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Original Research

Accuracy of Two Methods in Estimating Target Muscle Force During Shoulder Submaximal Isometric Contractions

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Background

Submaximal isometric exercises are used for pain control and neuromuscular facilitation. Typically, an ipsilateral maximal voluntary isometric contraction (MVIC) is used as a reference; however, when this is not clinically feasible, an alternative must be considered. Two options are (1) the no reference (NR) method (submaximal contraction at a self-perceived effort level without reference) and (2) the reciprocal reference (RR) method (MVIC on the contralateral side serves as a reference for a submaximal effort-level on the ipsilateral side). No research evidence exists as to which alternative method is more accurate at the shoulder.

Purpose

To determine the accuracy of the NR and RR methods in estimating target muscle force during shoulder ER and IR submaximal isometric contractions among healthy adults.

Study Design

Observational cross-sectional

Methods

Isometric shoulder force was measured via a hand-held dynamometer on 48 healthy participants (36 females and 12 males) mean age of 27.4 ±1.6 years. Both methods (NR and RR), direction of force (IR and ER), and starting test-side (right or left) were randomized. RR testing involved a contralateral MVIC (reference) prior to a 50% submaximal contraction. NR testing entailed a 50% submaximal contraction with no prior reference MVIC.

Results

Actual submaximal efforts were compared to MVIC-based estimated submaximal efforts. Significant moderate - good correlations existed for both the RR (r = 0.691) and NR (r = 0.620) methods, regardless of test-side or shoulder motion. Significant moderate - good correlations were found between both methods for both ER [RR (r = 0.717) and NR (r = 0.614)] and IR [RR (r = 0.669) and NR (r = 0.628)].

Conclusion

Both methods had moderate - good accuracy levels and were not influenced by the test side or direction of force. Either method (RR or NR) can be equally useful for shoulder isometric exercise prescription when an ipsilateral reference cannot be determined.

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Level of Evidence

3

INTRODUCTION

Isometric exercises are commonly prescribed for patients/clients with various musculoskeletal pathologies, including tendinopathies, fractures, and post-operative care.[1-7] Often, submaximal [i.e., 25-50% of maximal voluntary isometric contraction (MVIC)] isometric contractions are prescribed in the early stages of rehabilitation, including for the shoulder, in an effort to effectively manage pain and improve functional recovery with minimal muscle overload.[8-10] In such cases, a degree of uncertainty may exist on whether an individual is accurately exerting the appropriate amount of submaximal muscle force prescribed by a clinician. The apparent clinical concern is whether a patient safely exerts an isometric muscle effort level appropriate for a given level of physiological tissue healing.

A direct way to improve accuracy on exercises that utilize submaximal isometric muscle efforts could be having the patient first perform an MVIC in the same direction and the same side in order to establish an ipsilateral muscle force reference criterion. This ipsilateral muscle-force criterion (IMFC) develops a conscious sense of how an MVIC muscle effort feels first and may help a patient's acuity in more accurately estimating a prescribed submaximal isometric muscle-force level. Previous research has established the accuracy of the IMFC approach described above for both shoulder external rotation (ER) and internal rotation (IR) (ICC for ER=0.909 and IR=0.849).[11]

Despite these results, producing an ipsilateral MVIC for reference may not always be possible, such as in the acute phases of post-operative management, fracture, or highly irritable tendinopathy. In these cases, another instructional method for producing a targeted submaximal isometric muscle force must be used. Two possible alternative techniques include a no reference (NR) method and a reciprocal reference (RR) method. The NR method is done through simple verbal commands directing the individual to perform a given percentage of one's MVIC level (i.e., "only use 50% of your total effort level"). This submaximal contraction is done without the patient first performing an MVIC as a reference to base their effort level. Instead, the person is only asked to imagine and then perform what a hypothetical submaximal muscle contraction at the given target would be. The RR method, on the other hand, is done by asking the patient to perform an MVIC on the contralateral (uninvolved) side to serve as the baseline reference criterion. In this case, developing a sense of how an MVIC muscle effort feels first on the opposite side helps a patient's ability to apply the targeted force on the opposite (reciprocal) side by downgrading the intended submaximal muscle contraction force during exercise.[12] Both of these alternative methods may potentially be clinically useful approaches among patients when an ipsilateral muscle MVIC is not advisable or practical.

