

Original Research

Closed Kinetic Chain Upper Extremity Stability Test Reference Values for NCAA American Football

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Background

The Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) is a valid and reliable test commonly used during return to sport testing. While reference values have been determined for multiple sports, few have specifically considered National Collegiate Athletic Association (NCAA) American football players.

Purpose

To provide reference values on the CKCUEST for NCAA football players with considerations for position, history of upper extremity injury, year in school, and division of college football.

Study Design

Cross-sectional study

Methods

Eighty football players from three NCAA schools were recruited to participate in this study. Height, mass, position, year in school, and history of upper extremity injury were collected. Subjects completed three trials of the CKCUEST with their means recorded. Means were compared using ANOVA with post hoc Bonferroni tests. A T-test was used for a secondary comparison of mean touches of linemen versus all other positions. Pearson correlation coefficients assessed the relationship between number of touches and subject characteristics.

Results

Subjects were all males with a mean of 2.5 years in school (95% CI 2.18-2.85). Subjects of the study averaged 27.3 touches. There were no statistically significant performance differences between players from NCAA divisions, with/without injury history, years in school, or athlete demographics. Linebackers had significantly more touches compared to offensive linemen, 29.7 and 24.8 ($p < 0.03$), respectively. Additionally, linemen as a group (offensive and defensive) averaged 25.7 touches, which was significantly lower compared to all other positions combined (28.1 touches, $p < 0.01$). The minimal detectable change was 1.2 touches.

Conclusion

A reference value of 27 touches was found for the CKCUEST in NCAA football players. A change of at least two touches would indicate a measurable change. Position differences

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should play a role in clearance for return to sport; specifically, linemen may produce less touches than other non-lineman positions.

Level of Evidence

Level 2c: Cross-sectional study

INTRODUCTION

The Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) is a functional test commonly used after upper extremity injuries. The CKCUEST has excellent test-retest, inter-session, and intra-session reliability for healthy individuals, injured individuals, and athletes.¹⁻⁶ Additionally, this test demonstrates strong correlations with hand grip strength and shoulder internal and external rotator isokinetic and isometric testing, positioning it as a valuable component of a comprehensive return-to-play assessment battery.⁷⁻⁹

Mean values for the CKCUEST in healthy individuals are 22-31 touches.^{2,7,10,11} Due to the high reliability and validity of this test, it has been utilized to assist with return to play decision making in multiple sports.¹⁻⁶ Mean number of touches for the CKCUEST in baseball players ranged from 18 -30 touches, with no significant difference found between positions.^{10,12} The CKCUEST demonstrates strong reliability for non-overhead athletes, but lacks research needed to establish reference values for sports that spend time in closed chain positions and pressing motions, such as football.⁶

Pontillo et al. initially reported a mean of 22 touches in collegiate football players, with an increased risk of injury during the season if an athlete recorded less than 21 touches.¹³ More recently, Pontillo and Sennett¹¹ reported normative values for multiple Division 1 National Collegiate Athletic Association (NCAA) sports including football. They reported 29 touches for the CKCUEST in football players, but this study only utilized collegiate freshman.¹¹ In a study examining upper extremity functional testing in football players with labral repairs, all athletes were able to achieve 25 touches on the CKCUEST prior to return to sport.¹⁴ However, the external application of these studies should be interpreted with caution due to their small sample sizes and homogeneity of their subjects.

To the authors' knowledge, no research has considered other factors which may alter CKCUEST performance such as position played, history of upper extremity injury, year in school, or division of college football. The purpose of this study was to provide reference data for the CKCUEST to be used with NCAA football players while considering the impact of position, history of upper extremity injury, year in school, and division of college football.

METHODS

STUDY DESIGN

A cross-sectional study was approved by three university human subject committees, with data collection being performed by researchers at each school. All data were col-

lected during the spring and summer of 2024. Eighty subjects provided consent and participated in this study. The inclusion criterion was any football player who competed at the NCAA Division 1, 2, or 3 level regardless of injury status. The exclusion criterion was any player who could not complete the CKCUEST.

RESEARCH PROCEDURES

A video and directions were sent to each school representative explaining the testing procedure to optimize the reliability while conducting this study. The video included a review of the IRB requirements for consent, overview of subject recruitment, data collection, and directions on how to perform the CKCUEST. Any additional questions from researchers were answered through phone calls to address concerns with form and scoring. Subjects were recruited via email and word of mouth to participate in the study. No incentives were provided. Independent variables included position, height, mass, body mass index (BMI), year in school, and upper extremity injury history. Injury history included any reported history of upper extremity injury that the subject experienced at any point in their playing history, even prior to college. The dependent variable was the number of touches completed during the CKCUEST.

