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# UPPER BODY PUSH AND PULL STRENGTH RATIO IN RECREATIONALLY ACTIVE ADULTS

**Rodney J. Negrete, DPT, CSCS[1]**
**William J. Hanney, DPT, PhD, ATC, CSCS[2]**
**Patrick Pabian, DPT, SCS, OCS, CSCS[2]**
**Morey J. Kolber, PT, PhD, OCS, CSCS[3]**

## ABSTRACT

***Introduction:*** Agonist to antagonist strength data is commonly analyzed due to its association with injury and performance. The purpose of this study was to examine the agonist to antagonist ratio of upper body strength using two simple field tests (timed push up/timed modified pull up) in recreationally active adults and to establish the basis for reference standards.

***Methods:*** One hundred eighty (180) healthy recreationally active adults (111 females and 69 males, aged 18-45 years) performed two tests of upper body strength in random order: 1. Push-ups completed during 3 sets of 15 seconds with a 45 second rest period between each set and 2. Modified pull-ups completed during 3 sets of 15 seconds with a 45 second rest period between each set.

***Results:*** The push-up to modified pull-up ratio for the males was 1.57:1, whereas females demonstrated a ratio of 2.72:1. The results suggest that for our group of healthy recreationally active subjects, the upper body "pushing" musculature is approximately 1.5–2.7 times stronger than the musculature involved for pulling.

***Conclusions:*** In this study, these recreationally active adults displayed greater strength during the timed push-ups than the modified pull-ups. The relationship of these imbalances to one's performance and or injury risk requires further investigation. The reference values, however, may serve the basis for future comparison and prospective investigations. The field tests in this study can be easily implemented by clinicians and an agonist/antagonist ratio can be determined and compared to our findings.

***Keywords:*** Muscle imbalance, strength ratio, upper body strength

***Level of Evidence:*** 2b

[1] Florida Hospital Sports Medicine and Rehabilitation, Celebration, FL, USA
[2] University of Central Florida, Orlando, FL, USA
[3] Nova Southeastern University, Fort Lauderdale, FL, USA

**CORRESPONDING AUTHOR**
Rodney Negrete DPT, CSCS
Florida Hospital Celebration Health
Sports Medicine and Rehabilitation
400 Celebration Place
Celebration, FL 34747
Phone# 407-303-4003
Fax# 407-303-4303
E-mail: rodney.negrete@flhosp.org

## INTRODUCTION

An important goal in the rehabilitation process is to achieve symmetrical strength and mobility of involved body segments (contralateral and agonist/antagonist). When assessing the balance between agonist and antagonist muscle actions a strength ratio can be an important measure in order to determine deficits and design the plan of care for return to function. There are many methods of evaluating muscle performance ranging from isokinetic dynamometry to manual muscle testing and hand held dynamometry. For many clinicians certain field tests (ie. push-up, pull-up, sit-up) using minimal to no equipment offer an effective low cost method to assess strength and power for their recreationally active patients. When evaluating the scores of these tests the clinician may refer to normative data to determine if a patient's muscle performance is within an acceptable range as compared to a peer group. Achieving normative milestones is often a criterion used for determining discharge and readiness for return to sport for an athlete.

Muscle imbalance has been described as a failure of the agonist to antagonist relationship which can have an effect upon the joints they cross.[1] These muscular imbalances may lead to changes in arthrokinematics and movement patterns, which can ultimately cause structural damage.[2] Deficits in flexibility or strength in an agonistic muscle must be compensated for by antagonist or synergistic muscles and could lead to dysfunction and or pathology.[2] Some authors have suggested that muscular imbalance caused from over training one muscle group will lead to postural deterioration, and shoulder pathology.[3-5] For example, an individual may over train chest muscles for esthetic purposes and neglect sufficient training of the back musculature during a typical exercise routine. This could potentially cause an imbalance leading to a rounded shoulder posture, and pathology such as subacromial impingement syndrome.[4-6]

