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Original Scientific Research Study

RELIABILITY OF PULL UP & DIP MAXIMAL STRENGTH TESTS

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BLUF

Upper extremity Pull Up and Dip maximal strength tests demonstrate high reliability and a smallest worthwhile change of 3% in relative Pull Up strength and 4% in relative Dip strength; respectively.

ABSTRACT

Upper extremity (UE) pressing and pulling strength are vital for success in many sports. Therefore, testing UE strength is considered an integral component of a complete athletic testing profile. Although open kinetic chain (OKC) UE strength tests and associated protocols are common, closed kinetic chain (CKC) UE tests are less so. Hence it is worthwhile to examine the utility of the Pull Up and Dip as CKC measures of UE maximal strength. A group of 15 adult males of mixed level (recreational to international) athletes performed a 1 RM maximum Pull Up and Dip test on 2 occasions separated by 7 days. Distinct anatomical markers and movement standards were identified to assist with the evaluation of the subjects' performance. From the trials, the test-retest reliability, smallest worthwhile change and ratio between the Pull Up and Dip were examined. These Pull Up and Dips were measured in both absolute (105.9 ± 17.78, and 116.89 ± 23.48, respectively) and relative to body weight (1.43 ± 0.15, and 1.59 ± 0.23, respectively). Both tests demonstrate high reliability (ICC 0.96-0.99) and determined a smallest worthwhile change of 3% in relative Pull Up strength and 4% in relative Dip strength; respectively. When taking into account relative strength, the upper body musculature used for the Dip movement is 1.11 times stronger than the musculature involved in Pull Up. Strength and conditioning coaches can use these protocols to examine possible differences between higher and lower performers and correlations with performance measures in a sport.

Key Words - Pull up, dip, structural balance, relative strength, testing.

INTRODUCTION

Evaluation of upper extremity (UE) strength has long been considered an integral component of a complete testing profile for a large proportion of sports (3,4,6,24). Many sports require athletes to be able to use the UE to apply large forces in both pressing and pulling actions. Certain sports demand sufficient strength to press and pull large external resistances in an open kinetic chain (OKC). An example of an UE OKC in sports is a shot putter putting (throwing) the shot or wrestler throwing their opponent to the floor. Other sports entail athletes to possess significant strength in a closed kinetic chain (CKC) to move their own body around an implement or fixation point. Examples of this include a gymnast performing a manoeuvre on the high bar or a freestyle swimmer stroking through water. Therefore, both OKC and CKC UE pressing and pulling strength are vital for success in many sports; including endurance sports (1,15,16,32,33). Significant differences in UE strength in either movement could also limit the success of the athlete in these sports or could intensify the chances of injuries, such as muscle strains or tendon impingement (e.g., bicep or rotator cuff)(5, 20). As such, it would seem advisable for strength and conditioning coaches and sports medicine professionals to assess UE strength when appropriate. It may also be appropriate to assess UE strength in the kinetic chain that is predominant in the athlete or athletes' chosen sport.

In strength and conditioning practice, OKC exercises can be defined as a combination of successively arranged joints in which the terminal segment can move freely (e.g. where an athlete applies force to is allowed to move) (13). Exercise examples of this include a knee extension, hamstring curl or DB bicep curl. Perhaps the most common UE maximal strength test is the Barbell Bench Press (2,3,5,7,9,12,21,23,26,27,29,35). This test involves lowering a barbell resistance to the chest and then pressing the barbell back to arm's length. Although the bench press is very well documented in research, it is an OKC exercise.

CKC exercises are the opposite of OKC exercises in that the terminal segment cannot move freely or is restrained (e.g. where an athlete applies force to does not move) (13). Examples of this in strength and conditioning include a squat, push up or glut-ham raise. A CKC strength exercise and assessment may possess greater context validity for some sports. For example in swimming and paddling actions (surfboard, paddleboard) the athlete 'pulls' and then 'pushes' their body over the water surface, e.g. their distal segment is fixed. This makes it a CKC activity (13,17). As such, CKC strength exercises may be better suited for athletes in these sports for both assessment and training purposes (8).

