UNIVERSIDADE FEDERAL DE SERGIPE
PRÓ- REITORIA DE PÓS-GRADUAÇÃO E PESQUISA
MESTRADO EM EDUCAÇÃO FÍSICA

ANÁLISE DA ASSIMETRIA NA VELOCIDADE MÉDIA, ATIVIDADE MUSCULAR E FORÇA EM DIFERENTES INTENSIDADES NO TREINO DE *POWERLIFTING* PARAOLÍMPICOS

LEONARDOS DOS SANTOS

São Cristóvão

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Dissertação apresentada ao Programa de Pós-Graduação em Educação Física da Universidade Federal de Sergipe como requisito parcial para obtenção do grau de Mestre em Educação Física.

Orientador: Prof. Dr. Felipe José Aidar Martins

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PARECER

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Dedico este trabalho aos atletas do Powerlifting Paralímpico Sergipano, pelo tempo que cada um dedicou para a realização da pesquisa, tolerando todo rigor do meio científico, superando suas limitações, estando presente em cada dia que foi necessário. Sei que isso não basta, mas é minha forma de gratidão a todos.

RESUMO

Introdução: Nas últimas décadas, vários benefícios do treinamento de força relacionados a saúde e a performance foram registrados pela ciência. Isto tem contribuído para a popularidade e eficiência dessa modalidade de treino. Além disso, o universo do treinamento para preparação esportiva, manutenção, prevenção e recuperação da saúde tem se mostrado muito inclusivo, importante para uma adesão duradoura da prática e consolidação dos benefícios. Dentre os diferentes esportes que utilizam o treinamento de força destacam-se o powerlifting convencional e o powerlifting paralímpico (PP), este último, é marcado pelo rigor técnico com relação simetria do movimento. **Objetivo**: Analisar as assimetrias nos membros superiores, considerando a velocidade média, a atividade muscular e a força isométrica após uma sessão de treinamento de força no PP. **Métodos:** Doze homens atletas do PP de elite (idade: 27,7±5,7 anos; experiência: 2,1±0,9 anos; massa corporal: 74,0±19,5kg; 1RM: 113,0±31,3kg; 1RM/BM: 1,6±0,3). Todos foram submetidos a duas sessões de treinamento, a primeira para familiarização e teste de 1RM e a segunda para coleta dos dados da força isométrica máxima, velocidade média e atividade elétrica dos músculos nos lados do corpo, em duas intensidades distintas. **Resultados:** Foi registrado uma diferença estatística na repetição "2", no membro dominante, entre o momento antes e depois com carga de 45% de 1RM, na fase excêntrica e sem diferença significativa nas velocidades médias concêntricas. Com a intensidade de 80% de 1RM, houve diferenças estatísticas em relação ao membro dominante. Contudo, os dados absolutos evidenciam assimetria maior na fase concêntrica em favor do membro dominante. Considerando a atividade elétrica dos músculos, houve diferenças no músculo peitoral no membro não dominante entre os momentos antes (110,75 ± 59,52%) e depois (130,53 ± 98,48%, $p < 0,001$), e não houve diferença na ativação do tríceps. Na Força Isométrica Máxima (FIM), houve diferença no membro não dominante entre antes (710,36 ± 129,36) e depois (620,27 ± 69,73; $p < 0,030$). Houve diferença no momento antes nos membros dominante (626,89 ± 120,16; IC 95% 550,55–703,24) e não dominante (710,36 ± 129,36; $p = 0,011$). Não houve diferença do tempo para o FIM. **Conclusão:** Houve assimetrias na velocidade média, na atividade elétrica muscular e na força isométrica máxima entre os membros direito e esquerdo, quando o atleta executa o movimento com diferentes intensidades. Visto o modo particular que cada sujeito experiencia essas assimetrias, destaca-se a importância de avaliações frequentes a fim de manter a prática saudável e o alto desempenho. Contudo, novas investigações são necessárias para analisar outros fatores que podem interferir na simetria do levantamento de peso dessa modalidade.

Palavras-chave: esportes paraolímpicos; powerliting; força muscular; simetria.

ABSTRACT

Introduction: In recent decades, several benefits of strength training related to health and performance have been recorded by science. This has contributed to the popularity and efficiency of this training modality, in addition, the universe of training, for sports preparation, maintenance, prevention and recovery of health has proven to be very inclusive, important for lasting adherence to the practice and consolidation of benefits. Among the different sports that use strength training, conventional powerlifting and Paralympic powerlifting (PP) stand out, the latter being marked by technical rigor with symmetry of movement. **Objective:** To analyze asymmetries in the upper limbs, considering average speed, muscular activity and isometric strength after a strength training session in the PP. **Methods:** Twelve male elite PP athletes (age: 27.7±5.7 years; experience: 2.1±0.9 years; body mass: 74.0±19.5kg; 1RM: 113.0±31 .3kg; 1RM/BM: 1.6±0.3). Everyone underwent two training sessions, the first for familiarization and 1RM testing and the second for collecting data on maximum isometric strength, average speed and electrical activity of the muscles on the sides of the body, at two different intensities. **Results:** A statistical difference was recorded in repetition “2”, in the dominant limb, between the moments before and after with a load of 45% of 1RM, in the eccentric phase and without a significant difference in average concentric speeds. With an intensity of 80% of 1RM there were statistical differences in relation to the dominant limb. However, the absolute data show greater asymmetry in the concentric phase in favor of the dominant limb. Considering the electrical activity of the muscles, There were differences in the pectoralis muscle in the non-dominant limb between moments before (110.75 ± 59.52%) and after (130.53 ± 98.48%, $p < 0.001$), and there was no difference in triceps activation. In the Maximum Isometric Strength (MIF), there was a difference in the non-dominant limb between before (710.36 ± 129.36) and after (620.27 ± 69.73; $p < 0.030$). There was a difference before in the dominant (626.89 ± 120.16; 95% CI 550.55–703.24) and non-dominant (710.36 ± 129.36; $p = 0.011$) limbs. There was no difference in time to MIF. **Conclusion:** There were asymmetries in average speed, muscular electrical activity and maximum isometric strength between the right and left limbs, when the athlete performs the movement with different intensities. Given the particular way in which each subject experiences these asymmetries, the importance of frequent assessments is highlighted in order to maintain healthy practice and high performance. However, further investigations are necessary to analyze other factors that may interfere with the symmetry of weightlifting in this modality.

Keywords: paralympic sports; powerlitting; muscle strength; symmetry.

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1. INTRODUÇÃO GERAL

Pesquisas científicas no campo esportivo evidenciam os benefícios do treinamento de força (TF), o comportamento de diferentes variáveis, efeitos agudos e crônicos, bem como, novas perspectivas em relação a aptidão física, qualidade de vida e alta performance (1-3). Neste sentido, o treinamento de força vem ganhando cada vez mais adesão entre a população em geral, atletas de diferentes modalidades e esportes específicos, como é o caso do Powerlifting e o Powerlifting Paralímpico (PP) (3).

O Powerlifting é um esporte de desenvolvimento de pura força, onde o objetivo buscado é realizar uma única repetição de um movimento com o máximo de quilos na barra, sendo dividido em três disciplinas conforme o exercício: agachamento completo (AC), supino reto (SR) e o levantamento terra (LT) (3). O PP é um esporte adaptado do modelo convencional, sendo que o levantamento de peso no supino é o único exercício para disputa. Ele é realizado com o atleta inteiramente sobre o banco em decúbito dorsal (4,5). A execução válida do exercício é efetiva quando o atleta retira a barra do hack, inicia o movimento descendente/excêntrico e ascendente/concêntrico de modo controlado, e ambos os braços sincronizados, evidenciando uma simetria do movimento (6).

Por outro lado, sabe-se que os humanos usam preferencialmente um dos lados do corpo em suas ações voluntárias e associam a uma habilidade motora (7,8). Além disso, a dominância dos membros, que é a especialização funcional dos hemisférios cerebrais, sugere que a seleção direita e esquerda é dependente da natureza da tarefa (7). Isto afeta o desempenho funcional e pode caracterizar diferentes assimetrias entre os membros em uma atividade motora (7). Tratando-se de atletas com limitações nos membros inferiores, o que pode gerar instabilidade nas fases do exercício, possíveis assimetrias podem ser notadas (9). Desse modo, é razoável supor que no levantamento de peso no supino adaptado existam assimetrias, observadas em diferentes componentes cinético, cinemático e atividade eletromiográfica dos músculos.

Com base nas evidências, os fatores carga e velocidade influenciam sobre os níveis de assimetria, sugerindo que maiores velocidades podem melhorar a simetria (8). Considerando esse fator, estudos firmam a velocidade como um componente importante na avaliação do desempenho (10-14). Ainda nesse sentindo, ao ser investigada a velocidade com intensidade de 50%, foi encontrado um desempenho simétrico, enquanto com intensidade de 90%, houve assimetria significativa em favor do membro dominante, observado nos momentos iniciais e finais do movimento no SR (15).

Percebendo-se a exigência da regra pela simetria (6), a tendência natural entre os humanos pela assimetria (7,8), além da influência da velocidade, intensidade da carga e fadiga de uma sessão de treino na simetria (8,14-17), buscamos analisar as assimetrias de velocidades médias, atividade muscular e força isométrica máxima entre os membros após uma sessão de treinamento de força no PP.

1.1 Revisão de Literatura

O esporte tem se apresentado na sociedade em inúmeras formas e a ciência tem demonstrado evidências positivas dessas práticas corporais na saúde, qualidade de vida e no alto rendimento (1,2,18). Diferentes tipos de práticas levam ao aprimoramento das diferentes capacidades físicas (força, resistência, equilíbrio, agilidade e velocidade). Os esportes, na sua grande maioria, desenvolvem mutuamente estas capacidades físicas, mas alguma predomina em relação a outra, quando levado em conta a especialidade da prática. Dentro desse mundo esportivo, o PP é o formato de powerlifting adaptado para atletas com deficiência e difere da versão para atletas hígidos por realizar apenas SR na competição (3), sendo este um esporte que visa predominantemente o desenvolvimento de pura força (3,4,6,19).

