRECO, C. C. *et al.* Fatigue and rapid hamstring/quadriceps force capacity in professional soccer players. **Clin Physiol Funct Imaging,** v. 33, n. 1, p. 18-23, 2013.

GRUBER, M.; GOLLHOFER, A. Impact of sensorimotor training on the rate of force development and neural activation. **Eur J Appl Physiol,** v. 92, n. 1-2, p. 98-105, 2004.

GUILHEM, G.; CORNU, C.; GUEVEL, A. Muscle architecture and EMG activity changes during isotonic and isokinetic eccentric exercises. **Eur J Appl Physiol,** v. 111, n. 11, p. 2723-33, 2011.

GUR, H. *et al.* Effects of age on the reciprocal peak torque ratios during knee muscle contractions in elite soccer players. **Scand J Med Sci Sports,** v. 9, n. 2, p. 81-7, 1999.

GUR, H. *et al.* Concentric versus combined concentric-eccentric isokinetic training: effects on functional capacity and symptoms in patients with osteoarthrosis of the knee. **Arch Phys Med Rehabil,** v. 83, n. 3, p. 308-16, 2002.

HENDERSON, G.; BARNES, C. A.; PORTAS, M. D. Factors associated with increased propensity for hamstring injury in English Premier League soccer players. **J Sci Med Sport,** v. 13, n. 4, p. 397-402, 2010.

HIEMSTRA, L. A. *et al.* Hamstring and quadriceps strength balance in normal and hamstring anterior cruciate ligament-reconstructed subjects. **Clin J Sport Med,** v. 14, n. 5, p. 274-80, 2004.

HIGBIE, E. J. *et al.* Effects of concentric and eccentric training on muscle strength, cross-sectional area, and neural activation. **J Appl Physiol,** v. 81, n. 5, p. 2173-81, 1996.

HOLCOMB, W. R. *et al.* Effect of hamstring-emphasized resistance training on hamstring:quadriceps strength ratios. **J Strength Cond Res,** v. 21, n. 1, p. 41-7, 2007.

HORTOBAGYI, T. *et al.* Adaptive responses to muscle lengthening and shortening in humans. **J Appl Physiol,** v. 80, n. 3, p. 765-772, 1996.

IGA, J. *et al.* Cross-sectional investigation of indices of isokinetic leg strength in youth soccer players and untrained individuals. **Scand J Med Sci Sports,** v. 19, n. 5, p. 714-9, 2009.

JENKINS, N. D. *et al.* Functional hamstrings: quadriceps ratios in elite women's soccer players. **J Sports Sci,** v. 31, n. 6, p. 612-7, 2013.

JOHNSON, T. M. *et al.* Effect of four different starting stances on sprint time in collegiate volleyball players. **J Strength Cond Res,** v. 24, n. 10, p. 2641-2646, 2010.

KLASS, M.; BAUDRY, S.; DUCHATEAU, J. Age-related decline in rate of torque development is accompanied by lower maximal motor unit discharge frequency during fast contractions. **J Appl Physiol,** v. 104, n. 3, p. 739-746, 2008.

KOVALESKJI, J. E.; HEITMAN, R. J. Testing and training the lower extremity. In: BROWN, L. (Ed.). **Isokinetics in human performance.** . Champaign, IL: Human Kinetics, 2000. p.171-195.

KRAEMER, W. J.; RATAMESS, N. A. Fundamentals of resistance training: progression and exercise prescription. **Med Sci Sports Exerc,** v. 36, n. 4, p. 674-688, 2004.

LACOURPAILLE, L.; HUG, F.; NORDEZ, A. Influence of passive muscle tension on electromechanical delay in humans. **PloS one,** v. 8, n. 1, p. e53159, 2013.

LAND, H.; GORDON, S. What is normal isokinetic shoulder strength or strength ratios? A systematic review. **Isokinet Exerc Sci,** v. 19, n. 4, p. 231-241, 2011.

LASTAYO, P. *et al.* Eccentric exercise in rehabilitation: safety, feasibility, and application. **J Appl Physiol,** v. 116, n. 11, p. 1426-1434, 2014.

LEHANCE, C. *et al.* Muscular strength, functional performances and injury risk in professional and junior elite soccer players. **Scand J Med Sci Sports,** v. 19, n. 2, p. 243-51, 2009.

MAGALHÃES, J. *et al.* [Isokinetic strength assessment in athletes of different sports, ages, gender and positional roles]. **Rev Port Ciênc Desporto.,** v. 1, n. 2, p. 13-21, 2001.

MARKWICK, W. J. *et al.* The intraday reliability of the reactive strength index calculated from a drop jump in professional men's basketball. **Int J Sports Physiol Perform,** v. 10, n. 4, 2015.

MILLER, L. E. *et al.* Knee extensor and flexor torque development with concentric and eccentric isokinetic training. **Res Q Exerc Sport,** v. 77, n. 1, p. 58-63, 2006.