The most familiar CKC pressing exercise for testing maximal strength may be the parallel-bar Dip. The Dip involves an athlete supporting themselves on the parallel bars with extended arms and then lowering their body with elbow flexion and shoulder extension to a specified point before pressing their body and any external load back to the starting support position. Although the Dip is used extensively by strength and conditioning professionals in the training of athletes, results for strength in the Dip seem to be normally expressed as the maximum number of repetitions that can be performed with body weight (10). As athletes in certain sports can perform a considerable number of repetitions in the Dip with bodyweight, these types of tests may become tests of strength-endurance rather than maximum strength. As such, the authors could not find any research on the reliability or protocols for use of the Dip as a maximal strength test.

In regards to UE pulling, pronated Pull Ups are one of the most commonly used UE exercises to develop and test UE pulling strength (6,11,14,20,22,30). Similar to the Dip, the Pull Up is performed in a CKC. The Pull Up involves an athlete hanging off a bar in a pronated grip (supinated for chin ups) and pulling a portion of their body up and over the height of the bar (e.g. they might have to place their chin over the bar or even more demanding, touch their chest to the bar). Likewise for the Dip, results for upper body pulling strength in the Pull Up are often stated as the maximum number of repetitions that can be performed with body weight (25,34) and as such become tests of strength-endurance rather than maximum strength(10,26).

The investigators were unable to locate any research involving the assessment of maximal strength (e.g. 1RM) with the Dip exercise. However, research using the Pull Up as an assessment of maximum strength has been performed with an array of protocols (5,20,30). In order to promote reliability, there are important considerations to standardize. For example, differences in testing protocols include whether the test begins from a hanging position or from a flexed position (i.e. beginning with an eccentric action or a concentric action) (6,31). Additionally, whether a controlled tempo or hold in the lengthened or flexed position was enforced, and different descriptors to determine the achievement of the flexed position. To the investigators' knowledge, no research has been published which examines these factors, especially tempo of execution in either the Pull Up or Dip exercises.

Simple but consistent protocols aid strength and conditioning specialists and researchers as this leads to more reliable results and therefore, greater sensitivity to detecting change in athletic populations. As such, the purpose of this study was to develop and evaluate the reliability of a simple, but strictly controlled CKC UE 1RM strength protocol for pulling and pressing strength (Pull Up & Dip). We also aimed to investigate whether assessing absolute external load and/or relative to bodyweight strength in the Pull Up and Dip were reliable. Alongside this, we determined the Smallest Worthwhile Change (SWC) value for these tests and to note the interaction between the two different (pushing vs. pulling) strength qualities by comparing results within-subjects.

METHODS

Approach to the Problem

To assess the reliability of two UE maximal strength tests, this study employed a within subjects repeated measures analysis of a group of adult male athletes who performed 1 RM maximum Pull Up and Dips on 2 occasions separated by 7 days.

Subjects

Fifteen male athletes (27.8 ± 6.5 years, 174.2 ± 10.1cm, 73.9 ± 9.8kg) participated in this study. Subjects were familiar with Pull Up and Dip exercises, surfers or swimmers of varied ability levels (recreational to international competitors) and mixed resistance training experience (novice to greater than 10 years' experience). Subjects were excluded if they had a recent history of UE orthopaedic disorders or were unable to complete the tests as prescribed. All the subjects received a clear explanation of the study. This included risks and benefits of participation. All subjects, or their parent or guardian, provided written informed consent. The study procedures were approved by the Human Ethics Committee at Edith Cowan University, and procedures conformed to the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Procedures

Subjects were asked to refrain from resistance training 48 hours prior to both tests. To begin testing, subjects were weighed and then performed a generalized warm up consisting of callisthenic and dynamic stretching exercises, lasting 10 minutes. After the warm up, athletes commenced the Pull Up testing procedure first. This involved 5 repetitions with bodyweight followed by 4, 3, 2 and 1 repetitions with an increasingly greater external load by suspending certified plate weights from a standard lifting belt worn around the waist for every decrease in repetitions. After these repetitions, the athletes performed only single repetitions with additional external load attached to their waists with 2 to 3 minutes of rest provided between repetitions. Once a failed lift occurred as defined by our movement and tempo standards the successful weight lifted in the previous lift was recorded as the subject's 1RM. External load was increased by 1.25 to 10kg between sets by adding calibrated weight plates to a weight belt and chain secured around the waist. The increase in load depended on the strength levels of the subjects, speed of concentric movement and relative body mass. The subject's results were determined by adding the subject's body weight to the external load lifted (absolute load 1RM) and then dividing that total load by bodyweight (relative 1RM).