O esporte adaptado tem seu desenvolvimento a partir da década de 1940, quando o médico alemão Ludwig Guttman foi convidado por autoridades inglesas, para fazer pesquisas na Universidade de Oxford. Neste período, soldados ingleses voltavam da guerra com lesões severas e aproximadamente 80% desses combatentes vinham a óbito durante a reabilitação. Para intervir neste quadro, Dr. Ludwig Guttman utilizou o esporte como meio de reabilitação, o que evoluiu de sua forma recreacional ao modelo competitivo (6). Inicialmente, nem todas as práticas foram adaptadas à conduta de terapia proposta pelo Dr. Ludwig Guttman, mas devido ao engajamento da comunidade que era atendida, os esportes foram gradativamente adaptados à realidade de cada limitação (6). Nesse sentido, se desenvolve o PP, para atender muitas necessidades das pessoas com deficiência física nos membros inferiores, compreendido que o PP se caracteriza como esporte de força dos membros superiores (6).

Este esporte tem crescido mundialmente, considerando o rendimento, a sua adesão entre os paratletas e suas marcas em levantamentos de peso BP (3,20,21). Por outro lado, mesmo que o PP não sendo um esporte de contato, seguro e podendo ser realizado por pessoas com deficiência, no entanto, estudos evidenciam taxas de incidências de lesões significativas (22-25). O excesso da carga de treino, a instabilidade natural da pessoa com deficiência, a dominância de membros e rigor da regra por excelência simétrica na execução, podem ser fatores importantes no desenvolvimento dessas lesões (22,24,25).

Estudos evidenciam a influência da carga e da velocidade na elevação e diminuição de assimetrias, considerando os esportes de resistência (8,26,27). Quando estudamos os esportes de força, PP, a velocidade também é um elemento importante, presente desde a preparação dos atletas e sua avaliação do desempenho. (10,12-14). Desse modo, entendemos a interferência de variáveis, a clara exigência da regra pela simetria (6), a tendência natural entre os humanos pela assimetria (7,8), por isso, buscamos analisar as assimetrias nos membros superiores, considerando a velocidade média, a atividade muscular e a força isométrica após uma sessão de treinamento de força no PP. Nossa hipótese é que existam assimetrias entre os membros em intensidades mais altas e na fase concêntrica do exercício.

1.1.1 Assimetrias de movimento

Assimetrias de movimento podem ser entendidas como a diferença em indicadores cinéticos e cinemáticos entre os membros direito e esquerdo, que levam a compensações e desequilíbrios nos agrupamentos musculares envolvidos como a diferença de atividade muscular, da força, potência, da velocidade de execução (28, 17).

Assimetrias entre os lados do corpo é algo comum em atletas, ou pessoas em geral, desenvolvidas pela interação de múltiplos fatores ambientais e genéticos (28,29). Recentemente, tem aumentado o número de estudos investigando a relação da assimetria com os riscos de lesões e o desempenho atlético em diversas modalidades esportivas (8,30-33). Estudos tem mostrado que assimetrias maiores que 15% foram associadas a incidência de lesões aumentada, quando comparado entre grupo de atletas e não atletas que apresentam um percentual menor do que esse limite (34).

Por outro lado, assimetrias menores que 10% são utilizadas como parâmetro de recuperação de lesões e retorno seguro a prática esportiva (34). Contudo, o papel das assimetrias entre os membros em relação ao desempenho físico ou esportivo é menos conhecido, visto que estudos identificam a presença de diferenças entre membros em uma variedade de população (34-36)

Componentes do treinamento de força como carga, volume, repetições, frequências de treinamento, assim como a demanda esportiva de algumas modalidades são fatores importantes a um reforço ou desenvolvimento de assimetrias entre os lados do corpo (33).

Os esportes de alto rendimento exigem que os atletas tenham o domínio completo das habilidades motoras e das técnicas regulamentadas, (15). Considerando o PP, uma das exigências é pela simetria do movimento, os braços coordenados durante as fases de descida e subida no SR. Embora esse esporte não seja de contato, as taxas de lesões são significantes (22,23,25). Sabemos que as deficiências elegíveis para esse esporte, naturalmente, causam instabilidade nos membros superiores, e que pode ser afetado pela dominância lateral de um dos lados (5).

O PP como esporte de levantamento de peso, busca aumentar a força nos membros superiores, especifica e igualmente em seus lados, o que permite levantar equilibradamente o máximo de carga no SR. A regra não deixa dúvida, quanto ao objetivo da prova, os atletas devem abaixar a barra até o peito, parar visivelmente sobre o peito e pressioná-la para cima até o comprimento dos braços com os cotovelos travados (6). A execução válida é julgada por três árbitros, que avaliam a sequência correta do levantamento, depois que o atleta deita e assume a posição do levantamento, inicia a sequência de descida (azul), barra controlada sem cair, ou bater no peito; sequência da parada (laranja), a barra toca o peito e permanece estática, sem afundar, entre a transição de movimento de descida e subida da barra; sequência da subida (roxo), a barra é pressionada pra cima, com bloqueio igualmente cronometrado de ambos os braços e cotovelos (6). Desse modo, entendemos que a regra solicita simetria do movimento, uma distribuição de força equilibrada entre os membros para validar a execução.

Os diferentes esportes apresentam riscos de lesões específicos devido às particularidades de cada prática (incluindo as categorias de peso e sexo) e as técnicas utilizadas de acordo com os diferentes regulamentos esportivo (31). No contexto do PP, a assimetria do movimento pode ser observada como uma diferença em indicadores cinemáticos e/ou cinéticos entre os membros direito e esquerdo, o que leva a compensações e desequilíbrios nos grupamentos musculares envolvidos como diferença de força muscular, de potência, diminuição de velocidade do movimento (32).

1.1.2 Velocidade Média

A velocidade pode ser uma das estratégias para monitorar a intensidade de treinamento (10,16). Ela possui algumas variáveis, que são velocidade de pico (VP, a máxima velocidade instantânea alcançada durante a fase concêntrica do levantamento do peso); velocidade média propulsiva (VMP, ele é determinada pelo início do movimento concêntrico até o momento que sua aceleração é menor que a da gravidade [-9,81 $m.s^{-1}$]); e a velocidade média, que pode ser nas duas fases do movimento, excêntrico (quando a barra parte do ponto mais alto até o ponto mais baixo, que é a parada no peito, e concêntrico (a barra parte do peito até o ponto mais alto) (12).

A velocidade tem uma relação linear e inversa com a carga de treinamento em PP, especialmente com intensidades ≥70% de 1RM (13). Monitorar a velocidade ao longo da preparação, permite um controle instantânea sobre a intensidade de cada treino, o que torna o processo mais eficiente e seguro (10,13).

A utilização da velocidade também constitui uma estratégia eficiente para diminuir o tempo de execução de levantamento de peso e ganhos de resistência de força em atletas do PP (37). A velocidade também pode ser utilizada como um indicador de fadiga, que alteram a cinemática do movimento e provocam efeitos distintos relacionados a força, hipertrofia e resistência (10,14,38). Além disso, em outras modalidades, a velocidade vem sendo investigada como instrumento para reduzir as assimetrias bilaterais (8).

Devido a importância que a velocidade assume no treinamento de força como instrumento avaliativo e prescritivo, assim como indicador de desempenho e fadiga, faz-se necessário analisar o modo que ela se comporta nos lados do corpo ao longo das sessões de levantamento de peso SR.

Neste estudo os levantamentos no supino foram gravados com uma câmera de smartphone (Iphone X, Apple Inc., Cupertino, CA, EUA), configurada com uma resolução comum de vídeo a 4k e 30 fotos por segundo (fps) (39,40), sendo posicionada em um tripé, a uma altura aproximada de um metro do solo, e em frente a uma distância de 3.0 m dos marcadores reflexivos distribuídos equidistantes do centro as extremidades da barra, (15,40,41) formando um ângulo perpendicular ao plano de movimento, que captaram o movimento nas diferentes posições da barra (lado direito e lado esquerdo).

Os vídeos gravados foram descarregados no software de código aberto Kinovea versão 0.9.5 (39,42) para aquisição dos dados registrados, após análise quadro a quadro de 30 fps. Para a calibração do software utilizamos três bastões em posições conhecidas, medidas fixas de 1.0 m no sentido vertical, com marcadores reflexivos e alinhados com a câmera que gravou o movimento, além de três marcadores reflexivos posicionados no centro, na extremidade esquerda e direita da barra, o que garante a consistência de medição, isso permite que o programa converta as medidas digitais de pixel em medidas reais conhecidas em cm, assim possamos calcular a velocidade nas fases de movimento (42).

1.1.3 Atividade Muscular

A eletromiografia de superfície (EMGs) corresponde ao sinal elétrico das variações coletivas dos músculos, que é controlado pelo sistema nervoso e produzido durante a contração muscular (43). Estes sinais foram registrados por eletrodos não invasivos e sem dor, usando adesivos sobre a pele tricotomizada e podem ser repetidos sempre que necessário, (43). Nos últimos anos, a utilização desse instrumento tem crescido bastante tanto nos campos do desporto, movimento e análise da marcha, quanto em novos espaços como (obstetrícia, medicina ocupacional e artística, envelhecimento, medicina veterinária, reabilitação e jogos) (44). Os sinais captados na superfície são usados para obter informações sobre o tempo ou a intensidade da ativação muscular superficial e entender os comportamentos do corpo humano em condições normais, ou patológicas (43,44).

A atividade muscular tem sido observada em várias condições de pessoas portadoras e não portadoras de deficiência e sendo comprovada como um marcador sensível para distinguir as formas de ativação das unidades motoras (45). Assim como tem sido bem utilizada para verificação e testes importantes nas diferentes condições em que os agrupamentos musculares são submetidos (46). Direcionando as análises para SR, estudos tem se preocupado com a atividade muscular em diferentes regiões do exercício e entre os membros dominantes e não dominantes (19,47). Ao analisar atividades eletromiográficas dos membros superiores, foram evidenciadas a assimetria na ativação muscular nos lados do corpo, entre os três grupos musculares importantes na ação do SR, especialmente, no peitoral maior, em uma amostra de levantadores de peso paralímpicos durante uma execução com 80% de uma repetição máxima (1RM), (17). Em contrapartida, o efeito da intensidade da carga no exercício de SR também já foi testado, levando em consideração o lado dominante e não dominante, que mostraram diferenças para o DA e TB, mas não para o PM, usando cargas baixas e altas (47).