O'HAGAN, F. T. *et al.* Comparative effectiveness of accommodating and weight resistance training modes. **Med Sci Sports Exerc,** v. 27, n. 8, p. 1210-9, 1995.

PALMER, T. B. *et al.* Reliability of Panoramic Ultrasound Imaging in Simultaneously Examining Muscle Size and Quality of the Hamstring Muscles in Young, Healthy Males and Females. **Ultrasound Med Biol,** v. 41, n. 3, p. 675-684, 2015.

PINTO, R. S. *et al.* Short-term strength training improves muscle quality and functional capacity of elderly women. **Age,** v. 36, n. 1, p. 365-372, 2014.

PORTES, E. M. *et al.* Isokinetic torque peak and hamstrings/quadriceps ratios in endurance athletes with anterior cruciate ligament laxity. **Clinics,** v. 62, n. 2, p. 127-32, 2007.

RADAELLI, R. *et al.* Effect of two different strength training volumes on muscle hypertrophy and quality in elderly women. **J Sports Med Phys Fitness,** v. 53, p. 1-2, 2013.

RECH, A. *et al.* Echo intensity is negatively associated with functional capacity in older women. **Age,** v. 36, n. 5, p. 1-9, 2014.

REEVES, N. D. *et al.* Differential adaptations to eccentric versus conventional resistance training in older humans. **Exp Physiol,** v. 94, n. 7, p. 825-833, 2009.

REID, S. *et al.* Neuromuscular adaptations to eccentric strength training in children and adolescents with cerebral palsy. **Dev Med Child Neurol,** v. 52, n. 4, p. 358-363, 2010.

REMAUD, A.; CORNU, C.; GUEVEL, A. A methodologic approach for the comparison between dynamic contractions: influences on the neuromuscular system. **J Athl Train,** v. 40, n. 4, p. 281-7, 2005.

RHEA, M. R. Determining the magnitude of treatment effects in strength training research through the use of the effect size. **J Strength Cond Res,** v. 18, n. 4, p. 918-920, 2004.

ROIG, M.; SHADGAN, B.; REID, W. D. Eccentric exercise in patients with chronic health conditions: a systematic review. **Physiother Can,** v. 60, n. 2, p. 146-160, 2008.

ROSENE, J. M.; FOGARTY, T. D.; MAHAFFEY, B. L. Isokinetic Hamstrings:Quadriceps Ratios in Intercollegiate Athletes. **J Athl Train,** v. 36, n. 4, p. 378-383, 2001.

RUAS, C.; BROWN, L.; PINTO, R. Lower-extremity side-to-side strength asymmetry of professional soccer players according to playing position. **Kinesiology,** v. 47, n. 2, p. 188-192, 2015.

RUAS, C. V. *et al.* Lower-extremity strength ratios of professional soccer players according to field position. **J Strength Cond Res,** v. 29, n. 5, p. 1220-6, 2015.

RUAS, C. V. *et al.* The association between conventional and dynamic control knee strength ratios in elite soccer players. **Isokinet Exerc Sci,** v. 23, n. 1, p. 1-12, 2015.

RUAS, C. V. *et al.* Angle Specific Analysis of Side-to-Side Asymmetry in the Shoulder Rotators. **Sports,** v. 3, n. 3, p. 236-245, 2015.

RUAS, C. V. *et al.* Specific joint angle assessment of the shoulder rotators. **Isokinet Exerc Sci,** v. 22, n. 3, p. 197-204, 2014.

RUAS, C. V. *et al.* Strength and power in children with low motor performance scores: a descriptive analysis. **Braz J Mot Behav,** v. 8, n. 1, 2014.

SAHALY, R. *et al.* Maximal voluntary force and rate of force development in humans–importance of instruction. **Eur J Appl Physiol,** v. 85, n. 3-4, p. 345-350, 2001.

SANTOS, H. H. *et al.* The effects of knee extensor eccentric training on functional tests in healthy subjects. **Rev Bras Fisioter,** v. 14, n. 4, p. 276-83, 2010.

SEGER, J. Y.; ARVIDSSON, B.; THORSTENSSON, A. Specific effects of eccentric and concentric training on muscle strength and morphology in humans. **Eur J Appl Physiol Occup Physiol,** v. 79, n. 1, p. 49-57, 1998.

SEKIR, U.; GUR, H.; AKOVA, B. Early versus late start of isokinetic hamstring-strengthening exercise after anterior cruciate ligament reconstruction with patellar tendon graft. **Am J Sports Med,** v. 38, n. 3, p. 492-500, 2010.

SEKIR, U. *et al.* Effect of isokinetic training on strength, functionality and proprioception in athletes with functional ankle instability. **Knee Surg Sports Traumatol Arthrosc,** v. 15, n. 5, p. 654-64, 2007.

SMITH, M. J.; MELTON, P. Isokinetic versus isotonic variable-resistance training. **Am J Sports Med,** v. 9, n. 4, p. 275-279, 1981.

