

Original Research

Baseline Functional Testing in Competitive Youth Swimmers

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Background

Shoulder injuries are very prevalent in youth adolescent swimmers. As a result, there has been increasing focus on testing athletes post injury using functional testing to assess whether the athlete is ready to return to sports activity. Specifically, the closed kinetic chain upper extremity stability test (CKCUEST) and two versions of a prone ball drop test with elbow straight and elbow bent have been suggested. In order for these functional tests to be used for return to activity decision making normative values for different populations must first be established.

Hypothesis/Purpose

The purpose of this study was to establish normative values for the CKCUEST and prone ball drop tests in the elbow extended and elbow bent positions in a population of uninjured competitive youth swimmers

Study Design

Observational Cross-Sectional Study

Methods

Fifty-three swimmers without active shoulder pain were recruited from a single competitive swimming club. The CKCUEST as well as prone ball drop at 90 degrees of abduction with elbow straight and with elbow bent at 90 degrees were performed in a randomized order. All subjects were tested prior to the beginning of competition for the year. Participants were then categorized into subgroups by sex and age(10-14 or 15-18). Descriptive statistics were analyzed for all tests and groups were compared using two sample t-tests.

Results

Among this youth population CKCUEST demonstrated mean of 17.8 ± 3.5 touches with increased ball drop with elbow extended on the dominant vs non-dominant arm (31.8 ± 12.1 vs 28.6 ± 11.0 reps) as well as with elbow bent to 90 degrees (43.7 ± 13.6 vs 39.6 ± 15.4 reps). Additionally, there were differences in repetitions when groups were split by age with the 15-18 year old group demonstrating significant ($p < 0.05$) increase vs the younger group across all testing.

Conclusion

Baseline values in an uninjured competitive youth swimming population are provided for three commonly described upper extremity functional tests.

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Level of Evidence

Level 3

INTRODUCTION

It is estimated that approximately 16 million people under the age of 18 participate in recreational swimming across the United States.¹ Elite swimmers in that group report swimming eleven months out of the year and four to ten miles per day beginning at age 10 to 12.² Non-traumatic injuries are common in these athletes with shoulder injuries reported to be the most common with prevalence between 40% and 91%.³

Several authors have examined risk factors associated with injury in swimmers across a large range of ages. These studies have demonstrated that increased or decreased external rotation range of motion and prior injury were significant factors for developing shoulder injury.^{4,5} Additionally, a positive sulcus sign (indicating shoulder laxity) was correlated with increased incidence of tendinosis in Olympic level swimmers.⁶ It has also been shown that hours of training per week and weekly mileage are both positively correlated with shoulder pain caused by supraspinatus tendinopathy.⁷

These associations are important not only for understanding potential ways to reduce overall injury risk in this population but also for making a decision about when it is safe to return an athlete to participation following an injury and a course of rehabilitation. In addition to the standard strength and range of motion measurements that are used it is common to use functional testing to examine the athlete's readiness.⁸ Functional tests are commonly utilized and well described related to the lower extremity but have not been studied as much in the upper extremity.⁹ There are several tests that have been described in the literature to examine an athlete's readiness to return from an upper extremity injury,¹⁰ the most studied of which is the closed kinetic chain upper extremity stability test (CKCUEST).¹¹ However, as most upper extremity sports do not take place in closed chain positions there is a question about the ecological validity of the CKCUEST. To account for this gap in validity there are a number of newer tests described in the literature designed to mimic the loads seen during sports where the upper extremity is more frequently used in an open kinetic chain (swimming, baseball, tennis, volleyball, etc.). In particular, the current study explored two tests that place the subject into end range positions seen in swimming and throwing in order to examine strength and endurance in those vulnerable positions.¹⁰ It was hypothesized that these tests may have greater validity for assessing the particular population of competitive swimmers. The first step to being able to use these tests to decide on an athlete's safety to return to their sport is to establish normative values for different populations. Therefore, the purpose of this study was to establish normative values for the CKCUEST and prone ball drop tests in the elbow extended and elbow bent positions in a population of uninjured competitive youth swimmers.