1.1.4 Força Isométrica Máxima e o Tempo Até a Força Isométrica Máxima

A manutenção da força é alcançada devido uma combinação de fatores morfológicos e neurais, incluindo área e arquitetura da seção transversal do músculo, rigidez musculotendinosa, recrutamento da unidade motora, codificação da taxa, sincronização da unidade motora e inibição neuromuscular (48). A força também é expressa pelo produto da massa pela aceleração, conforme a lei de Newton (49). Dessa forma a força pressupõe a realização visível de um movimento, no entanto, a força máxima pode ser alcançada na velocidade zero, sendo este ponto conhecido como força isométrica (19). Desse modo, a força pode ser medida em suas diferentes manifestações, dinâmica e estática, sendo segura e eficiente para avaliar a força máxima (50).

Os testes de FIM e tempo até a FIM entre os lados direito e esquerdo dos membros superiores, antes e depois do treinamento, em nosso estudo foram determinados por uma célula de carga Musclelab (Modelo PFMA 3010 e MuscleLab System; Ergotest, Langesund, Noruega), fixada no banco de Supino Reto adaptado, através do uso de mosquetões modelo Spider HMS Simond (Chamonix, França), com carga de ruptura de 21 KN, aprovados para escalada pela *Union Internationaledes Associations d'Alpinisme* (UIAA). Uma corrente de aço com carga de ruptura de 2.300 Kg foi utilizada para fixar a célula de carga ao banco. A distância perpendicular entre a célula de carga e o centro da articulação foi determinada e usada para calcular o resultado dos indicadores nos dois lados do corpo, conforme (51,52).

1.2 Questões de Estudo

Nesta dissertação buscamos analisar os seguintes problemas:

1) Qual a diferença na velocidade média entre os membros após uma sessão de treinamento de força no PP?

2) Qual a diferença na atividade muscular entre os membros em séries diferentes do SP executado por PP?

3) Qual a diferença na força isométrica máxima e tempo até a força isométrica máxima entre os membros após uma sessão de treino de força?

1.3 Organização da Dissertação

Este trabalho foi desenvolvido pensando nas exigências das regras do ICP, as condições físicas dos atletas paralímpicos da modalidade powerlifting e repercussões dos efeitos das sessões de treinamento de força nestes indivíduos, visando melhorar os benefícios para o esporte em termos de superação de recordes, ampliação do número de atletas e redução do número de possíveis equívocos cometidos em competição, no julgamento da execução do movimento.

Considerando a quantidade de dados recolhidos, o número de variáveis em estudo e, sobretudo, a diversidade das questões acima indicadas, optou-se por apresentar, nesta dissertação, dois estudos, que no seu conjunto permitem dar resposta às questões.

O estudo “1” intitulado “Análise cinemática da assimetria após uma intervenção de treinamento de força em Powerlifters Paralímpicos”, pretende responder a questão 1.

O estudo "2", Diferenças de atividades musculares e força isométrica máxima intermembros em séries do treino de supino em Powerlifting Paralímpico", pretende responder às questões 2 e 3.

Assim, no capítulo dois são apresentados os estudos realizados. Cada investigação encontra-se dividido nas seções tradicionais do formato de artigo (Resumo, Introdução, Métodos, Resultados e Discussão).

Na última sessão desta dissertação são refletidas as considerações finais, procurando dar resposta às questões em estudo, sugerindo implicações práticas nas preparações do PP e nas competições, além de novas linhas de investigação.

1.4 Objetivos

Para melhor visualização, o objetivo geral deste estudo foi analisar a assimetria entre membros em diferentes intensidades de treinamento e fases (concêntrica e excêntrica) no levantamento de peso SR, considerando a velocidade média, a atividade muscular através da eletromiografia de superfície, a força isométrica máxima e o tempo até a força isométrica máxima. Porém, os objetivos específicos estão assim definidos:

1.4.1. ESTUDO 1: Análise cinemática da assimetria após uma intervenção de treinamento de força em Powerlifters Paralímpicos.

a) Comparar a velocidade média entre os membros na fase concêntrica e excêntrica com intensidade de 45% de 1 RM;

b) Comparar a velocidade média entre os membros na fase concêntrica e excêntrica com intensidade de 45% de 1 RM, em cada uma das quatro repetições da série;

c) Comparar a velocidade média entre os membros na fase concêntrica e excêntrica com intensidade de 80% de 1 RM;

d) Comparar a velocidade média entre os membros na fase concêntrica e excêntrica com intensidade de 80% de 1 RM, em cada uma das cinco repetições da série;

1.4.2. ESTUDO 2: Diferenças de atividades musculares e força isométrica máxima intermembros em séries do treino de supino em Powerlifting Paralímpico

a) Comparar a atividade muscular entre os membros com intensidade de 45% de 1 RM;

b) Comparar a atividade muscular entre os membros com intensidade de 80% de 1 RM;

c) Comparar a força isométrica máxima entre os membros depois de uma sessão de treinamento de força;

d) Comparar o tempo até a força isométrica máxima entre os membros depois de uma sessão de treinamento de força;

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ESTUDOS REALIZADOS

2 ESTUDO 1: **Santos, Lda; Aidar, FJ; Nobari, H; Badicu, G; Greco, G; Souza, RLM; Britos, JB; Nikolaidis, TP; Kinematic analysis of asymmetry after strength training session in Paralympic powerlifters.** **Sport Sciences for Health. Received: 24 Dez 2023**

Kinematic analysis of asymmetry after strength training session in Paralympic powerlifters

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Abstract: (1) Background: Para Powerlifting (PP) is the bench press with a single contest exercise. The rules require symmetry in lifting, but the natural tendency among humans is for asymmetry. Objective: The aim of the present study was to examine the influence of speed, load intensity and fatigue of a training session on symmetry, and analyse asymmetries of average speeds between the limbs after a training session. (2) Methods: Twelve male PP athletes (age 28.58±5.50 years, experience 4.53±1.27 years, body mass 79.25±18.82kg, 1RM 150.42±42.07kg, 1RM/BM 1.94±0.46), had their bench press lifts recorded and downloaded into the Kinovea software. Measures of central tendency, mean ± standard deviation (SD) and the Shapiro-Wilk test were performed. (3) Results: There was a difference in repetition 2, in the dominant limb, between the moment before and after, however, our hypothesis that at higher intensities and in the concentric phase of the exercise it would cause velocity asymmetry between the limbs was not confirmed. (4) Conclusion: It is important to observe the absolute data and carefully evaluate the statistical differences since asymmetries are observed in different sports and are not determinant in sports performance; thus, being acceptable up to a certain level and unfavourable when it exceeds this level, which is individual and intimate to the sports activity.

Keywords: Paralympic athletes; Symmetry; muscle strength.

1. Introduction

Para Powerlifting (PP) is an adaptation of conventional Powerlifting with bench press weightlifting being the only exercise for dispute [1], which became a paralympic sports discipline in 1984. It is performed with the athlete fully on the bench in the supine position [2,3]. The valid execution of the exercise is effective when the athlete removes the bar from the hack, starts the descending/eccentric and ascending/concentric movement in a controlled way and both arms are synchronized, evidencing a symmetry of the movement [1]. On the other hand, it is known that human beings preferentially use one of the body hemispheres in motor actions [4,5]. This characterizes asymmetry, which is the dominance of one of the limbs, specialization of the cerebral hemispheres and adaptations in motor skills [4]. In addition, in the case of athletes with limitations in the lower limbs, this can generate instability in the phases of the exercise [6].

It is reasonable to assume that there are asymmetries in weightlifting on the adapted bench press. Thus, coaches and athletes aim to meet the demands of good execution and validity of the movement [1] and overcome asymmetry conditions to prevent injuries and improve performance [7,8]. However, even though PP is not a contact sport, it has high injury rates [9,10]. They may be related to the use of high loads, the rigor of the execution techniques, the underestimation of pain and the demands of competition [10,11]. In other sports, asymmetry has been studied. In sitting volleyball, athletes exhibited an asymmetric rotational strength profile [12]. In Wheelchair Rugby, the chair propulsion asymmetry was evaluated, where the measurement of asymmetries proved to be important in improving performance, enabling the necessary adaptations both in equipment and in training [13]. The assessment of asymmetry, as already mentioned, has also been shown to be important for Para Powerlifting [8].