This testing procedure was then repeated in the exact same manner for the 1RM Dip test. Subjects then returned 7 days after the initial testing session to repeat this testing sequence of 1RM Pull Up followed by 1RM Dip.

Distinct anatomical markers and movement standards were identified to assist with the evaluation of the subjects' performance. For the Pull Up, the testing protocol entailed subjects holding a fully flexed shoulder with extended arms for 2s (to eliminate any slight jumping off the floor, stretch shortening cycle activity e.g. kipping, or a lack of shoulder flexion) before beginning their pulling action (see Figure. 1 - Pull up start position). To ensure a successful repetition, the subjects' proximal inferior aspect of the mandible (see Figure 2 - Proximal inferior aspect of mandible) must have passed the horizontal plane of the Pull Up bar (e.g. the technique cue used was to "beach the jaw on the bar") (see Figure 3 - End position of pull up). Subjects were then required to return to the initial position taking 4s to complete the repetition. Subjects were not allowed to swing, kip, or repeatedly bounce out of the bottom ROM to generate elastic energy during the Pull Up. However they were allowed to flex their hip (e.g. raise their knees) to complete a successful repetition as long as the repetition met the range of motion and tempo standards.

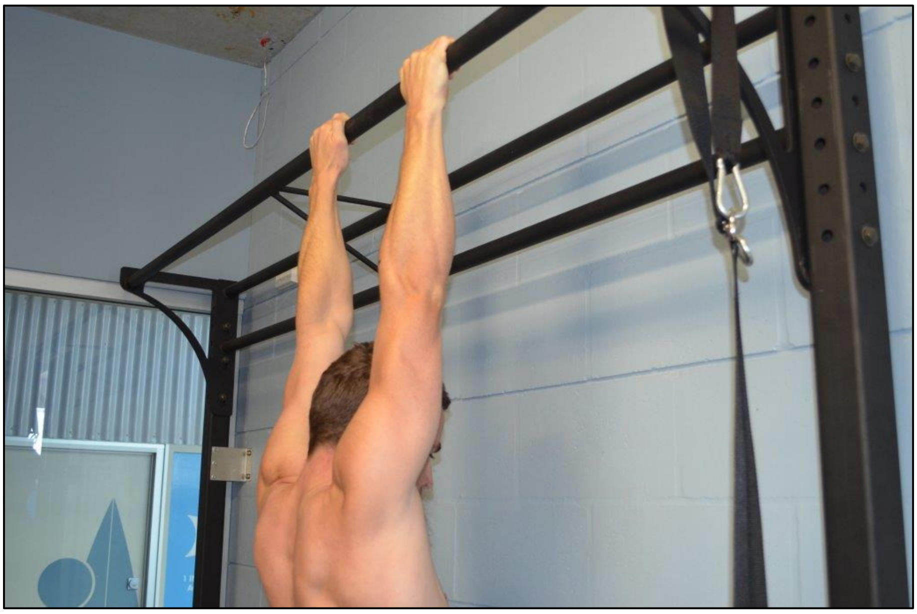

Figure 1 - Pull up start position.