SYMONS, T. B. *et al.* Effects of maximal isometric and isokinetic resistance training on strength and functional mobility in older adults. **J Gerontol A Biol Sci Med Sci,** v. 60, n. 6, p. 777-81, 2005.

VIKNE, H. *et al.* Muscular performance after concentric and eccentric exercise in trained men. **Med Sci Sports Exerc,** v. 38, n. 10, p. 1770-1781, 2006.

WHITE, L. J. *et al.* Resistance training improves strength and functional capacity in persons with multiple sclerosis. **Mult Scler,** v. 10, n. 6, p. 668-674, 2004.

YEUNG, S. S.; SUEN, A. M.; YEUNG, E. W. A prospective cohort study of hamstring injuries in competitive sprinters: preseason muscle imbalance as a possible risk factor. **Br J Sports Med,** v. 43, n. 8, p. 589-94, 2009.

ZEBIS, M. K. *et al.* Rapid hamstring/quadriceps force capacity in male vs. female elite soccer players. **J Strength Cond Res,** v. 25, n. 7, p. 1989-93, 2011.

6. ANEXO 1

RESOLUÇÃO Nº 114/2014

A Câmara de Pós-Graduação, considerando a demanda já existente na UFRGS,

RESOLVE:

ESTABELECER as seguintes orientações sobre o idioma de apresentação de teses, dissertações e outros trabalhos de conclusão nos cursos de pós-graduação no âmbito da UFRGS:

Art. 1º - As teses, dissertações e outros trabalhos de conclusão de cursos de pós-graduação podem ser apresentados em português, inglês ou espanhol, conforme regulamentado pelo Programa de Pós-Graduação.

Parágrafo único – Quando em inglês ou espanhol, a tese, dissertação ou outro trabalho de conclusão deverá apresentar, também, título e resumo expandido em português.

Art. 2º - Excepcionalmente, tendo em vista a peculiaridade de certas áreas, serão admitidos:
I - outros idiomas, desde que justificado pelo Programa de Pós-Graduação e aprovado pela Câmara de Pós-Graduação;
II - na Área de Letras, Línguas e Literatura Estrangeira, teses e dissertações redigidas nos idiomas estrangeiros correspondentes, que devem incluir, ao início do volume, resumo substancial em português, que evidencie os objetivos da obra, os métodos utilizados no seu desenvolvimento, o seu núcleo e as conclusões obtidas, destacando o que é apresentado em cada capítulo;
III - teses e dissertações que contenham artigo(s) para publicação ou já publicado(s) em periódico científico, em idioma estrangeiro, desde que apresentados na forma e idioma da publicação.
Art. 3º - Teses e dissertações realizadas em cotutela serão redigidas nos idiomas previstos no respectivo acordo de cotutela assinado entre as instituições, resguardado o parágrafo único do Art. 1º desta Resolução.
Art. 4º - A presente Resolução passa a vigorar a partir desta data, revogando-se as demais disposições em contrário.

Sala das Sessões, 18 de novembro de 2014.

Claudia Wasserman
Presidente

7. ANEXO 2

CALIFORNIA STATE UNIVERSITY, FULLERTON

Office of Research Development
P.O. Box 6850 or 800 N. State College Blvd., MH-103, Fullerton, CA 92831 / T 657-278-7640 / F 657-278-7238

APPROVAL NOTICE

From the Institutional Review Board
California State University Fullerton

Date: **November 12, 2014**

From: Matt Englar-Carlson, PhD, Chairperson MEC
CSUF Institutional Review Board

To: **Dr. Lee Brown**
Department: Kinesiology

Re: Use of Human Subjects in Research Project entitled:
The Effect of Isokinetic Training on Knee Strength Ratios and Neuromuscular Adaptations

The forms you submitted to this office regarding the use of human subjects in the above-referenced proposal have been reviewed by the Regulatory Compliance Coordinator and the Chair of the California State University Fullerton, Institutional Review Board ("CSUF IRB"). Your proposal is determined to be Expedited per 45 CFR § 46.110(4e)

The CSUF IRB has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval notice does not replace any departmental or additional approvals which may be required.

If the above-referenced project has not been completed by **November 11, 2015** you must request renewed approval for continuation of the proposal.

It is of utmost importance that you strictly adhere to the guidelines for human participation and that you follow the plan/methodology/procedures described in your research proposal. Any change in protocol or consent form procedure requires resubmission to the CSUF IRB for approval prior to implementation. Additionally, the principal investigator must promptly report, in writing, any unanticipated or adverse events causing risks to research participants or others.

Please be advised that if you are seeking external funding for this proposal, the above-referenced title should match exactly with the title submitted to the funding sponsor. Any change in project title should be submitted to the CSUF IRB prior to implementation.

By copy of this notice, the chairman of your department (and/or co-investigator) is reminded that s/he is responsible for being informed concerning research projects involving human participants in the department, and should review all protocols of such investigations as often as needed to ensure that the project is being conducted in compliance with our institutional policies and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protections.
The Assurance Number is FWA00015384.

Cc: Dr. William Beam
Application No. HSR-14-0454