Currently, there are no studies, in the shoulder or elsewhere, that examine the accuracy of these alternative methods of isometric force production when an ipsilateral reference criterion is not available. Exploring this research gap is clinically meaningful, especially for the initial rehabilitation stages of various shoulder pathologies requiring submaximal isometric exercises' application and progression. These exercises have been shown to reduce pain threshold, increase pain tolerance, and safely improve neuromuscular control.[8,9,13,14] Additionally, training-specific adaptations to targeted submaximal isometric exercises may include improvements in muscular endurance, muscle hypertrophy, and muscle strength.[15] The level of these physiological muscle adaptations may be influenced by the patient's accuracy with which submaximal muscle force production can be estimated and applied during exercises.[13] The purpose of this study was to determine the accuracy of the NR and RR methods in estimating target muscle force during shoulder ER and IR submaximal isometric contractions among healthy adults. The first aim of the study was to determine and compare the overall accuracy of the NR and RR in producing a targeted submaximal shoulder isometric force (50% of MVIC) as compared to the IMFC regardless of the test side or shoulder motion (ER and IR). The second aim was to determine the accuracy between the NR and RR methods as compared to the IMFC in producing a targeted submaximal isometric force (50% of MVIC) specifically for shoulder ER and IR, regardless of the test side.

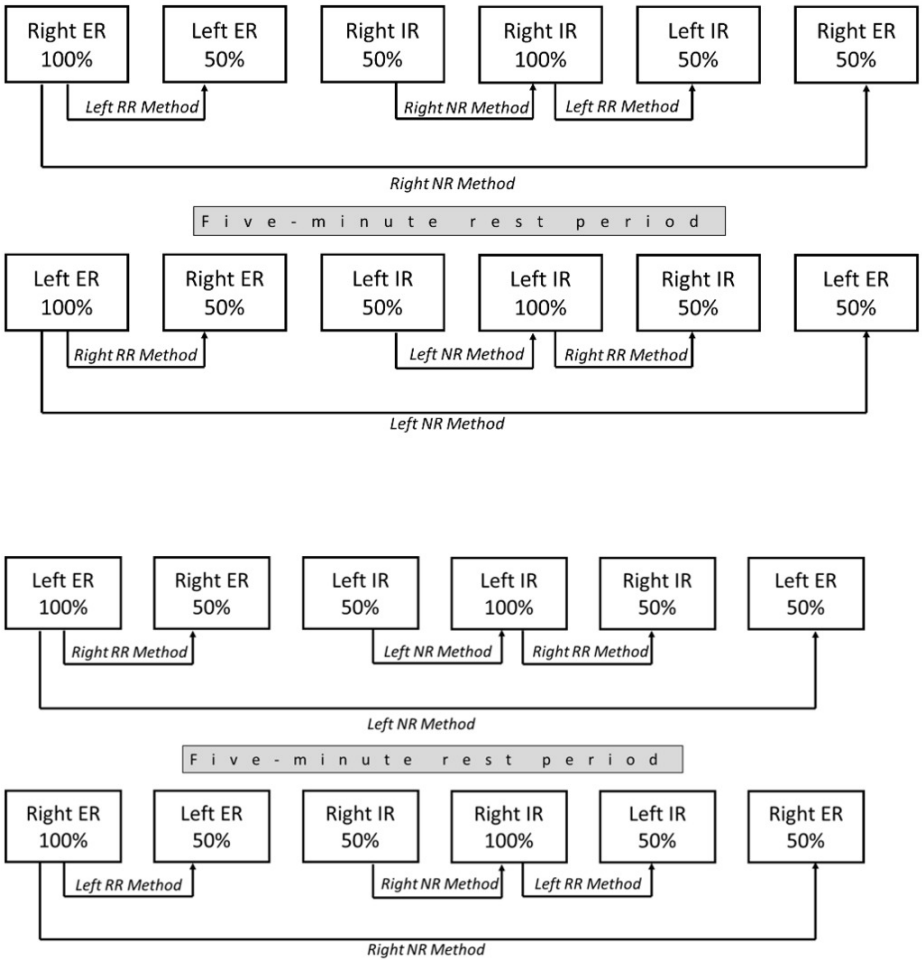
METHODS

DESIGN AND PARTICIPANTS

This was a cross-sectional observational study, which was approved by the DeSales University Institutional Review Board (ED60-110821). A convenience sample of healthy participants were recruited from the University community via word of mouth and electronic communication. All participants signed informed consent and were screened for eligibility through a questionnaire that was completed by the participant with a researcher present. Inclusion criteria included healthy adults over the age of 18 years. Exclusion criteria included those with known current shoulder or neck pain and associated weakness of the shoulder within the past six months, a history of shoulder or neck surgery within the past two years, any history of neurologic or rheumatologic conditions that may be affecting the upper extremities, and inability to communicate in English.

INSTRUMENTATION

Force production was measured using the ActivForce (AF; Activbody, San Diego, CA) digital dynamometer. Although the isokinetic dynamometer is considered the gold-standard measurement of isometric force production,[16,17] hand-held dynamometry (HHD) has been shown to be strongly correlated (ρ = .65–.82) with force production out-