Many sports require the athlete to use their upper body to perform a throwing motion (baseball, softball, handball) or use a racquet (tennis, racquetball) in order to propel an object. Sports like football, wrestling, martial arts, or gymnastics involve pressing and pulling with the upper limbs against an opponent or apparatus. Imbalances in strength between opposing muscle groups may predispose an athlete who participates in a certain sport to injury. Kolber et al[4] reported strength ratios between a group of recreational weight training subjects compared with a control group of non-weight trainers. Their results revealed agonist/antagonist muscle imbalances which the authors speculated may predispose recreational weight training participants to shoulder disorders.[4] The authors also postulated that common weight-training programs are frequently biased toward large muscle groups such as the pectorals and deltoids while neglecting muscles responsible for stabilization, such as the shoulder external rotators and lower trapezius.[4] Several researchers suggest certain balances in muscle performance between upper body agonist and antagonist should exist to enhance performance and decrease the potential for injury.[7-14] Wang and Cochrane[15] reported the antagonists eccentric force of the shoulder external rotators should be as strong as the agonists' concentric force of the shoulder internal rotators during overhead sports activity.[15] Their study concluded that rotator cuff muscle imbalance plays an important role in shoulder injuries among elite level volleyball players. Cools et al[16] evaluated scapular muscle performance using a Biodex isokinetic dynamometer. They concluded scapular muscle performance in elite gymnasts demonstrated altered muscular balance characterized by increased protraction as compared to retraction strength when compared to nonathletic adolescents.[16]

Given the aforementioned research, it would be clinically useful to have a means to assess muscle imbalances of the upper extremity due to their predilection for increasing injury risk. However, without normative ratios, researchers and clinicians have no way of defining an imbalance and setting objective goals to address them. Objective and quantifiable functional testing may be used as a baseline preseason screening, or a comparative value to evaluate the efficacy of a particular rehabilitation/training program. If strength ratios are lower than normative values, the patient may not be considered fully rehabilitated from a muscular standpoint. Therefore, the purpose of this research study was to investigate whether two simple field tests (timed push-up/timed modified pull-up) could be used to determine a normative ratio between these opposing muscle actions of the upper body for males and females. Clinicians could utilize this data during the rehabilitation process to assist with identifying impairments and for return to activity decisions.

## METHODS

Two tests of upper body strength were performed in a group of asymptomatic, healthy, recreationally active adults in random order:

1. Push-ups for 3 sets of maximum repetitions in 15 seconds with a 45 second rest period between each set.
2. Modified pull-ups for 3 sets of maximum repetitions in 15 seconds with a 45 second rest period between each set.

These tests have been previously described and studied by Negrete et al, with ICC (3,K) reliability values of 0.96 for the push-up and 0.99 for the modified pull-up.[17-18] Examiners performed testing procedures as described in these previous studies in an attempt to maintain consistency with the methods used to obtain the reported reliability values.

### Instruments

Instruments used in this study included a digital stop watch (NuLine Products, Carlsbad, CA), a Smith machine (Prostar®, Kansas City, MO), and an Upper Body Ergometer (Biodex Inc. Shirley, NY).

### Subjects

One hundred and eighty (180) adults (Females n = 111, and Males n = 69) between the ages of 18 and 45 years (Females mean age = 24.87 years and Males mean age = 23.36) volunteered to participate in this multi-center study. The Institutional Review Boards from each facility approved the methods and procedures. Informed consent was obtained from the subjects prior to testing in a semi-private testing location. Each subject completed a health history form and was excluded if they had a history of an upper extremity orthopedic disorder within the past year, were unable to complete the tests as prescribed, or unable to read, write and communicate in English.

### Procedures

Upon obtaining consent subjects were brought to a climate controlled indoor testing area. Subjects wore loose comfortable clothing which would not encumber physical movements. All participants watched a short video demonstrating the technique for each of the tests to be evaluated. After watching the video, participants began a five-minute warm-up of self-selected moderate intensity, on a seated Upper Body Ergometer. This was followed by three minutes of upper body stretching including; a corner stretch for the anterior shoulder girdle, a shoulder horizontal adduction stretch for the posterior shoulder girdle, and a trunk side-bending overhead reach for the trunk and inferior shoulder girdle. Each subject was given a random ordered data sheet to take to each testing station for recording results of the three maximal effort attempts for each test. The mean of the three attempts was calculated as the final score and entered for statistical analysis.

### The Push-up Test

The push-up test was done in either the standard position (males) on hands and toes or in the modified position (females) in which the subjects assumed the hands and knees position (Figures 1 and 2). Participants were positioned with hands shoulder width apart and the trunk held in a rigid straight position. Push-ups were performed as quickly as possible for the 15-second duration. Participants began the test with their elbows fully extended. Upon descending the body toward the ground, participants flexed their elbows until the upper arm was parallel to the testing surface. The participant was instructed to limit head and trunk motion. A warm-up 15-second sub-maximal trial was completed prior to three maximal trials.