METHODS

Participants aged 10-18 were recruited from a single competitive swimming club. Patients with active shoulder pain or shoulder pain limiting participation in the prior three months were excluded from testing. All testing took place within one month of the beginning of the season and prior to any competition in order to reduce any seasonal effects that may be present. Parental consent with subject assent or subject informed consent was obtained for all subjects prior to their participation in the study. The Hospital for Special Surgery Institutional Review Board approved the study.

Data were collected in a single session. Participants were told not to warm up and testing was done prior to practice on the day of enrollment. The order of testing was randomized in order to reduce the effect of fatigue. In addition to physical testing each patient was interviewed regarding history of shoulder injury requiring medical or physical therapy intervention. Following enrollment subgroups were formed by sex as well as by age greater than fifteen or between ten and fourteen. The age cutoff was created to split the enrolled range into approximately equal ranges while also being split to allow comparison between a high school aged cohort and a younger middle school aged cohort.

The prone medicine ball drop was performed with the participant lying prone on a treatment table with the shoulder abducted to 90°, elbow straight, and palm facing the floor.¹⁰ Participants had the head turned toward the arm and the opposite arm supported on the table. Participants were instructed to drop and catch a 1 kg medicine ball as many times as possible in thirty seconds. This testing was previously described using a 2-pound ball and therefore 1kg was chosen as the closest available alternative.¹⁰ Three trials were performed with 30 seconds rest between each trial while alternating sides between each trial. The average was recorded for both the dominant and non-dominant arms. Form was monitored to maintain a level torso and arm at 90 degrees abduction during testing. Verbal cues were provided as needed for correction.

The 90-90 prone medicine ball drop was performed with the participant lying prone on a treatment table with the shoulder abducted to 90°, the elbow flexed to 90°, and the palm facing the floor. Participants were instructed to drop a 1kg medicine ball and catch the ball as many times as possible in thirty seconds. As in the elbow extended testing, a 1kg ball was used as the closest available alternative to the 2-pound ball previously described in the literature.¹⁰ Form was monitored to maintain a level torso and arm at 90 degrees abduction during testing. Participants alternated arms and were given 30 seconds break between each trial. Verbal cues were provided as needed for correction.

The CKCUEST was performed with two marks on the floor placed 36 inches apart. Each participant was instructed to assume a plank position on their feet and tap back and forth with the opposite hand as has previously

Table 1. Participant Demographics and Overall Sample Means

Gender (M/F)	25/28
Age (years, mean $\pm$ SD)	14.19 $\pm$ 1.89
Years Swam Competitively (mean $\pm$ SD)	6.03 $\pm$ 2.42
Breathe on Both Sides (n)	26
Reported History of Shoulder Pain (n(M/F))	16 (6/10)
CKCUEST (repetitions)	17.8 $\pm$ 3.5
Prone Ball Drop dom (repetitions)	31.8 $\pm$ 12.1
Prone Ball Drop non-dom (repetitions)	28.6 $\pm$ 11.0
90-90 Ball Drop dom (repetitions)	43.7 $\pm$ 13.6
90-90 Ball Drop non-dom(repetitions)	39.6 $\pm$ 15.4

Demographics of population as well as overall mean and standard deviations for functional testing for the entire sample. All functional testing is reported as mean and standard deviations of number of repetitions performed during the testing period. Side was separated by dominant arm (dom) and non-dominant arm (non-dom) for unilateral tasks.

been described.¹¹ The number of successful taps in 15 seconds was recorded. Each subject was given one practice trial and then completed two repetitions of the test with a 30 second break between each trial. The average of the two trials was recorded for analysis.

Statistical analysis was conducted using R version 4.2.2. Descriptive statistics were analyzed for all tests. Limb symmetry index was calculated as the ratio of dominant (dom) to non-dominant (non-dom) arm for each unilateral test. Subgroup differences were evaluated using two sample t tests.