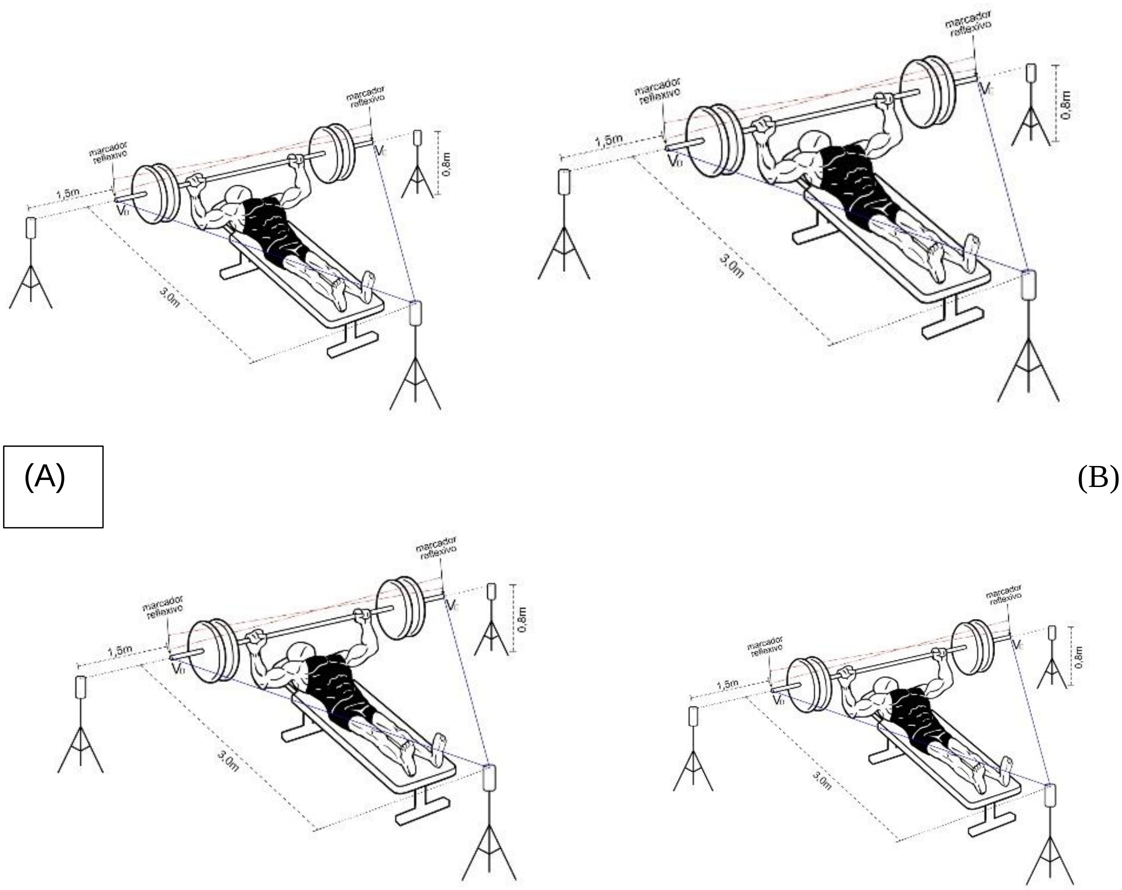
Based on the evidence, load and velocity factors influence asymmetry levels, suggesting that higher velocities can improve symmetry [5]. Considering this factor, studies establish speed as an important component in performance evaluation [14–18]. Still in this sense, when the velocity was investigated with an intensity of 50%, a symmetrical performance was found, while with an intensity of 90%, there was significant asymmetry in favor of the dominant limb, observed in the initial and final moments of the movement [8].

Realizing the rule's requirement for symmetry [1], the natural tendency among humans for asymmetry [4,5], in addition to the influence of speed, load intensity and fatigue of a training session on symmetry [5,8,18–20], the aim of the present study was to examine the asymmetries of average speeds between the limbs after a strength training session in the PP. We hypothesized that there are asymmetries between the limbs at higher intensities and in the concentric phase of the exercise.

2. Materials and Methods

2.1 Study design

The athletes were evaluated in two sessions, the first for familiarization and to test 1 Maximum Repetition (RM) and the second to obtain the data of the average speed, in meters per second, in the bench press exercise. Data were collected at two different times with intensities of 45% and 80% of 1RM. At the intensity of 45% 1RM, the athletes performed four repetitions and at the intensity of 80% 1RM, five repetitions were performed.



(A) (B)

(C) (D)

Figure1. (A) Moment before 45% of 1RM; (B) Moments before 80% of 1RM; (C) Moment after 80% of 1RM; (D) Moment after 45% of 1RM.

2.2 Participants

Twelve male elite PP athletes (age 28.58±5.50 years, experience 4.53±1.27 years, body mass 79.25±18.82kg, 1RM 150.42±42.07kg, 1RM/BM 1.94±0.46) linked to an extension project of the Department of Physical Education of the Federal University of Sergipe – Sergipe – Brazil. All participants have already competed at the national level, are eligible to compete in the modality [1] and share the ranking among the top ten in their respective categories. Among the deficiencies: six athletes present malformation in the lower limbs (arthrogryposis); one with sequelae due to poliomyelitis; four with amputations; one with spinal cord injury due to an accident with an injury below the eighth thoracic vertebra.

The athletes participated in the study voluntarily and signed an informed consent form, in accordance with resolution 466/2012 of the National Research Ethics Commission, CONEP, of the National Health Council, and the ethical principles expressed in the Declaration of Helsinki (1964, reformulated in 2013), from the World Medical Association. The project was submitted and approved by the Research Ethics Committee of the Federal University of Sergipe under CAAE number: 2,637,882 (approval date: May 7, 2018).

2.3 Procedures

The athletes' body mass was obtained using a platform-type electronic Michetti Digital Scale (Michetti, Brazil) to facilitate their weighing seated, with a maximum weight capacity of 300 kg and a dimension of 1.50 x 1.50 m. To perform the bench press exercise, an official straight bench measuring 210 cm, a 220 cm bar, and weight plates were used, all from the brand (Eleiko, Sweden) and approved by the International Paralympic Committee (IPC) [1].

The bench press lifts were recorded with three smartphone cameras (iPhone X, Apple Inc., Cupertino, CA, USA), all set to a common video resolution at 4k and 30 frames per second (fps) [21,22], being positioned on tripods, at a height of approximately one meter from the ground. Two cameras were placed on the sides of the bar at a distance of 1.5 m from the reflective markers, and another was positioned in front, with a distance of 3.0 m from the reflective markers distributed equidistantly from the center to the ends of the bar, forming an angle perpendicular to the motion plane, which captured the velocity tracking data at the different positions of the bar (right side and left side) as used in [8,23,24].

The recorded videos were downloaded in the open-source software Kinovea version 0.9.5 [25] for the acquisition of recorded data, after frame-by-frame analysis at 30 fps. For the software calibration, we used three sticks in known positions, fixed measures of 1.0 m in the vertical direction, with reflective markers and aligned with each camera that recorded the movement, in addition to three reflective markers positioned in the center, at the left and right end of the bar, which ensures measurement consistency, this allows the program to convert digital pixel measurements into known actual measurements in cm [26].

The measurements related to the speed in each phase (eccentric and concentric) of the bench press lifting were obtained in each cell phone and the four repetitions with a load of 45% of 1RM, in the moments before and after the training, in the first and fifth series of the main session with five maximum repetitions and 80% of 1RM protocol described in [27,28]. To obtain the data related to the average speed recorded in the eccentric phase, we considered the beginning of the phase, represented by the frame of movement when the athlete is positioned to lower the bar to the chest, computed all frames until the final moment of this phase, when the athlete for the chest bar, as required by the IPC [1]. To record the data of the concentric phase, from the frame that the athlete starts the ascent until the moment that he completely extends his elbows, and the velocity values of these frames were calculated for the average and reduction of the data. These bench press movements were guided by a coach with experience in the sport, requiring maximum symmetry from the athletes in each lift as described [1].

In the first session, the 1RM test was performed, where each subject started the attempt with a weight that they believed could be lifted only once using maximum effort. Load increments have been increased until the maximum possible load can be lifted once. If he could not perform a single repetition, 2.4 to 2.5% of the load used was subtracted [29,30]. Subjects rested between 3-5 minutes between trials [30]. This test was performed 72 hours in advance of the evaluation process that took place in the second session.

In the second session, the athletes performed a previous warm-up for upper limbs and specifically in the bench press with 30% of the load for 1RM, where 10 slow repetitions (3.0 X 1.0 seconds, eccentric x concentric) and 10 fast repetitions were performed (1.0 X 1.0 seconds, eccentric x concentric) to then start the collections [31]. After this step, the athletes performed a series of 4 repetitions with an intensity of 45% of 1RM, and then a 5X5 protocol with a load of 80% of 1RM was performed [27,28], and finally, one more series of 4 repetitions and a load of 45% of 1RM, being this initial and final series considered as moments before and after with 45% 1RM. While the first and fifth series of the 5X5 protocol were considered as the moments with 80%.

2.4 Statistical analysis

Descriptive statistics were performed considering measures of central tendency, mean ± Standard deviation (Mean±SD). To check the normality of the variables, the Shapiro-Wilk test was used, observing the sample size. Three-way repeated measures ANOVA was performed to assess the difference between the sides (dominant and non-dominant), and moments (before and after), with an intensity of 45% and 80% 1RM and Bonferroni Post Hoc test. Statistical analysis was performed using the computerized Statistical Package for the Social Science (SPSS 25.0) package (IBM, New York, USA). The significance level adopted was $p < 0.05$. The effect size, i.e., partial eta square ($\eta 2p$), was interpreted as small effect ≤0.05, medium effect 0.05 to 0.25, high effect 0.25 to 0.50, and very high effect > 0.50.

3. Results

Figure 2 shows the results of the Eccentric and Concentric Mean Velocity in the moments before and after, with regards to the dominant and non-dominant limb with 45% of 1RM.

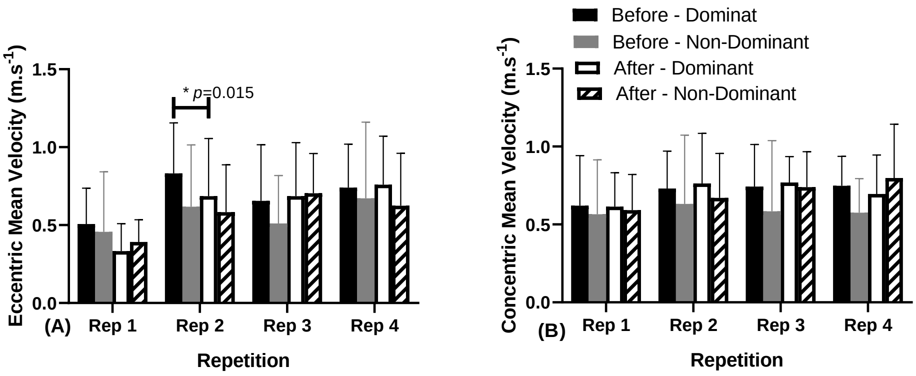


Figure 2. Mean Eccentric (A) and concentric (B) Velocity in the moments before and after exercise, for dominant and non-dominant limb with 45% of 1RM. Legend: Rep: Repetition.

In figure 2 (A), there was a significant difference in repetition 2, as the dominant limb was larger, between the moment before and after (* $p=0.015$, $F=2.829$, $\eta 2p=0.205$, mean effect).

In Table 1, the results of the Mean Eccentric Velocity were presented, in the moments before and after, in relation to the dominant and non-dominant limb with 80% of 1RM.