**Figure 1.** *Standard Push Up.*

**Figure 2.** *Modified Push Up Position for Female Participants.*

**Figure 3.** *Modified Pull Up.*

The maximal effort trials were performed for 15 seconds each followed by 45 seconds of rest. Repetitions were not counted if they deviated from the proper trunk position. The average number of push-ups completed for the three 15 second bouts was recorded and entered for data analysis. This test has been previously studied with inter-tester test-retest reliability of ICC = 0.96 (3,K) using average values.[17]

### The Modified Pull-Up Test

The modified pull-up was performed using a secure adjustable height bar for gripping and pulling, and a bench was used to support the subject's feet or lower legs. Participants assumed a supine position with their heels on a bench, and using an overhand grip to grasp the bar. The bar was positioned approximately 8 cm out of arms reach when the participant was supine on the floor. Males performed the pull-up with their legs supported at their heels. Females had their lower legs supported just below the knees. When performing the modified pull-up participants started by hanging from the bar with arms fully extended and pulled up high enough so the upper arms were parallel to the floor. The participants then lowered themselves back to the elbows fully extended position (Figure 3). The participants were instructed to continuously keep a straight trunk posture and to limit trunk and head motion. A warm-up trial was completed prior to the 3 maximal effort trials. Each participant completed as many pull-ups as possible in 15 seconds during the 3 maximal trials. Repetitions were not counted if they deviated from the proper trunk position. A 45 second rest period was given between each maximal test bout.

**Table 1.** *Descriptive statistics for Males ($n = 69$).*

| Variable | Mean (range) | Std. Deviation |
|---|---|---|
| Age | 23.36 (18.00-38.00) | 4.66 |
| Height (cm) | 181.33 (154.94-200.66) | 8.03 |
| Mass (kg) | 81.92 (56.70-120.20) | 10.82 |
| PU (mean repetitions) | 18.99 (12.33-25.33) | 3.66 |
| MPU(mean repetitions) | 12.12 (2.67-21.67) | 3.80 |
| RATIO PU/MPU 1.57:1 | | |

PU= push-up, MPU= modified pull-up

The average number of modified pull-ups completed for the 3 maximal effort 15 second bouts was recorded and entered for data analysis. This test has been previously studied with a inter-tester test-retest reliability of ICC = 0.99 ( 3,K) using average values.[17]

## STATISTICAL METHODS

The strength ratio was calculated by dividing the mean score of the timed push-up by the mean score of the timed pull-up. Descriptive statistics for all variables were tabulated and are presented in Tables 1 and 2.

## RESULTS

All 180 subjects successfully completed the testing procedures. Descriptive variables including the

**Table 2.** *Descriptive statistics for Females (n = 111).*

| Variable | Mean (range) | Std. Deviation |
|---|---|---|
| **Age** | 24.87 (18.00-45.00) | 5.65 |
| **Height (cm)** | 166.15 (144.78-193.04) | 7.43 |
| **Mass (kg)** | 63.28 (45.36-102.97) | 11.17 |
| **PU (mean repetitions)** | 12.73 (4.33-20.33) | 3.18 |
| **MPU (mean repetitions)** | 4.68 (0.00-13.33) | 3.15 |
| **RATIO PU/MPU 2.72:1** | | |

PU= push-up, MPU= modified pull-up.

mean and standard deviations (SD) for the two tests were calculated. Males performed an average of 18.99 push-ups in 15 seconds with a SD of 3.66 and an average of 12.12 modified pull-ups with a SD of 3.80. Females performed an average of 12.73 push-ups in 15 seconds with a SD of 3.18 and an average of 4.68 modified pull-ups with a SD of 3.15.

The results from the descriptive statistics (mean values) were used to calculate the agonist/antagonist ratio for each group. The push-up to modified pull-up ratio for the male subjects was 1.57:1. The females demonstrated a ratio of 2.72:1 for the pushing to pulling musculature. Our results suggest the upper body musculature used for pushing are approximately 1.5–2.7 times stronger than the musculature involved for pulling for this group of normal recreationally active subjects.

## DISCUSSION

The purpose of this study was to identify preliminary normative values for upper body pushing and pulling musculature in recreationally active males and females. The physical capacity norms presented in Tables 1 and 2 may be used for comparison with a general population of healthy, physically active adults within a similar age category. This normative data may not be generalizable to specific populations such as overhead athletes, elite athletes, or those performing compulsory pushing or pulling as part of their occupation. In clinical practice and in sports medicine settings these tests can be used as an assessment throughout the course of treatment to quantify changes in muscular balance. As an outcome measure the test scores can be used by comparing the patients/clients scores with the presented normative data in order to assess which muscle groups exhibit dysfunction. When the goal is to return to a physically active life style, the comparison to normal healthy physically active values is most appropriate in lieu of pre-injury values; hence the need for normative data.