RESULTS

Fifty-three participants were recruited for the study including 25 male and 28 female. Demographics of the subjects as well as overall means and standard deviations of the functional tests are presented in [Table 1](#).

There were significant differences between sex as well as between age groups ($p < 0.05$) for all tests with the exception of the CKCUEST. Limb symmetry indices were not significantly different between groups. Descriptive statistics of the tests split by sex and by age group are presented in [Tables 2](#) and [3](#) respectively.

Table 2. Normal Values by Sex

Test	Females (mean $\pm$ SD)	Males (mean $\pm$ SD)	p-Value
CKCUEST (repetitions)	17.2 $\pm$ 3.3	18.4 $\pm$ 3.6	0.20
Prone Ball Drop – dom (repetitions)	27.4 $\pm$ 12.0	36.8 $\pm$ 10.4	<0.01
Prone Ball Drop – non-dom (repetitions)	24.8 $\pm$ 9.7	32.9 $\pm$ 11.1	<0.01
Prone Ball Drop – Limb Symmetry Index (%)	114.1 $\pm$ 39.3	116.4 $\pm$ 25	0.80
90-90 Ball Drop – dom (repetitions)	38.7 $\pm$ 13.5	49.3 $\pm$ 11.5	<0.01
90-90 Ball Drop – non-dom (repetitions)	34.6 $\pm$ 13.6	46.6 $\pm$ 13.3	<0.01
90-90 Ball Drop – Limb Symmetry Index (%)	117.6 $\pm$ 33.9	108.2 $\pm$ 14.4	0.20

All functional testing is reported as mean and standard deviations of number of repetitions performed during the testing period. Side was separated by dominant arm (dom) and non-dominant arm (non-dom) for unilateral tasks.

There were no significant differences between prior shoulder injury and no injury groups when the sample was split by whether the participant had reported prior seeking medical care for a prior shoulder injury ([Table 4](#)).

DISCUSSION

The primary goal of this study was to establish normative values for upper extremity functional performance tests that had not previously been examined in this population. To the author's knowledge there are no prior published normative values for the ball drop tests in this age group or specific population.

Previous studies have examined both the CKCUEST and the ball drop tests in adult populations.^{11,12} The prone ball drop with elbow extended was reported in male and female groups with dominant arm repetitions of 74.7 $\pm$ 9.9 and 64.7 $\pm$ 13.4 respectively.¹² While the bent elbow ball drop had repetitions of 61.5 $\pm$ 9.9 and 50.4 $\pm$ 12.0 in the same groups respectively.¹² These values are much greater than the means reported in this study population. There was a similar trend with the CKCUEST which previously had reported values of 27.728 and 22.758 for male and female athletes respectively.¹¹ This difference is likely related to the decreased strength and motor control associated with this age population as opposed to adult populations that had previously been studied. It is important to ensure that when using normative data for comparisons the subject being examined is similar to the population that was examined to create the data. It would not be recommended to use previously reported values from an adult population when examining this age group of swimmers.

One way to potentially counteract the differences between age group and between sexes would be to use within subject normalization. In this study using limb symmetry ratio demonstrates similar results to previous studies in an adult population where limb symmetry was reported between 106.4 and 119.2 for the different groups during the ball drop tests.¹² Limb symmetry may be a useful metric to control for differences in raw numbers that were noted between age groups and sex. However, swimming is a bilateral sport so it is possible that the normative values for limb symmetry may be altered when looking at a unilateral dominant sport such as baseball/softball, tennis, or volleyball.