Figures 1A (upper figure) and 1B (lower figure). Modified permuted block randomization flow for determining the direction of force and starting test side.

puts compared to isokinetic dynamometry, including across different clinician experience levels.[18,19] The AF was chosen due to its lighter weight compared to other HHDs, making it much easier to fixate the dynamometer at specific heights on the wall. Additionally, the lower profile design did not impede the normal alignment for shoulder ER and IR isometric contraction. Specifically, the AF HHD has been previously shown to be reliable for different shoulder movements (ER, IR, forward elevation) and across different experience levels (intra-rater ICC = 0.97, inter-rater ICC =0.91).[19]

PROCEDURES

All subjects' active range of motion was screened for functional IR (ability to place the hand behind their back) and ER (ability to place the hand behind their head/neck) prior to participating. Participants were asked to perform a series of maximal (MVIC) and submaximal (50% of MVIC) isometric contraction efforts in pre-determined randomly selected directions (IR or ER). This predetermined randomization enabled NR and RR methods to be assessed in each direction on both sides (Figure 1).

Values were determined by the peak force over a five-second timeframe. A single tester placed the AF HHD between the subject's distal forearm and the wall, with the location of the dynamometer set by the participant having the shoulder at 0° of abduction and the elbow flexed to 90°. The dynamometer location was fixed to the wall throughout testing for each subject (Figure 2).

Standardized verbal instructions were given to the subject to perform a maximum isometric contraction for a five-second hold into either ER or IR. The direction of force and the starting test side were randomized using a permuted block randomization. This randomized process was determined by a simple coin flip, and then required participants to follow either procedure A or B (Figure 1). Each procedure consisted of two series (based on which side was tested first) of six isometric contractions (100% MVICs and submaximal 50% MVICs) with a one-minute break between each contraction. The 100% MVIC recorded initially was used as the IMFC to establish the accuracy of both the RR and NR at a submaximal effort by dividing this value by two. After each series, a five-minute break was given, and the patient was asked to report their fatigue based on the Modified Borg Rate of Perceived Exertion (RPE) 0-10 scale.[20] It has been previously established that a 1-minute rest in between consecutive five-second MVICs is ample time for recovery with no signs of fatigue.[8,20] Completing the testing sequences within either procedure A or B enabled partici-