Baker and Newton[7] theorized that a balance in strength should exist between opposing muscles or muscle actions to help avoid injury and enhance performance. Based on this theory, they evaluated the ability of two field tests to assess strength balances between contrasting muscle actions of the shoulder girdle and concluded that the ratio between upper body pressing and upper body pulling should be approximately 100% if the two different muscle groups were equally addressed in training. Using 42 highly skilled athletes for test subjects, Baker and Newton[7] had each subject perform a one repetition maximum (1RM) bench press for assessing the strength of upper body pressing and also a vertical body weight pull-up for assessing the strength of upper body pulling. The strength ratio was found to be 97.7% and the correlation, 0.81 for the 2 tests.[7] In the current study, the two field tests utilized were the timed push-up and modified pull-up. These were performed in order to find the ratio between the upper body pushing and pulling musculature. The current study had markedly different results than the Baker and Newton study. The ratios calculated between the push-up and modified pull-up ranged between 1.57 and 2.72:1. The muscles involved in the pulling movement were 64% and 37% of the pushing musculature for the males and females, respectively. One explanation for this may lie in the manner in which the tests were performed. The modification used in the push-up exercise changes the lever arm as the distance pushing is from the knees to the shoulder. The modified pull-up position used in this study unweights the lower extremity from the knee down, however doesn't shorten the lever arm thus the difficulty of the pull-up may not be mitigated to the same degree as the push up.

Differences in the results between these two studies could be related to the fitness level of the subjects and the different test procedures. The participants in the Baker and Newton study were highly skilled male semiprofessional and professional athletes, and the current project included male and female subjects who were recreationally active. The study by Baker and Newton[7] used the 1RM bench press and a vertical body weight pull-up while the current study used a standard body weight push-up and the horizontal body weight modified pull-up. These tests are somewhat similar in that they assess muscle performance of pushing and pulling actions, but it may be difficult to make a direct comparison due to the varied body positions and the potential for different muscles to be recruted during these varied tasks.

Normative values for concentric isokinetic strength of the shoulder musculature have been reported.[9,10] Ivey et al[9] tested normal volunteers and found shoulder internal rotation (IR) strength to be greater than external rotation (ER) by a ratio of 3:2 for both fast and slow isokinetic speeds. Shoulder extension strength was greater than flexion by a ratio of 5:4 at both test speeds. Lastly, shoulder adduction strength was greater than abduction by a ratio of 2:1. They went on to say overall, adduction strength was the greatest followed by extension, flexion, abduction, IR, and ER strength. In 2003, Ellenbecker and Reotert[10] studied isokinetic glenohumeral IR and ER strength ratios in 147 elite junior tennis players aged 12 to 21. They found the males ER/IR strength ratios ranged between 64-72% for the dominant arm, while female ER/IR strength ratios for the dominant arm ranged between 61-76%. The non-dominant strength ratios were slightly higher for both genders.[10]

Negrete et al[17,18] reported that the modified pull up and push up tests may be beneficial assessment tools for throwing athletes given their predictive validity related to throwing distance as compared to two other functional tests. Analysis revealed that the modified pull-up test was the best predictor of a softball throw for distance as it had the highest correlation with the distance throw ($r = 0.70$), followed closely by the push up test ($r = 0.63$). Performance on both the modified pull up and the push up test demonstrated statistically significant correlations ($p = 0.001$) with performance on the softball throw.

Limitations of the current study include a narrow age range. Also, while those considered recreationally active were included this may encompass a wide variety of activity levels. While every attempt was made to ensure strict adherence to the testing protocol minor deviations in postures during the tests may have occurred. Finally, a causal relationship cannot be established with the current study design. Future studies may compare recreationally active individuals with those that have a given upper extremity injury.

## CONCLUSION

Clinicians can easily implement the field tests used in this study and an agonist/antagonist ratio can be determined and compared to the normative data provided. The results of this study can only be used as normative data for those recreationally active males and females aged 18 to 45, for comparison with patient or client test scores. These tests are easy to perform and require minimal space and equipment, thus could be performed in most rehabilitation settings. The ratios measured in this study describe normative data that can be used as a goal by clinicians, researchers, and strength coaches in developing rehabilitation and preventative conditioning programs for recreationally active individuals.

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