Table 3. Results for age groups

Test	Age < 15 (n=33)	Age ≥ 15 (n=20)	p-Value
CKCUEST (repetitions)	16.9±3.1	19.3±3.7	0.02
Prone Ball Drop – dom (repetitions)	26.4±9.7	40.8±10.2	<0.01
Prone Ball Drop – non-dom (repetitions)	23.8±8.4	36.5±10.6	<0.01
Prone Ball Drop – Limb Symmetry Index (%)	115.5±38.7	114.7±21.4	0.94
90-90 Drop – dom (repetitions)	38.9±11.2	51.6±13.7	<0.01
90-90 Drop – non-dom (repetitions)	35.1±12.3	48.8±14.4	<0.01
90-90 Drop – Limb Symmetry Index (%)	116.3±31.3	108.2±16.3	0.29

All functional testing is reported as mean and standard deviations of number of repetitions performed during the testing period. Side was separated by dominant arm (dom) and non-dominant arm (non-dom) for unilateral tasks.

Table 4. Comparisons between prior injury/no injury groups

Test	Prior Shoulder Injury (n=16)	No Injury History (n=37)	P-Value
CKCUEST (repetitions)	18.0±3.2	17.7±3.6	0.78
Prone Ball Drop – dom (repetitions)	36±11.5	30±12	0.10
Prone Ball Drop – non-dom (repetitions)	31.8±11.4	27.2±10.7	0.16
Prone Ball Drop – Limb Symmetry Index (%)	117.8±27.9	114.1±35.3	0.71
90-90 Drop – dom (repetitions)	48±12.8	41.9±13.7	0.13
90-90 Drop – non-dom (repetitions)	43±16.7	39.1±13.7	0.38
90-90 Drop – Limb Symmetry Index (%)	119.2±25.0	110.6±27.4	0.29

All functional testing is reported as mean and standard deviations of number of repetitions performed during the testing period. Side was separated by dominant arm (dom) and non-dominant arm (non-dom) for unilateral tasks.

Of particular interest are the large differences in testing averages when split between high school and middle school athletes. This is especially important when considering the variability that exists and changes that occur in skeletal maturity within the youth and adolescent population. While skeletal age and skeletal maturity were not assessed in this study there are a number of methods for assessing that are clinically feasible without specialized equipment.¹³ As a substitute for skeletal age the authors chose to split the population evenly and group ages 11-14 and 15-18 together respectively. Given the differences associated with this seemingly arbitrary split it warrants further investigation from future studies.

One finding that the authors found particularly interesting was that there were no differences when the groups were split by prior injury. Given that previous injury has frequently been shown to be a predictor of future injury¹⁴ it was hypothesized that there would be some difference. Based on the current study it is unknown if this lack of association is an indication that the functional tests not being discriminatory for future injury or whether this was simply a function of the small sample size or that the inclusion criteria of no active shoulder pain within 3 months eliminated subjects that would have demonstrated a difference. While the current study did not attempt to establish any association w/ future injury hopefully the data can serve as a starting point for comparison.

There are several limitations to this study. Most importantly is that the sample size is limited such that it is difficult to draw any conclusions from subgroup analysis due to the increased possibility of Type 2 error. Additionally, drop tests were performed with a standard weight and CKCUEST was performed in a standard position across all subjects. This is potentially more impactful in the youth populations where there is significant variability in size and skeletal maturity of the participants. It was noted that some of the smallest participants had difficulty reaching the standard distance apart for CKCUEST as well as holding the weighted ball during drop testing due to the size and weight of the ball. In order to reduce the variability of the results it may be beneficial to use anthropometric measurements in order to create a scaled version of the tests individual to each subject. This has been examined in twelve to seventeen year old basketball and volleyball players for the CKCUEST¹⁵ but was not implemented in this study as to the authors knowledge this had not been described in the literature at the time of planning and data collection.

CONCLUSION

The results of the current study provide a baseline of normal values for upper extremity functional measures in a competitive youth swimming population that can potentially be used in return to sport testing in the future. There were significant differences between sex as well as between

age groups for both of the ball drop tests. However, limb symmetry indices and the CKCUEST were not significantly different between the groups.

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CONFLICTS OF INTEREST

The authors affirm that we have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript.

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