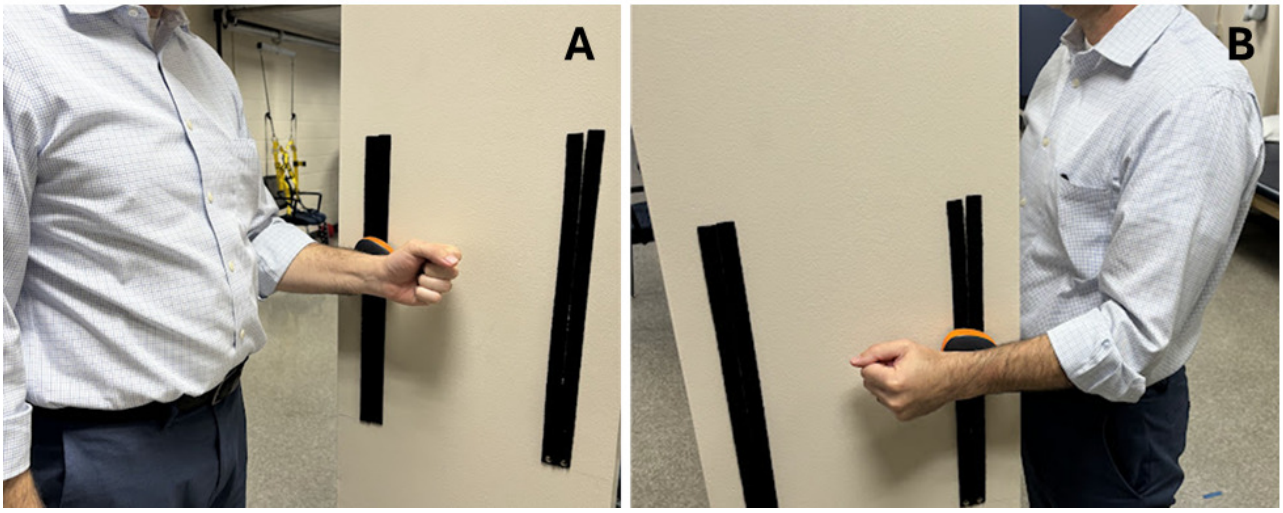


Figure 2. Set up to measure isometric force of shoulder external rotation (A) and internal rotation (B) using dynamometer fixed to the wall

pants to perform both methods (RR and NR) in a different order on both sides. Both the tester and participant were blinded to the results of their force production. This was achieved because the HHD utilized does not have a digital display. It requires a remote connection with a wireless device. In this study, it was remotely connected to a device managed by an independent researcher who recorded participant force production for all isometric contractions. An additional researcher timed each trial and rest period throughout the data collection process.

STATISTICAL ANALYSIS

Descriptive and inferential statistical analysis was performed using SPSS version 27 (IBM Corp., Armonk, NY). Data were assessed for normality by using the K-S statistic and examining Q-Q plots. The assumptions of Pearson correlation were met; and, therefore, were used to analyze both study aims. Pearson correlations were intended to assess the accuracy of the participants' ability to perform a self-estimated 50% submaximal effort for both the NR and RR methods compared to their actual submaximal effort, which was used as a reference criterion. The actual submaximal effort was calculated as 50% of the MVIC (actual MVIC divided by 2) produced by each participant during procedures A or B. Pearson correlations were interpreted as: > 0.75 strong, 0.50 - 0.75 moderate - good, and < 0.50 fair - poor.[21] Statistical significance for this study was based on an alpha value of p = 0.05.

RESULTS

Thirty-sic females and 12 males with a mean age of 27.4 ±1.6 years participated (Table 1). The majority of the 48 participants were right-hand dominant females.

For study-aim 1, significant correlations existed between the actual and estimated submaximal efforts for both the RR [r (190) = .69, p <0.001] and NR [r (190) = .62, p<0.001] methods, regardless of test-side or shoulder motion. The mean difference between the actual and estimated efforts was -1.36% and 2.25% for the RR and NR methods, respectively (Table 2). A 2-tailed power analysis (utilizing G-Power) of aim 1 results indicated that a 0.99 power was achieved based on a medium effect size at a .05 alpha level and a sample size of 192 data comparison points (two methods were compared using both sides of 48 participants for both shoulder ER and IR).

For study-aim 2, significant moderate - good correlations were found between the actual and estimated submaximal efforts for the RR method [ER r (94) = .72, p <0.001 and IR r (94) = .67, p <0.001] and the NR method [ER r (94) = .61, p <0.001 and IR r (94) = .63, p <0.001], regardless of test-side. A 2-tailed power analysis (utilizing G-Power) of aim 2 results indicated that a 0.85 power was achieved based on a medium effect size at a .05 alpha level and a sample size of 96 data comparison points (two methods were compared for shoulder ER and IR using both sides of 48 participants). The mean differences between the actual

Table 1. Demographic Information for Participants

Variable	Participants *n* = 48
Age, y, mean (SD)	27.7 (10.9)
Gender	
Male, *n* (%)	12 (25)
Female, *n* (%)	36 (75)
Hand Dominance	
Right, *n* (%)	45 (93.75)
Left, *n* (%)	3 (6.25)
RPE	
Middle, mean	1.35
Post, mean	1.41
% change	4.4%

Note. RPE – rate of perceived exertion on a 0-10 scale; Middle – fatigue between testing series; post–fatigue immediately after both testing series

Table 2. No Reference Versus Reciprocal Reference Methods

	NR method	RR method
Pearson correlation	0.620*	0.691*
Sig. (2-tailed)	.000	.000
Difference between actual and calculated (%)	2.25%	-1.36%
n	192[a]	192[a]

Note. *Correlation is significant <0.001 (2-tailed)
[a] Sample size includes 48 subjects tested into ER and IR for both left and right sides.