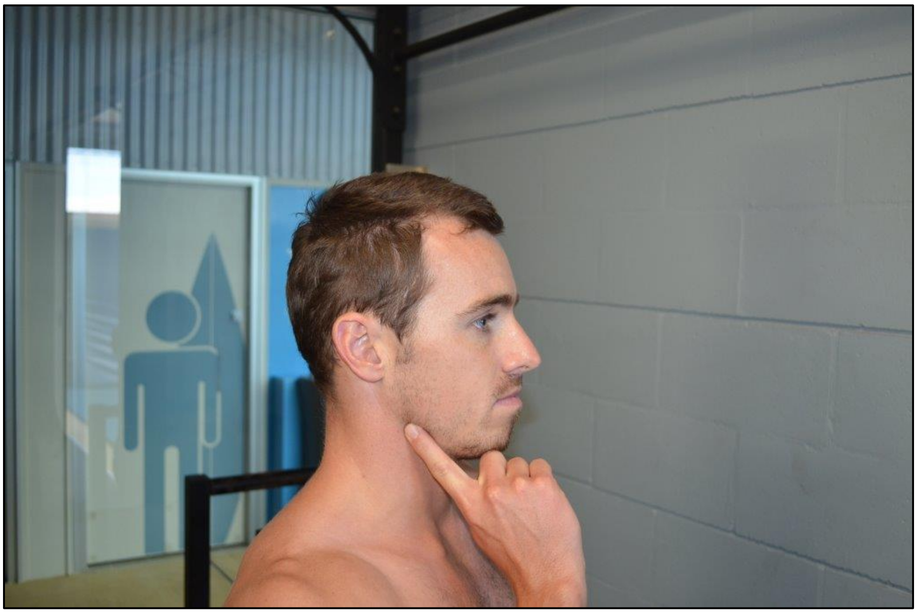

Figure 2 - Proximal inferior aspect of mandible.

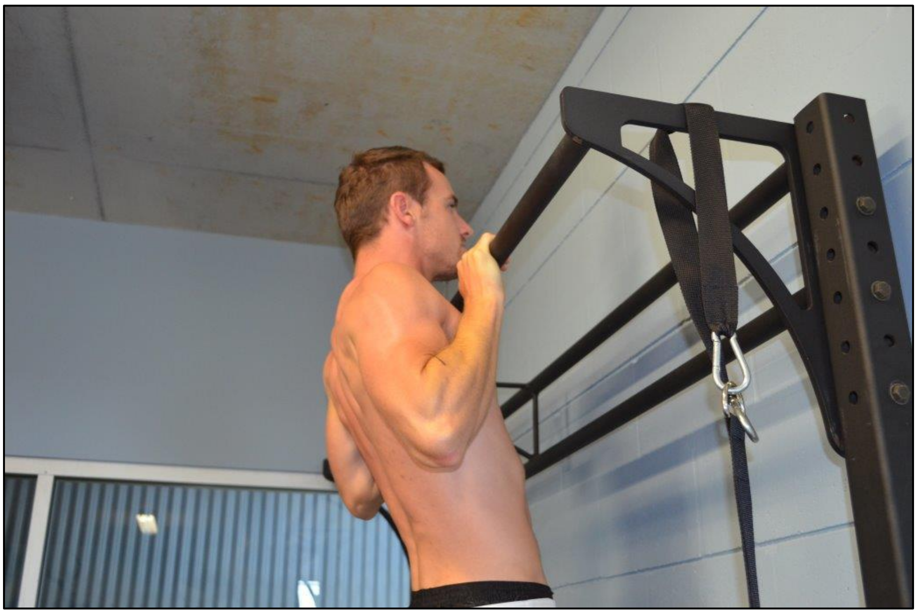

Figure 3 - End position of pull up.

For the Dip, the testing protocol required the subjects to begin supported on the parallel bars in a fully extended elbow position (see Figure 4. Dip Start Position). From this position, subjects lowered themselves over 4 seconds to a “depth” point where the bicep made contact with the forearm greater than the subject’s combined 2^{nd} and 3^{rd} digit width from distal biceps tendon (see Figure 5. Depth Marking On Forearm, and Figure 6. Bottom Dip Position). This “depth” point was marked on each subject’s forearm. To complete the successful repetition, subjects were then required to return to the initial support position. As with the Pull Up, subjects were not allowed to swing, kip, or repeatedly bounce out of the bottom ROM to generate elastic energy during the repetition. Again, they were allowed to flex their hip (e.g. raise their knees) to complete a successful repetition as long as the repetition met the range of motion and tempo standards.