Table 1. Mean Eccentric Velocity, in the moments before and after, in relation to the dominant and non-dominant limb with 80% of 1RM (Mean ± SD, and CI 95%).

	Before		After			
	dominant	**Non-Dominant**	**dominant**	**Non-Dominant**	**P**	**η2p**
repetition 1	0.26±0.0a (0.23-0.30)	0.26±0.08 (0.21-0.32)	0.27±0.15a,b,c (0.17-0.36)	0.22±0.09a,b,c, d (0.17-0.28)		

repetition 2	0.36±0.08a (0.30-0.41)	0.39±0.15* (0.29-0.48)	0.45±0.18a (0.33-0.56)	0.39±0.12a (0.31-0.46)		
repetition 3	0.34±0.12* (0.26-0.42)	0.39±0.17* (0.29-0.50)	0.42±0.15# (0.33-0.52)	0.37±0.13b# (0.29-0.46)	*=0.045 #=0.035	0.569
repetition 4	0.33±0.12* (0.25-0.40)	0.39±0.20 (0.26-0.52)	0.46±0.19b*# (0.34-0.58)	0.38±0.16c# (0.28-0.48)	*=0.034 #=0.003	0.569
repetition 5	0.32±0.13* (0.24-0.41)	0.31±0.16* (0.21-0.41)	0.47±0.20c*# (0.35-0.60)	0.36±0.17d# (0.26-0.47)	*=0.001 #<0.001	0.569
P	0.035	0.002	a=0.001 b=0.004 c=0.011	a=0.001 b=0.005 c=0.006 d=0.037		
η2p	0.545	0.545	0.545	0.545		

* p< 0.05 (ANOVA). η2p = partial eta square; small effect ≤0.05, medium effect 0.05 to 0.25, high effect 0.25 to 0.50 and very high effect > 0.50.

Figure 3 shows the kinetics of the Mean Eccentric Velocity in relation to the dominant and non-dominant limb with 80% of 1RM.

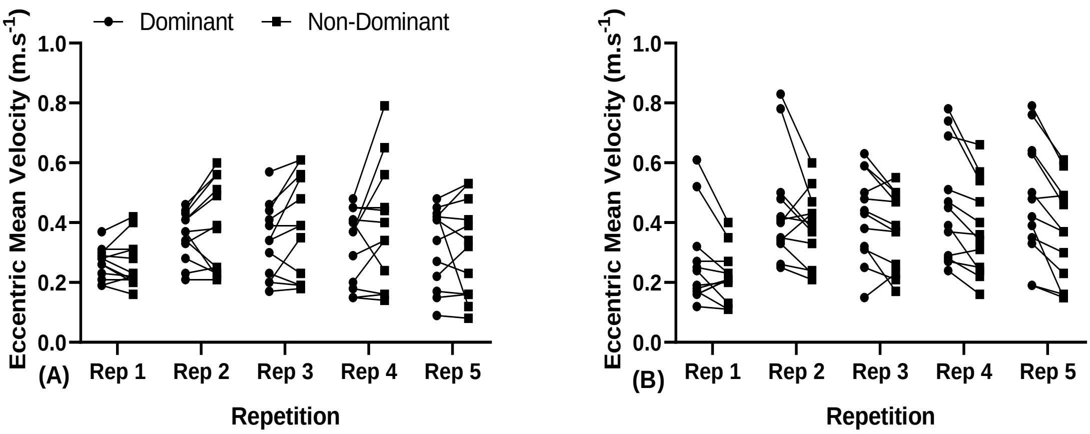


Figure 3. Kinetics of Mean Eccentric Velocity, in relation to the dominant and non-dominant limb with 80% of 1RM.

Note: Statistical results are shown in Table 1

In table 2 the results of the Concentric Mean Velocity, in the moments before and after, in relation to the dominant and non-dominant limb with 80% of 1RM.

Table 2. Concentric Mean Velocity, in the moments before and after, in relation to the dominant and non-dominant limb with 80% of 1RM (Mean ± SD, and CI 95%).

	Before		**After**	
	dominant	**Non-Dominant**	**dominant**	**Non-Dominant**
repetition 1	0.28±0.12 (0.20-0.35)	0.29±0.12 (0.22-0.37)	0.34±0.10 (0.27-0.40)	0.29±0.09 (0.23-0.35)
repetition 2	0.31±0.11 (0.25-0.38)	0.32±0.06a,b (0.28-0.35)	0.33±0.09 (0.27-0.39)	0.31±0.05 (0.28-0.35)
repetition 3	0.28±0.09 (0.22-0.34)	0.29±0.08c (0.24-0.34)	0.32±0.10 (0.25-0.38)	0.29±0.07 (0.25-0.34)
repetition 4	0.26±0.06 (0.22-0.30)	0.25±0.06a (0.21-0.30)	0.30±0.13 (0.22-0.39)	0.28±0.10 (0.22-0.34)
repetition 5	0.23±0.08 (0.18-0.28)	0.21±0.06b,c (0.17-0.25)	0.26±0.15 (0.17-0.36)	0.24±0.10 (0.18-0.31)
P		a=0.004 b=0.003 c=0.010		
η2p		0.372		

* $p < 0.05$ (ANOVA). η2p = partial eta square (small effect ≤0.05, medium effect 0.05 to 0.25, high effect 0.25 to 050 and very high effect (> 050).

Figure 4 shows the kinetics of the Concentric Mean Velocity in relation to the dominant and non-dominant limb with 80% of 1RM.

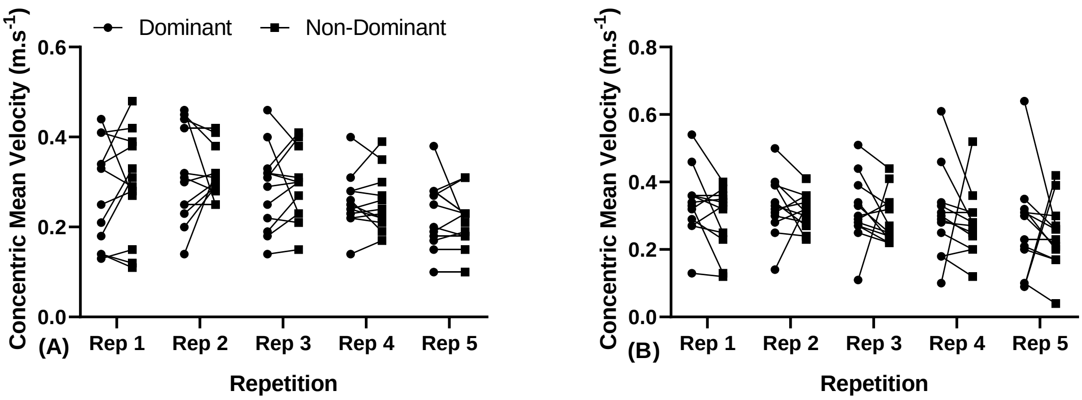


Figure 4. Kinetics of Concentric Mean Velocity, in relation to the dominant and non-dominant limb with 80% of 1RM.

Note: Statistical results are shown in Table 2

4. Discussion

The main objective of our study was to analyse whether the load intensity and fatigue during the training session cause asymmetries in the kinetics of velocities between the limbs. Our hypothesis that at higher intensities and in the concentric phase of the exercise it would cause velocity asymmetry between the limbs was not statistically confirmed. However, some particularities were registered when the exercise was performed with 45% and 80% of 1RM, thus, considering the absolute values, the asymmetries were noticeable in favour of the dominant limb.

To test our hypothesis regarding the intensity and phases of the movement (eccentric and concentric), we compared the speed at each moment, between repetitions, with an intensity of 45% and 80% 1RM. The intensity of 45% 1RM allowed a good representation of the effect of the load on the velocity kinetics, it is easily moved and tolerated by the athletes, in addition to being the load that causes an average velocity of one meter per second, in agreement with [15,18,32]. These characteristics of the 45% 1RM load may justify and demonstrate the little difference in asymmetry in well-trained PP athletes.

Regarding the results found in our study, a statistical difference was recorded in repetition "2", in the dominant limb, between the moment before and after with a load of 45% of 1RM, in the eccentric phase and without significant difference in the average concentric velocities. Our findings reinforce the evidence that lower intensities tend to cause little or no change in kinetics between limbs [8]. It should be noted that these findings occurred comparing statistical analysis methods, where no significant asymmetries were observed in the velocity profiles when the bench press exercise was performed with intensities of 50% of 1RM. Similar evidence occurred when analysing the movement of the bar as a function of weight in the bench press exercise, with the time to obtain the maximum angular velocity equal between both upper limbs, considering loads up to 60% of 1RM [33].

This phenomenon of little or no asymmetry at lower intensities and in the eccentric phase can be explained by the greater ability of the muscles to maintain strength during this phase [34]. In the 1RM test, the maximum concentric strength is evaluated, which does not correspond specifically to the maximum eccentric strength. This indicates that the fatigue-inducing factors and the EMG signal pattern presented changes during the exercise, notably in this phase [34,35].

Another justification for the findings, that is, little asymmetry, would be a progressive decrease in the work performed by the contractile components and an increase in the participation of the passive muscle components [35]. The increase in speed in the bench press exercise at lower intensities seems to reduce muscle effort, the same was observed when analysing asymmetries in runners, performing activities at higher speeds.[5].

Analysing the intensity of 80% of 1RM, there were statistical differences in a few repetitions in relation to the dominant limb. However, the absolute data show greater asymmetry in the concentric phase in favour of the dominant limb. Studies like that of Bernardina et al. [8] showed asymmetries in velocity between limbs when the exercise was performed at an intensity of 90% 1RM. Garcia, et al. [19] evidence fatigue in pre-exercise tests compared to post-exercise tests when analysing acute mechanical, metabolic and electro-activation effects after maximal and submaximal exercises. In the same study, the loss of speed, power and increase in lactate concentrations was also observed. Observing these effects and the results of our research, we understand that there are changes in velocities between the limbs, in absolute terms, however, they are not enough to statistically modify the symmetry pattern in PP athletes. Our records also partially follow the evidence from another investigation [36], while they verified the absence of differences in the peak amplitude of the EMGs within the evaluated muscles (anterior deltoid, pectoralis major and triceps brachii long head) between the examined loads of 50% and 90% 1RM during the bench press, even though the records of the electromyographic signals are not enough to justify our findings, on the other hand, they indicate certain similarities in the results on symmetry, increasing the need for different and deeper analyses regarding the advantages and disadvantages of asymmetry for the PP.