Table 3. ER versus IR for both No Reference versus Reciprocal Reference Methods compared to the Ipsilateral Muscle-Force Criterion Method

	External rotation			Internal rotation		
	NR method	RR method	IMFC method[11]	NR method	RR method	IMFC method[11]
Pearson correlation	0.614*	0.717*	0.909	0.628*	0.669*	0.849
Sig. (2-tailed)	.000	.000		.000	.000	
Difference between actual and calculated (%)[a]	3.76%[b]	5.50%[b]		-6.48%[c]	-0.99%[c]	
n	96[d]	96[d]	30	96[d]	96[d]	30

Note. *Correlation is significant <0.001 (2-tailed)
[a] Positive % infers an overestimation of muscle effort; a negative % infers an underestimation of muscle effort
[b] Percent of change for ER, regardless of the method, was 4.63%
[c] Percent of change for IR, regardless of the method, was -3.74%
[d] Sample size includes 48 subjects tested on both left and right sides

and estimated efforts for the NR method IR and ER ranged between 3.76% and -6.48%, and for the RR method, IR and ER ranged between 5.50% and - 0.99% (Table 3). Negative mean difference values in muscle effort inferred an underestimation while positive mean difference values in muscle effort represented an overestimation of the actual muscle force compared to the self-estimated submaximal muscle force levels. RPE scores on the modified Borg scale (0-10 scale) were assessed at the midway point (mean 1.35, SD 0.2) and again at the end of testing (mean 1.42, SD 0.21) of both procedures A and B.

DISCUSSION

This study aimed to determine how accurately a healthy adult could recreate a targeted submaximal (50% of MVIC) isometric force of the shoulder regardless of the test side (left or right) or shoulder motion (IR and ER) when IMFC is not possible. It was determined that both the NR and RR methods may have statistically meaningful accuracies at moderate - good (r > .60) levels among healthy adults for shoulder ER and IR motions bilaterally. To the best of the authors' knowledge, the accuracy of these two methods has yet to be determined for the shoulder.

Instead, what has already been reported in the literature is the reliability in estimating submaximal isometric shoulder IR and ER force efforts using an already performed ipsilateral MVIC effort as a reference criterion. A single study by Maenhout et al.[11] determined a high agreement (ICCs range .84 -.90) for shoulder IR and ER among healthy adults and patients with shoulder tendinopathy. Although these values indicate a higher accuracy level than this study's results, this discrepancy is expected when comparing these methods. Using an ipsilateral MVIC effort as a reference may result in a stronger perception of muscle force and memorization than methods in which a contralateral side MVIC effort (RR method) or having no previous muscle effort reference (NR method) is utilized. Thus, the RR and NR methods may be expected to offer slightly lower accuracy levels, as shown in the current study. However, the advantage of the RR and NR methods is their clinical utility in shoulder patient populations where an ipsilateral MVIC is unsafe or undesirable, especially during the early postoperative stages when only submaximal isometric exercises may be beneficial. In such cases, the RR or NR methods may be clinically meaningful viable options in estimating submaximal shoulder IR and ER isometric efforts with small but expected error levels (-6.48 – 5.50%). In the current study, the error levels for the RR or NR methods were determined by calculating the mean difference between the actual and targeted submaximal (50% of MVIC) performed efforts. These error levels are comparable to those (-5.76 – 6.04%) reported in the Maenhout et al.[11] study. The results indicate that errors in IR consistently had a negative value, indicating an underestimation of the target muscle force. Conversely, ER consistently had errors with a positive value, indicating an overestimation tendency.