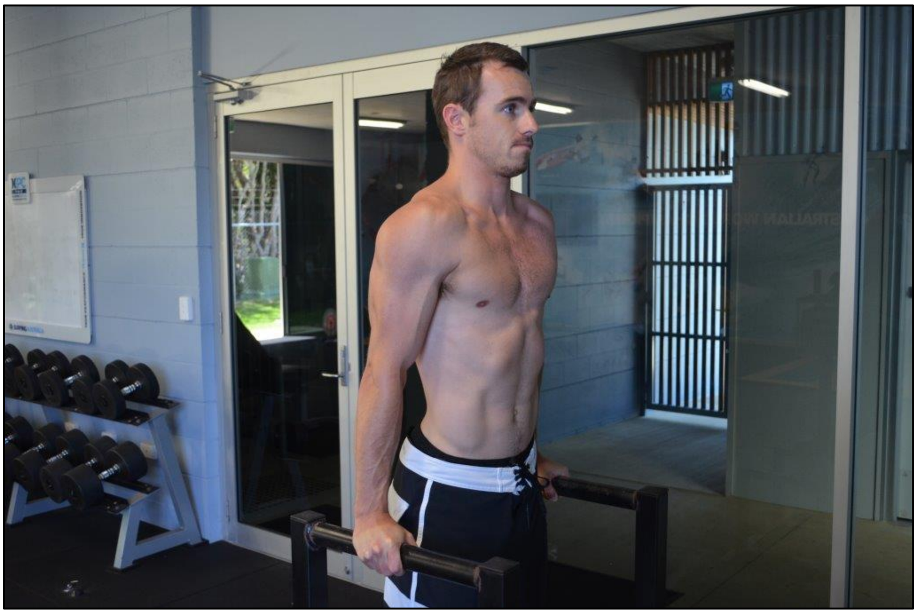

Figure 4 - Dip start position.

Figure 5 - Depth marking on forearm.

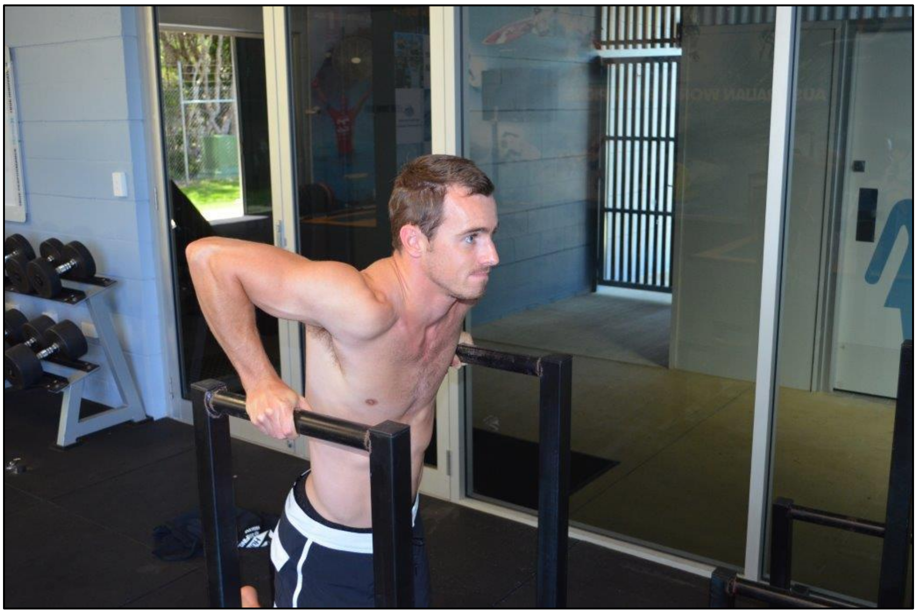

Figure 6 - Bottom dip position.

The following video illustrates the range of motion and speed of execution of the two tests –

https://www.youtube.com/watch?v=M1GFJBLnlRo&list=UUxhEOVR_h-PljqTc9LsR0yQ

Statistical Analyses
Reliability data was calculated by determining the Intra-Class Correlation co-efficient (ICC), Typical Error of Measurement, and Percentage Typical Error of Measurement (as co-variance, %TEM). Smallest Worthwhile Change (SWC) data was also calculated from the trial data as follows: 0.2 x Between Subjects Standard Deviation. A ratio between Pull Up and Dip to assess symmetry of pushing and pulling musculature was also generated from the mean values of Pull Up and Dip performance across trials.

RESULTS

All subjects successfully completed the testing procedures. The descriptive analysis, including means and ± SDs for the group, along with the ICC, TE and % Co-Variance, and SWC for the Pull Up and Dip are presented in Table 1. The mean absolute and relative Pull Up to Dip ratio for the cohort was 0.90.

Table 1 - Reliability of measures of Intra-Class Correlation Co-Efficient (ICC), Typical Error of measurement (TE), % Co-Variance (%CV) and Smallest Worthwhile Change (SWC) of absolute external load 1RM pull up, absolute external load 1RM dip, relative 1RM pull up and relative 1RM dip test in male athletes. 90% confidence intervals in parentheses.