The CKCUEST was performed per the description given by Goldbeck and Davies.¹ This method of administration was found to have an ICC of .82 indicating strong relative reliability when considering non-overhead athletes.⁶ Prior to performing the test, the CKCUEST was discussed with each subject and demonstrated by the researcher. The subject assumed a push-up position, with one hand on each piece of tape, placed on the ground 36 inches apart, with the body as straight as possible. The subject's shoulders were positioned in line with the hands ([Figure 1a](#)). When the researcher said "go," the subject removed one hand from the floor, touched the opposite hand ([Figure 1b](#)), and then replaced the hand on the original line ([Figure 1c](#)). The subject then removed the other hand from the floor, touched the opposite hand ([Figure 1d](#)), and returned it to its original line ([Figure 1a](#)). A single trial consisted of continuing this alternating procedure at a maximum effort for 15 seconds. Subjects were allowed time to practice the test prior to starting.

After the subject completed their practice trial, three maximal effort trials were completed. A touch was defined as one hand crossing over and touching the dorsum of the opposite hand and returning to the respective line. A rest period of 45 seconds was given after each 15 second trial. The work-rest ratio was 1:3, which allows for recovery with a short-duration, high-intensity test such as the CKCUEST.¹ Per the original study conducted on the CKCUEST, the three trials were averaged and became the subject's test score.¹

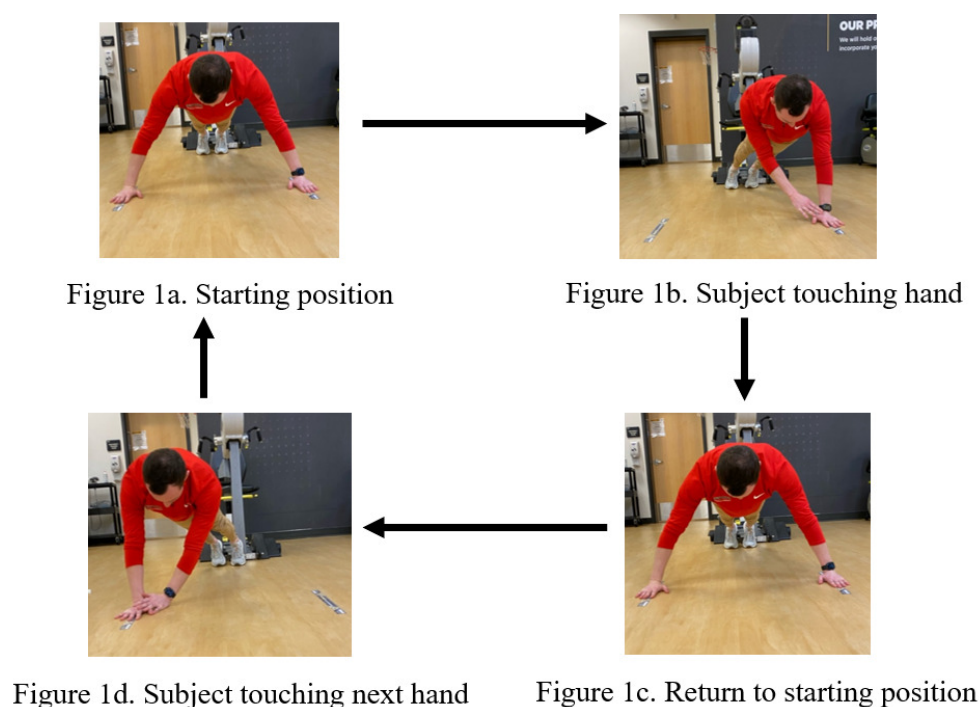


Figure 1. CKQUEST Sequence

DATA ANALYSIS

All statistical analysis was completed with SAS Studio, Version 9.4 (SAS Institute Inc). All alphas for differences and correlations were set at 0.05. Normality was checked with Shapiro-Wilk, Histograms, and Q-Q plots. A Shapiro-Wilk p value greater than .05 indicated normality. While a qualitative assessment for skewness and significant deviations was used with the Histograms and Q-Q plots, respectively, which were used to scrutinize the more objective Shapiro-Wilk interpretations. ANOVA was used to compare means. Bonferroni post-hoc testing was completed to determine if the significance was true and at which levels. A secondary analysis of linemen (offensive and defensive combined) compared to all other positions combined was completed with a t-test. Pearson Correlation Coefficients were used to assess the relationship of touches with height, mass, and BMI. Minimal detectable change (MDC) was calculated from the standard error of the mean (SEM) using the equation: $MDC_{95} = 1.96 * \sqrt{2} * SEM$.

RESULTS

Eighty male NCAA football players with a mean 2.5 years (95% CI 2.2-2.8) from three institutions participated in this study. The mean number of touches for all subjects was 27.3 (Table 1). The MDC was 1.2 touches; therefore, two touches were needed to signify a measurable change. Mean subject characteristics and characteristics based on NCAA football division can be found in Table 1.

There were no significant correlations between number of touches with height, mass, BMI, year in school, or division of school. BMI ($p=0.08$) and mass ($p=0.11$) were trending towards significance, although with weak negative cor-

relations. Table 2 reports all correlation values and their significance.