Symmetry is a required condition [1] and an important technical parameter evidenced in the studies for an optimization of the performance and reduction of the risks of injuries [7,8,37]. Some studies have analysed asymmetry in other sports and observed different effects concerning intensity, fatigue, and athletic performance [5,38–40]. Higher values of movement asymmetries were found at low and moderate intensities compared to high intensities [5,40]. On the other hand, when athletes with different levels of experience were analysed, they found asymmetries regardless of intensities [40]. Asymmetry is individual, activity-dependent and when it comes to team sports it does not have a negative impact [38]. Observing our absolute data, we agree with these statements, implying a specific need to analyse PP asymmetries, especially about the validity of the survey.

Our research has limitations that are related to food control, supplement intake, or other ergogenic aids. As well as the lack of control over the activity of daily living, work and history of pain and injuries in the joints involved in performing the bench press exercise. Due to the controversies of the findings and the reduced number of studies to describe this phenomenon in specific sports, we need further investigations to analyse this problem. On the other hand, strength of this study was its novelty as it was the first one to examine this topic. Considering the importance of bench press exercise for strengthening and the increasing popularity of Paralympic Powerlifting, the findings would have practical applications for sports scientists and coaches to optimize exercise prescription

5. Conclusions

However, our findings demonstrate the importance of looking at absolute data and carefully evaluating statistical differences. It is by checking these results that we detect the effects of intensity in the lifting phases of the bench press. Thus, knowing that humans have a lateral preference, PP is a predominant sport of strength, but its rules require absolute symmetry, we understand that this practice aims at the perfection that is difficult to find in humans. In addition, since PP is an adapted sport, we can think about how much the reasonableness of symmetry could bring benefits to the sport in terms of breaking records, increasing the number of athletes, and reducing the number of possible mistakes made in competition in the judgment of execution. of the movement. As other studies point out.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure S1: title; Table S1: title; Video S1: title.

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Evaluating the Asymmetry of Muscle Activation and Strength in Paralympic Powerlifting Athletes

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Abstract: Background: Strength training is a complex task, as it requires a combination of many variables. In paralympic powerlifting (PP) asymmetries for the evaluation of activation, and static force indicators have been increasingly studied. Objective: To investigate the asymmetries in the strength and muscle activation indicators, before and after a training session of PP athletes. Methodology: Twelve elite athletes from the PP participated in the study, and asymmetry was evaluated through surface electromyography (sEMG) and static strength indicators. Evaluations were made before and after a protocol of five series of five repetitions (5 × 5), with 80% of 1-Maximum Repetition (1RM). Results: In the pectoral muscles, there were differences in the non-dominant limbs between the before and after in the sEMG. There were differences in the pectoralis muscle in the non-dominant limb between moments before (110.75 ± 59.52%) and after (130.53 ± 98.48%, $p < 0.001$), and there was no difference in triceps activation. In the Maximum Isometric Strength (MIF), there was a difference in the non-dominant limb between before (710.36 ± 129.36) and after (620.27 ± 69.73; $p < 0.030$). There was a difference before in the dominant (626.89 ± 120.16; 95% CI 550.55–703.24) and non-dominant (710.36 ± 129.36; $p = 0.011$) limbs. There was no difference in time to MIF. Conclusion: PP athletes showed small levels of asymmetry before and after training, and adaptation to training tends to promote fewer asymmetries.

Keywords: disabled persons; asymmetry; force; paralympic sports

1. Introduction

Strength training is a complex task, as it requires a combination of many variables (such as exercise selection, execution order, number of repetitions, sets, and, loads)

[1]. Evaluating and controlling training are directly related to performance and injury prevention. The observation of muscular activity through electromyography has established a reliable relationship with evaluating acute training responses [2]. In strength training, one of the most utilized exercises for developing upper limb strength is the Bench Press, which is also a piece of equipment in modalities such as Conventional and Paralympic Powerlifting [3–5]. In Paralympic Powerlifting (PP), the bench press is the only competition exercise [6].

The presence of asymmetries between the limbs has been studied, with few studies specifically addressing performance [7]. Similarly, it has been reported that limb dominance influences movement kinematics, or is influenced by specific activity, as certain modalities place greater demands on one side of the body and highlight the dominant side compared to the non-dominant limb [8]. Thus, the dominant limb exerts greater control in more stable mechanical actions, while the non-dominant limb provides greater stability in unpredictable actions. Maximum voluntary force showed a difference between the dominant and non-dominant sides, with the average being higher on the non-dominant side [9].

The increase in asymmetries would be related to the increased risk of injuries [10,11]. Thus, training load control has been important in reducing the risk of injuries and improving performance [1,12]. On the other hand, fatigue would be related to loss of speed and metabolic stress [12,13]. Allied with this, the decrease in asymmetries would be related to improvements in function, strength, and power. Thus, studies have indicated that different neural control mechanisms are employed for dominant and non-dominant arm movements [14]. The neuromuscular control would be the muscular response to a stimulus linked to the dynamic stability of one or more joints. These neurological messages relate to different aspects of muscle actions, coordination, stabilization, posture, and balance [15]. Thus, fatigue could compromise these interactions and interfere with balance and symmetry. On the other hand, training would have effects on functional performance, biomechanics, and muscle activation patterns of the surrounding joint musculature. [14–16], and this asymmetry could be related to an increased risk of injuries [17,18].

One way to assess Bench Press and muscle activation would be through electromyography, where the activation of the muscles involved in the exercise tends to be better researched [19–21]. Evaluations have been used to identify the recruitment of muscles involved in exercises, muscle activation, the effect of different training methods, and asymmetry, among others [3,22,23]. In addition to the evaluation in terms of activation, several studies have focused on the assessment through dynamic and static force indicators [24,25]. In addition, the assessment of asymmetries in relation to muscle activation [26–28] and static strength indicators [9,29] has been widely used.

Thus, the aim of this study was to compare the asymmetry before and after a training session in PP athletes in relation to muscle activation and static strength indicators. For this, it was hypothesized that there will be differences in relation to muscle activation and static strength indicators in relation to the dominant and non-dominant side between PP athletes.

2. Materials and Methods

2.1. Design

The study was carried out over two weeks, with the first week focused on familiarizing and testing a maximum repetition (1RM) in the Bench Press (BP) exercise. Before and after the training session, the athletes were submitted to a test to evaluate the Maximum Isometric Strength (MIF) and time in milliseconds for MIF (time). The training session was performed using a protocol of five series of five repetitions (5 × 5) with 80% 1RM in the BP exercise. To assess muscle activity, it was performed using surface electromyography (sEMG), and surface electrodes were applied in the first and last series of the 5 × 5 protocol [23,24], to collect the electromyographic activity of the Pectoralis Major (PM) muscles, (sternal portion) and Triceps Brachii (TB) long head (Figure 1).

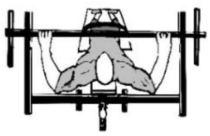
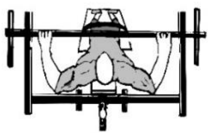
			Day 1		Other days	
Week 1 (Test)		➔	 1RM Test	➔		Rest
Week 2	➔	Before Intervention (MIF And Time)	Intervention  5 × 5 (1St e 5th Set sEMG)	➔	After Intervention (MIF And Time)	Rest

Figure 1. Experimental design. Legend: MIF: Maximum Isometric Force. Time: Time at MIF. The sEMG: surface electromyography. 5 × 5: five sets of five maximum repetitions.

The tests were carried out on Monday, from 8:00 am to 12:00 pm, and the athletes were instructed to maintain their eating habits, not to consume alcohol, and not to practice physical activities in the 48 h that preceded the tests. This was confirmed by interviewing the athletes before the tests.

2.2. Sample

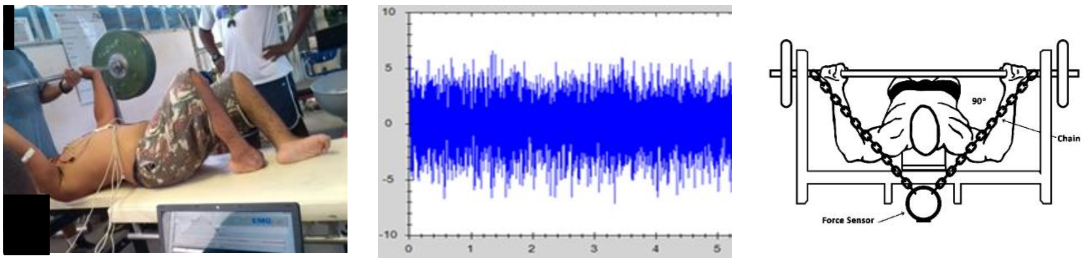
Twelve elite male athletes from PP (age: 27.7 ± 5.7 years; experience: 2.1 ± 0.9 years; body mass: 74.0 ± 19.5 kg; 1RM: 113.0 ± 31.3 kg; 1RM/Body Mass: 1.6 ± 0.3), all athletes were right-handed, linked to an extension project of the Physical Education Department of the Federal University of Sergipe—Sergipe—Brazil. All participants have competed at the national level, are eligible for the modality competition [6], and share a ranking among the top ten in their respective categories. Among the disabilities: six athletes have malformation in the lower limbs (arthrogryposis); one with sequelae due to poliomyelitis; four with amputations; and one with a spinal cord injury due to an accident with injury below the eighth thoracic vertebra. The athletes participated in the study voluntarily and signed an informed consent form, according to resolution 466/2012 of the National Commission of Ethics in Research—CONEP, of the National Health Council, in accordance with the ethical principles expressed in the Declaration of Helsinki (1964, reformulated in 1975, 1983, 1989, 1996, 2000, 2008, and 2013), of the World Medical Association. The project was submitted and approved by the Research Ethics Committee of the Federal University of Sergipe with the number Certificate of Presentation of Ethical Appreciation (CAAE): 2,637,882 (approval date: 7 May 2018).