Other strengths of the study are worth noting, including its randomized testing protocol, well-standardized testing conditions, and fatigue-level monitoring during testing. The two testing procedures, A and B, helped to randomize

the initial testing side and shoulder motion. This randomization helped to mitigate the effect of dominant versus non-dominant extremity as all participants were tested bilaterally. This randomization and the utilization of a well-standardized blinded testing protocol across all participants may also have resulted in the reported low estimated error of measurements, leading to greater trustworthiness of the current study's results. The estimated high study power ($\geqslant 0.85$) also adds credibility to the findings. Finally, monitoring participants' fatigue levels during and immediately after testing via the Modified Borg RPE scale,[20] a previously validated outcome measure, confirmed the stability of the study's result against any influence from muscle fatigue during testing. The average levels of perceived exertion were minimal during (1.2/10) and after (1.4/10) testing across all participants for both methods. This indicated that the implemented 1- and 5-minute resting periods between testing trials effectively controlled fatigue, as only a 4.4% level of exertion increase was noted by the end of each testing series. No adverse effects were reported by the participants during or after data collection.

LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The results of this study should be interpreted with some caution due to the following limitations. Participants' age and activity levels were not accounted for as independent variables, and therefore, their possible effect on isometric force production and determining the accuracy of the NR and RR methods in estimating target muscle force during shoulder ER and IR was not determined. Activity level prior to testing was not controlled in this study, and the RPE scale was utilized only at the end of the testing series. Thus, the effect of possible increased baseline physical fatigue from performing daily activities prior to testing was not accounted for in this study. Unfortunately, this study's sample consisted predominantly of young adults, and the results of this study cannot be extrapolated in middle age or older adult populations. Future studies should include a broader age spectrum to allow for age-appropriate comparisons. The lack of gender stratification was another weakness worth noting in this study as the majority of participants were females. Our study's gender disproportion (75% female) did not allow for a reliable investigation of gender-based differences in the accuracy of the NR and RR methods. A more balanced gender representation between males and females might be a useful aim of future similar studies. A trend of males over-estimating isometric target forces as compared to females has been reported in a previous study evaluating lower extremity musculature.[13] Finally, this study focused on only estimating submaximal isometric force levels of 50% among healthy participants. Thus, the results of this study may not be fully generalized at different other levels or individuals with shoulder injuries. Future studies should examine these methods' accuracy at different submaximal isometric force levels (e.g., 25% or 75% of MVIC) as well as if accuracy is affected by underlying shoulder pain or pathology.

CONCLUSION

This study sought to determine the accuracy of alternative methods for targeted submaximal (50% of MVIC) isometric contractions of the shoulder when an ipsilateral reference could not be obtained. This study's results indicate that, overall, the RR or NR are adequate methods in estimating submaximal target muscle forces with moderate - good accuracy levels. Both may be viable alternatives for clinicians working with individuals and athletes with shoulder pathology whose ipsilateral upper extremities should not be engaged in maximum isometric efforts during testing or exercises.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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REFERENCES

1. Nejati P, Ghahremaninia A, Naderi F, Gharibzadeh S, Mazaherinezhad A. Treatment of subacromial impingement syndrome: platelet-rich plasma or exercise therapy? A randomized controlled trial. *Orthop J Sports Med*. 2017;5(5):2325967117702366. doi:10.1177/2325967117702366

2. Marlow K, Morris R, Fogarty J, Gretsch Z, Riemann B, Davies G. Torque steadiness measurements of the shoulder in normal subjects and subjects with shoulder pain. Presented at: American Physical Therapy Association-Combined Sections Meeting; 2020; Denver, CO. Accessed April 20, 2023. https://digitalcommons.georgiasouthern.edu/health-kinesiology-facpres/290/

3. Foxen-Craft E, Dahlquist L. Brief submaximal isometric exercise improves cold pressor pain tolerance. *J Behav Med*. 2017;40(5):760-771. doi:10.1007/s10865-017-9842-2

4. van Ark M, Cook JL, Docking SI, et al. Do isometric and isotonic exercise programs reduce pain in athletes with patellar tendinopathy in-season? A randomised clinical trial. *J Sci Med Sport*. 2016;19(9):702-706. doi:10.1016/j.jsams.2015.11.006

5. Rio E, Kidgell D, Purdam C, et al. Isometric exercise induces analgesia and reduces inhibition in patellar tendinopathy. *Br J Sports Med*. 2015;49(19):1277-1283. doi:10.1136/bjsports-2014-094386