	Trial 1	Trial 2	ICC	TE	%CV	SWC
Absolute Load 1RM Pull Up (kg)	105.48 ± 17.59	105.92 ± 17.97	0.99 (0.96-0.99)	2.11 (1.55-3.33)	2.22 (1.6-3.6)	3.52
Absolute Load 1RM Dip (kg)	116.75 ± 24.05	116.93 ± 22.85	0.99 (0.96-0.99)	2.72 (1.99-4.29)	2.41 (1.8-3.9)	4.81
Relative 1RM Pull Up	1.43 ± 0.15	1.43 ± 0.15	0.96 (0.89-0.99)	0.03 (0.02-0.05)	2.22 (1.6-3.6)	0.03
Relative 1RM Dip	1.58 ± 0.22	1.59 ± 0.23	0.97 (0.90-0.99)	0.04 (0.03-0.07)	2.41 (1.8-3.9)	0.04

DISCUSSION

The purpose of this investigation was to examine the reliability of and interaction between two closed kinetic chain UE strength tests the Pull Up and Dip. Both tests, when performed with the movement and tempo standards utilized in this study, demonstrate high reliability in both absolute external load or relative to body mass terms. This is valuable because the ability to reliably assess strength qualities in these movements can give insight for the strength and conditioning or sports medicine professional for athlete selection, rehabilitation/return to sport and training determination. It also gives athletes and testers' confidence that observed changes are due to training or de-training induced changes, and not due to inconsistent methodology.

The information obtained in this study allows the strength and conditioning specialist to assess the balance of the agonist and antagonist musculature in two CKC tests that appear to be highly reliable and may have high context validity to a number of different sports. Specificity principles relating to the kinetic chain are especially important when developing an UE exercise program in rehabilitation and athletic training. If an athlete is involved in a predominately CKC sport (e.g. swimming, kayaking, gymnastics), it seems preferable to test the athlete with CKC exercises over OKC exercises (e.g. Lat Pull-Down, Barbell Bench Press). It may also be preferable to emphasize these exercises in the rehabilitation and training of individual's functional status (e.g. activities of daily living and/or sport require CKC movements) (17-19, 28).

The 1.11 ratio between Dip and Up Pull Up strength relative to body weight becomes a valuable resource to add to the structural balance figures already proposed in previous work (5, 20) which aid in prevention and rehabilitation of injuries and identification of potential limiting factors in performance. These results suggest for the cohort involved in this study, the relative strength of the upper body musculature used for the Dip movement is 1.11 times stronger than the musculature involved in pulling. Future research endeavours with specific populations (elite athletes, other sports, injured athletes) are warranted to assess the influence on this ratio.

Practitioners can also now distinguish when a worthwhile change has been observed in their athlete's performance in these two exercises (e.g. a 3% in relative Pull Up strength or 4% in relative Dip strength; respectively) whether in retesting or in training. These calculations can play an important role in goal setting for both the sports medicine and strength and conditioning professional.

By applying these tests, the strength and conditioning or sports medicine professional has a useful tool that can be incorporated into an athletic training or rehabilitation program to assess the efficacy of the training, aid in the progression of rehabilitation, and help determine readiness to return to sport. Another advantage of these tests is that they can give reliable assessments of UE strength maximums without need for extensive equipment (e.g. isokinetic devices) or staff, providing straightforward and practical assessment that can be conducted with limited resources.

The purpose of this paper was to investigate the reliability of tempo controlled Pull Ups and Dips which do not appear to have been examined previously. Strength and conditioning professionals are cautioned to perform analysis in their sports to determine whether these tests provide application within individual sporting context. This could be accomplished by discriminate analysis between higher and lower performers and correlational analysis between these tests and performance measures within a sport.

PRACTICAL APPLICATIONS

A combination of UE tests seem to be superior to a single test for evaluating upper body strength, to ensure that both pressing and pulling strength is evaluated, and to evaluate the ratio of strength between the two. Practitioners should decide whether these tests have relevance and/or context validity to their sport or populations based on biomechanical factors that include (but are not limited to) speed of contraction, open vs. closed kinetic chain and angle of force production. Possible limiting factors in performance and potential injury risk may be derived from the comparison of these two tests. Rehabilitation and return to sport from UE injury can also be monitored by performance in the Pull Up and Dip.

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