2.3. Instruments/Procedures

Individual body mass of the athletes was obtained using a digital electronic platform scale (Michetti, São Paulo, Brazil) with a maximum weight capacity of 300 kg and dimensions of 1.50 × 1.50 m to facilitate weighing while seated. For the execution of the bench press exercise, an official flat bench measuring 210 cm, a 220 cm barbell, and weight plates from the brand Eleiko (Eleiko, Halmstad, Sweden) were used, all approved by the International Paralympic Committee [6].

Prior to the 1RM test in the first session and the 5 × 5 protocol with 80% of 1RM in the second session, the athletes performed a specific warm-up for upper limbs on the bench press itself with 30% of 1RM, where 10 slow repetitions (3.0 × 1.0 s, eccentric × concentric) and 10 fast repetitions (1.0 × 1.0 s, eccentric × concentric) were performed, followed by data collection [30]. In the first session, the 1RM test was performed, where each subject started the attempt with a weight, they believed they could lift only once using maximum effort. Weight increments were added until the maximum load that could be lifted was reached. If the athlete was unable to perform a single repetition, 2.4 to 2.5% of the weight used in the test was subtracted [31–34]. The subjects rested between 3–5 min between attempts [22,32]. This test was conducted 72 h prior to the evaluative process that occurred in the second session.

On the second day, the tests of MIF and time to MIF between the right and left sides of the upper limbs were performed before and after the training. The data for these indicators were determined by a Force Sensor (Chronojump, Boscosystem, Barcelona, Spain), with a capacity of 500 kg and an output impedance of 350 ± 3 ohm, fixed on the adapted Flat Bench Press (Figure 2), through the use of Spider HMS Simond model carabiners (Simmond, Chamonix, France), with a breaking load of 21 KN, approved for climbing by the Union Internationale des Associations d'Alpinisme (UIAA). A steel chain with a breaking load of 2300 kg was used to fix the load cell to the bench. The perpendicular distance between the load cell and the joint center was determined and used to calculate the results of the indicators on both sides of the body [35–37].



(**A**) (**B**) (**C**)

Figure 2. (**A**) Demonstration of muscle activation assessment using surface electromyography (sEMG); (**B**) sEMG signal; and (**C**) Demonstration of force sensor fixation.

The electromyographic activity of the muscles was captured using a New Mio Miotool (Miotec Inc. Porto Alegre, Brazil), and the surface electrodes were double, bipolar, and disposable type. They were applied on the right and left sides of the PM (sternal portion) and TB (long head), and the grounding electrode was fixed on the olecranon, according to surface EMG for a non-invasive assessment of muscles (SENIAM) recommendations [38]. Before the tests and electrode application, local scraping and cleaning were performed, and then the measurement points of each muscle were marked with a felt-tip pen. High-pass and low-pass filters (500-20) and offset were used for signal rectification. The highest signal and root mean square (RMS) were used for signal presentation, and signal normalization was performed based on the maximum voluntary isometric contraction (MVIC) [22,32] (Figure 2).

The maximum voluntary isometric contraction (MVIC) of each muscle was then recorded to normalize the sEMG values that would be recorded in the bench press exercise. For this, two maximal isometric contractions were performed for 3 s with 10 s of rest between contractions [39] and 2 min between MVIC assessment of each muscle [40]. Specifically, the MVIC was performed as follows: For the PM and TB, the participants performed bench presses with a grip that would do the training. sEMG targeted the sternal portion of the pectoralis major (PSL) and the long head of the triceps brachii (LHTB), which were captured during 3-s maximal voluntary isometric contractions (MVIC). There was an elbow angulation of approximately

90°, with a distance of 15.0 cm from the bar to the stern [23]. The surface electrodes (double, bipolar, and disposable) were positioned at an average distance between the motor point and the tendon of the evaluated muscles, parallel to the muscle fibers with a distance of 20 mm between them. A reference electrode fixed to the olecranon was also used, as recommended by SENIAM (Surface Electro Myo Graphy for the non-invasive assessment of muscles) [38]. Before the test, local asepsis and trichotomy were performed, and then the measurement points were marked with a felt-tip pen.

The entire adapted bench press test was accompanied by an experienced professional who instructed the athletes to perform the efforts symmetrically and quickly impose a stop at the chest between the eccentric and concentric phases, and equal locking of the elbows [6].

2.4. Statistics

Descriptive statistics were performed using measures of central tendency, mean (X) ± standard deviation (SD), and 95% confidence interval (95% CI). The Shapiro-Wilk test was used to check for the normality of the variables given the sample size. Data from all analyzed variables were found to be homogenous and normally distributed. Two-way repeated-measures ANOVA and Bonferroni post-hoc tests were conducted to evaluate the differences between pre- and post-training as well as between the right and left sides. The level of significance was set at $p < 0.05$. Effect size (partial eta-squared: $\eta 2p$) was used to determine the magnitude of the differences, with values of low effect (≤0.05), medium effect (0.05 to 0.25), high effect (0.25 to 0.50), and very high effect (>0.50) [41,42]. All statistical analyses were performed using the Statistical Package for the Social Science (SPSS) software, version 22.0 (IBM, New York, NY, USA).

3. Results

In Figure 3, the results of muscle activation through surface electromyography (sEMG) in the pectoral and triceps muscles are presented.

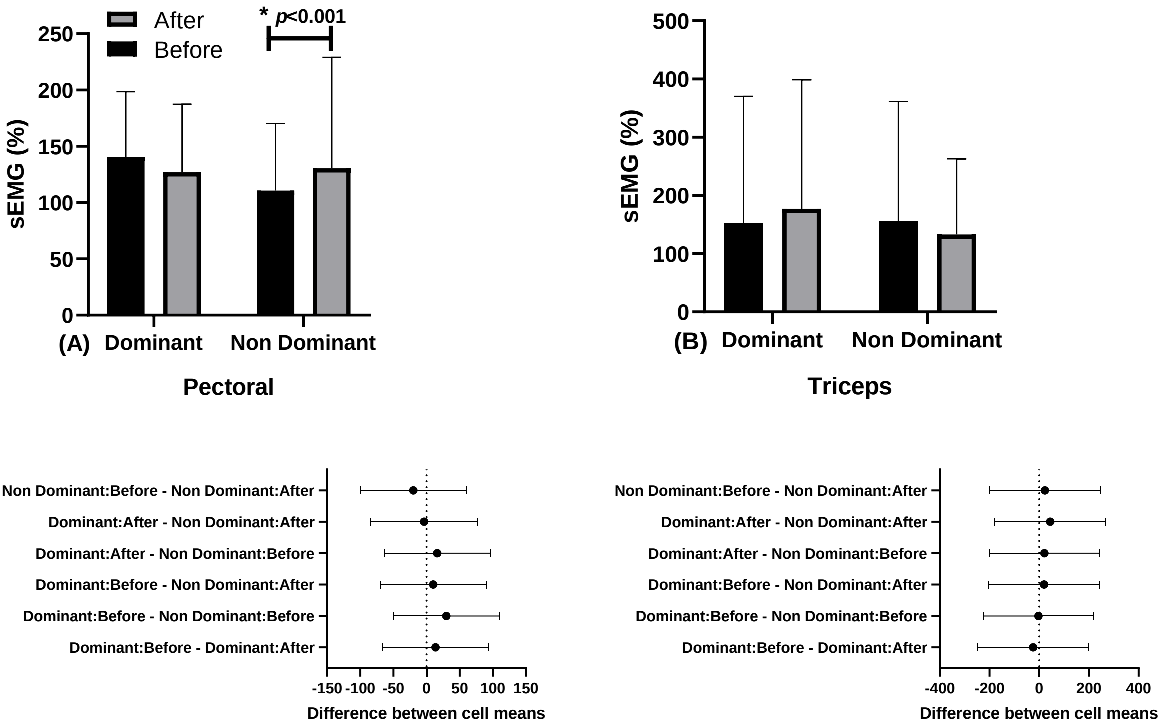


Figure 3. Muscle activation through surface electromyography (sEMG) in the pectoralis, and below in the same column is the 95% confidence interval (**A**) and triceps (**B**) muscles, in dominant and non-dominant limbs, at moments before (series 1) and after (series 5), with a load of 80% 1RM.

There were differences in the pectoralis muscle in the non-dominant limb between moments before (110.75 ± 59.52%; 95% CI 72.82–148.57) and after (130.53 ± 98.48%, 95% CI 67.96–193.11; “*” $p < 0.001$; η2p = 0.131, medium effect). No differences were observed for the triceps brachii muscle.

Figure 4 shows the results of maximum isometric force (MIF) and time to MIF, at moments before and after, in relation to the dominant and non-dominant limbs.