6. Khosrojerdi H, Tajabadi A, Amadani M, Akrami R, Tadayonfar M. The effect of isometric exercise on pain severity and muscle strength of patients with lower limb fractures: A randomized clinical trial study. *Med Surg Nurs J*. 2018;7(1). doi:10.5812/msnj.68104

7. Sgroi TA, Cilenti M. Rotator cuff repair: post-operative rehabilitation concepts. *Curr Rev Musculoskelet Med*. 2018;11(1):86-91. doi:10.1007/s12178-018-9462-7

8. MK HB, Dicapo J, Rasiarmos R, Hunter SK. Dose response of isometric contractions on pain perception in healthy adults. *Med Sci Sports Exerc*. 2008;40(11):1880-1889. doi:10.1249/MSS.0b013e31817eeecc

9. Lemley KJ, Drewek B, Hunter SK, MK HB. Pain relief after isometric exercise is not task-dependent in older men and women. *Med Sci Sports Exerc*. 2014;46(1):185-191. doi:10.1249/MSS.0b013e3182a05de8

10. Lewis J, McCreesh K, Roy JS, Ginn K. Rotator cuff tendinopathy: navigating the diagnosis-management conundrum. *J Orthop Sports Phys Ther*. 2015;45(11):923-937. doi:10.2519/jospt.2015.5941

11. Maenhout AG, Palmans T, De Muynck M, De Wilde LF, Cools AM. The impact of rotator cuff tendinopathy on proprioception, measuring force sensation. *J Shoulder Elbow Surg*. 2012;21(8):1080-1086. doi:10.1016/j.jse.2011.07.006

12. Ting LH, Raasch CC, Brown DA, Kautz SA, Zajac FE. Sensorimotor state of the contralateral leg affects ipsilateral muscle coordination of pedaling. *J Neurophysiol*. 1998;80(3):1341-1351. doi:10.1152/jn.1998.80.3.1341

13. Keller JL, Housh TJ, Smith CM, Hill EC, Schmidt RJ, Johnson GO. Sex-related differences in the accuracy of estimating target force using percentages of maximal voluntary isometric contractions vs. ratings of perceived exertion during isometric muscle actions. *J Strength Condit Res*. 2018;32(11):3294-3300. doi:10.1519/JSC.0000000000002210

14. Clifford C, Challoumas D, Paul L, Syme G, Millar NL. Effectiveness of isometric exercise in the management of tendinopathy: a systematic review and meta-analysis of randomised trials. *BMJ Open Sport Exerc Med*. 2020;6(1):e000760. doi:10.1136/bmjsem-2020-000760

15. Lum D, Barbosa TM. Brief Review: Effects of Isometric Strength Training on Strength and Dynamic Performance. *Int J Sports Med*. 2019;40(6):363-375. doi:10.1055/a-0863-4539

16. Sole G, Hamrén J, Milosavljevic S, Nicholson H, Sullivan SJ. Test-Retest Reliability of Isokinetic Knee Extension and Flexion. *Arch Phys Med Rehabil*. 2007;88(5):626-631. doi:10.1016/j.apmr.2007.02.006

17. Toonstra J, Mattacola CG. Test-retest reliability and validity of isometric knee-flexion and-extension measurement using 3 methods of assessing muscle strength. *J Sport Rehabil*. 2013;22(1). doi:10.1123/jsr.2013.TR7

18. Croteau F, Robbins SM, Pearsall D. Hand-held shoulder strength measures correlate with isokinetic dynamometry in elite water polo players. *J Sport Rehabil*. 2021;30(8):1233-1236. doi:10.1123/jsr.2020-0277

19. Karagiannopoulos C, Griech S, Leggin B. Reliability and validity of the ActivForce digital dynamometer in assessing shoulder muscle force across different user experience levels. *Int J Sports Phys Ther*. 17(4):669-676. doi:10.26603/001c.35577

20. Williams N. The Borg rating of perceived exertion (RPE) scale. *Occup Med*. 2017;67(5):404-405. doi:10.1093/occmed/kqx063

21. Portney LG. *Foundations of Clinical Research: Applications to Evidence-Based Practice*. 4th ed. F. A. Davis; 2020.