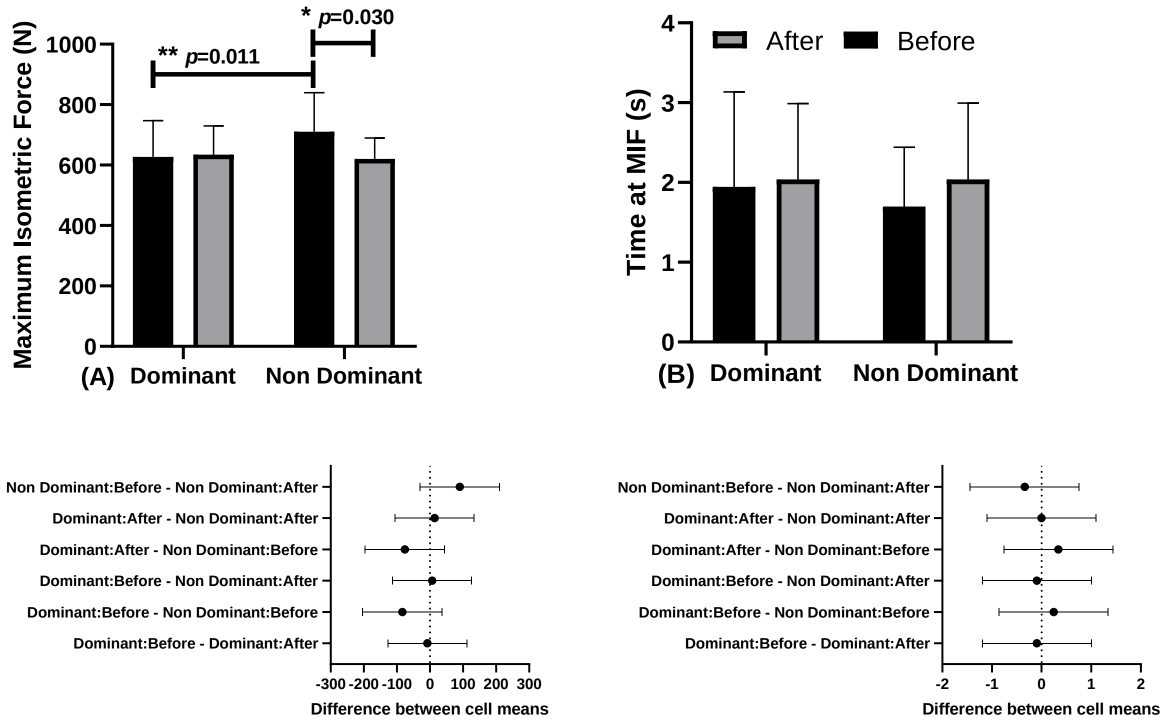


Figure 4. (**A**) Maximum Isometric Force (MIF) and (**B**) time to MIF, and below in the same column is the 95% confidence interval, before and after moments, in relation to dominant and non-dominant limbs.

There were differences in Maximum Isometric Force (MIF) in the non-dominant limb between the before moment (710.36 ± 129.36 N; CI 95% 628.17–792.55) and after moments (620.27 ± 69.73 N; CI 95% 575.96–664.57; "*" $p < 0.031$; η2p = 0.357, medium effect). There were also differences at the before moment between dominant (626.89 ± 120.16; CI 95% 550.55–703.24) and non-dominant limbs (710.36 ± 129.3 N; CI 95% 628.17–792.55; $p = 0.011$; η2p = 0.376, high effect). No differences were observed for the Time at MIF.

4. Discussion

The aim of this study was to investigate muscular activity asymmetries in different sets of the bench press exercises performed by powerlifters. We hypothesized that there were differences between members across different grades. In the analysis of sEMG in the non-dominant limb, an increase in activation was observed, however, there were no asymmetries in the PM and TB muscles.

The evidence from our study, which showed differences in the normalized average activity of electromyography (sEMG) in the PM muscle favoring the non-dominant limb in the post-exercise moment, may be related to greater sEMG signals from this area compared to other muscle segments, given that in the SP movement, the sternal and clavicular portions of the pectoral muscle are more solicited [43].

Understanding the last set as a more unstable means due to fatigue, this finding can also be explained by the Dynamic Dominance Model, in which in unexpected actions, such as fatigue, the non-dominant limb would be more activated than the dominant limb [8]. It was observed that during the assessment of maximal voluntary force when evaluating muscle actions, the non-dominant limb exhibited greater force than the contralateral limb [9]. Our study observed that activation in the Pectoralis Major muscle, on the non-dominant side afterwards, corroborates with other studies that presented similar results regarding the non-dominant side and recruitment patterns [9,44]. In addition to the aforementioned, the Pectoralis Major also showed greater asymmetry, especially with higher intensities (80% 1RM), where it was observed that the asymmetry would be specific to the mentioned muscle [8,14].

It is worth noting that the sEMG in the PM was higher in the post-exercise moment and on the non-dominant side, an effect explained by the logic of the recruitment progression of motor units (MU) [44]. The non-dominant PM exhibited greater muscle activity in the post-exercise moment, a behavior that suggests a different MU recruitment pattern between the limbs as the exercise series progressed in the SP at an intensity of 80% of 1RM.

When comparing the peak amplitude of sEMG in the PM, and TB during the bench press exercise at 50% and 90% of 1RM performed until muscular failure, investigators found different results from our study, showing significant sEMG differences only for the TB [45]. Another study aimed to analyze the inter-limb asymmetry index (IS) of sEMG in a group of powerlifting paraplegics, and they found significant IS for the pectoralis major, with a predominance for the right side [3].

Regarding the TB, they did not find statistical differences, but absolute values were highlighted due to an interesting particularity, as greater asymmetry was found on the left side, exceeding double that of the opposite side, a data that was not observed among other subjects in the study [3]. These findings indicate that muscle activity is complex and individual, dependent on load, repetition, and set quantity, making these variables important in evaluating differences in muscle activity between body sides.

Muscular strength is an important physical component that has been investigated by several studies [16,19,23] and among its indicators, the 1RM is considered the most reliable and efficient way to assess maximum strength [46]. As our sample was specialized in PP, a modality in which the development of maximum strength is a crucial element [6], we tested the 1RM and the time in milliseconds to reach it on each side of the limbs. To better understand muscle activity in the BP, our 1RM results showed significant differences in the non-dominant limb and at different moments. This reinforces the assumption that the dominant limb is more engaged in anticipating and dynamically controlling the movement, while the non-dominant limb performs the action of maintaining the position [15,16]. Regarding the time in milliseconds until the 1RM, there was no significant difference.

Another study evaluating grip widths of 1×, 1.3×, and 1.5× biacromial distance (BD) did not find significant differences in MIF [30]. The intersection of our findings with the results of this research enriches the interpretation of the interlimb training effect, as well as the effort generated after sets of the exercise. That is, the MIF of the upper limbs in SP does not change with different grip widths, but it is reflected differently in relation to the sides of the body.

The results regarding the time to reach MIF did not show significant differences between sides or between moments before and after. Under conditions of training with partial and total range of motion, this variable also did not undergo significant changes [23]. It is worth noting that this study did not evaluate the inter-limb effect of different training methods, but by combining our evidence, we contribute to understanding the behavior of these variables in the BP exercise.

Due to a multiplicity of reasons, para-athletes experience different levels of strength between the sides of the body (asymmetry) [47]. Time and specific activity make this asymmetry natural and individualized, and it is not determinant in compromising performance [48]. On the other hand, studies indicate that excessive asymmetries may be related to injury risks [10,11] and are also not accepted by the rules that govern PP competitions [6]. On the other hand, new studies are necessary to evaluate other perspectives, such as soft tissue radiodensity [49,50], functional electrical stimulation [51,52], the use of stimuli through stretching [53], and the combination of training [54].

Our study has certain limitations, including the lack of control over the athletes' diet and sleep patterns. Additionally, the research sample consisted of a small group of national and international level athletes who may have adapted to training and displayed less asymmetry than the general population due to the rules of the sport that prohibit asymmetry during lifts. We did not evaluate the relationship between disabilities and potential asymmetries, as many athletes had injuries on only one side of their body.

5. Conclusions

Our findings suggest that Paralympic powerlifting athletes showed very small levels of asymmetry and, even after training, this asymmetry was not observed in muscle activation through sEMG. With regard to FIM, there was asymmetry in the moment before, but not after training. While there were differences in terms of the pectoralis major and FIM muscle activation between the dominant and non-dominant sides, there was no asymmetry in terms of triceps FIM activation. Therefore, it seems that the PP athletes showed good symmetry, and even after training with high intensities, asymmetries were not observed in these athletes.

Author Contributions: Conceptualization, L.d.S. and F.J.A.; methodology, L.d.S. and F.J.A.; software, R.L.M.S.; validation, D.G.d.M., S.C. and G.G.; formal analysis, A.C.M.; investigation, L.M.V.S.; resources, J.L.d.S.; data curation, P.F.d.A.-N.; writing—original draft preparation, B.G.d.A.T.C.; writing—review and editing, G.B.; visualization, H.N.; supervision, M.G.-M.; project administration, R.F.d.S. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data that support this study can be obtained from the address: www.ufs.br/Department of Physical Education, accessed on 12 June 2023.

Conflicts of Interest: The authors declare no conflict of interest.

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CONCLUSÃO GERAL

Nos estudos realizados que constituem essa dissertação existe limitações, que estão relacionadas ao controle da alimentação, ingestão de suplementos, ou outros recursos ergogênicos. Assim como a falta de controle sobre a atividade da vida diária, laboral e histórico de dores e lesões nas articulações envolvidas na realização do exercício supino, aspectos merecedores de atenção em novas pesquisas. Devido as controvérsias dos achados e o número reduzido de estudos para descrever esse fenômeno em modalidades esportivas específicas, carecemos de mais investigações que analisem esse problema.

Contudo, nossos os resultados demonstram a importância de observar os dados absolutos e avaliar com cautela as diferenças estatísticas. Pois, são conferindo esses resultados que detectamos os efeitos da intensidade nas fases do levantamento no supino. Assim, sabendo que os humanos têm uma preferência lateral, o PP é esporte predominante de força, mas suas regras exigem uma simetria absoluta, entendemos que essa prática almeja uma perfeição difícil de ser encontrada nos humanos. Além disso, sendo PP um esporte adaptado podemos pensar o quanto a razoabilidade sobre a simetria poderia trazer de benefícios para o esporte em termos de superação de recordes, ampliação do número de atletas e redução do número de possíveis equívocos cometidos em competição no julgamento da execução do movimento. Assim como apontam outros estudos, também concordamos que o padrão de assimetria são observados em diferentes esportes e não sendo determinante no desempenho esportivo, deste modo, vale para os treinadores e atletas avaliar constantemente esses padrões para otimizar os resultados, observando que assimetria pode ser aceitável até determinado nível e desfavorável quando ultrapassa esse nível, que é individual e íntimo da atividade esportiva.

Devido a um conjunto de razões, muitos indivíduos experimentam diferentes níveis de força entre os lados do corpo (assimetria). O tempo de experiência em determinada atividade torna essa assimetria natural e individualizada não sendo determinante no comprometimento da performance. Por outro lado, sabemos que assimetrias excessivas podem estar relacionadas a riscos e também não são aceitas pelas regras que organizam as competições do PP. Desse modo, esclarecer as atividades dos músculos e os indicadores de força que são observados no levantamento de peso no SP, bem como seus efeitos intermembros são imprescindíveis para eficiência da performance e prevenção de lesões.