Nine position groups were tested with mean number of touches shown in the box and whisker plot in Figure 2. There was a statistically significant difference ($p=.03$) between linebackers and offensive linemen (Table 3). All other comparisons between position groups were found to have no statistically significant differences following Bonferroni adjustments. A secondary comparison of touches by offensive and defensive linemen as a group (25.7 touches) to all other players (28.1 touches) was significantly different ($p<0.01$).

Twenty-four of the 80 subjects (30%) reported a history of upper extremity injury. No statistically significant difference was found between players with and without upper extremity injury ($p=0.30$). Subjects without injury averaged 27.6 touches whereas those with injuries had 26.6 touches, see Table 4 for details.

DISCUSSION

The primary purpose of this study was to provide reference data for the CKQUEST to be used in the NCAA football setting with considerations for position, history of upper extremity injury, year in school, and division of college football. While the findings of 27 touches and two touches needed to signify a measurable change in performance were similar to previous studies conducted with NCAA football players, this study adds that differences exist between position groups.^{11,13,14}

To date no study has considered if differences in position in NCAA football impacted scoring on the CKQUEST. This is a key consideration, as variations in BMI, height, and positional demands in football may influence an athlete's abil-

Table 1. Subject characteristics, reported as mean (95% CI) and stratified by division

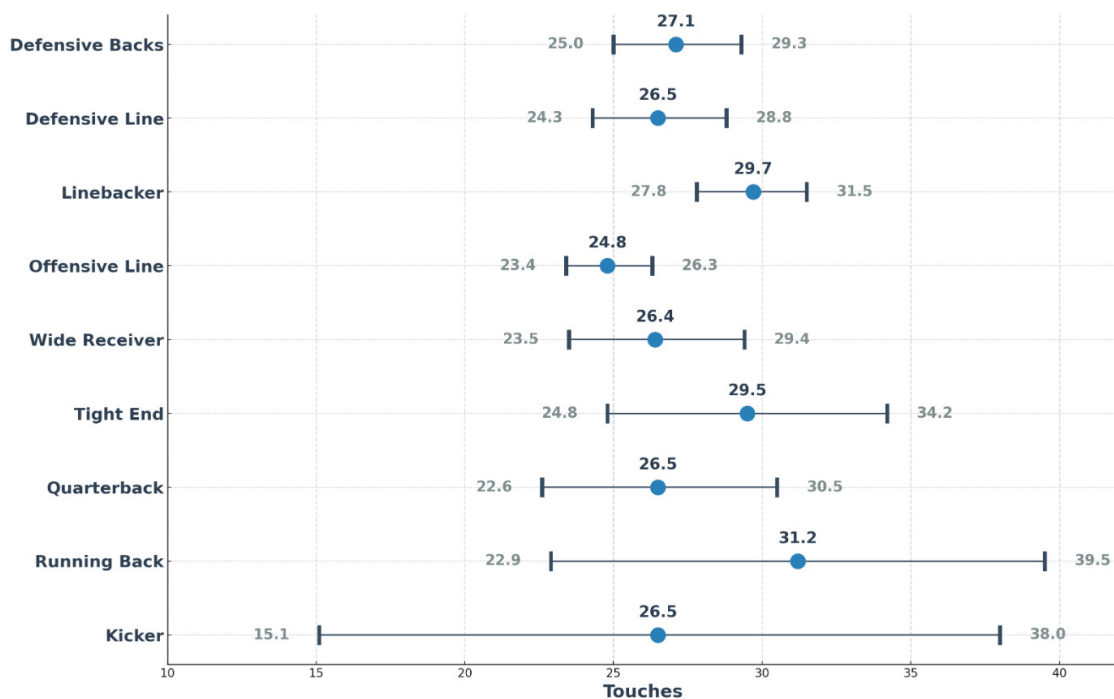
Variable	Mean	Division 1 (n=21)	Division 2 (n=37)	Division 3 (n=22)
Height (cm)	185.7 (184.4-186.9)	72.8 (71.5-74.0)	73.2 (72.5-73.9)	73.2 (72.2-74.2)
Mass (kg)	103.6 (99.3-107.8)	103.4 (94.4-112.4)	100.0 (94.2-105.8)	110.1 (100.6-118.8)
BMI (kg/m ²)	29.5 (28.3-30.7)	30.2 (28.0-32.4)	27.8 (26.1-29.4)	31.7 (29.3-34.0)
Year in School	2.5 (2.2-2.8)	3.0 (2.4-3.6)	2.6 (2.1-3.2)	1.9 (1.4-2.4)
Touches	27.3 (26.4-28.1)	26.0 (24.2-27.7)	28.0 (26.9-29.2)	27.2 (25.4-29.1)

Abbreviations: n= number of subjects, cm = centimeters, kg= kilograms, m= meters, CI= confidence interval

Table 2. Correlation between number of touches demographic characteristics

Variable	r	p value
Height (cm)	-0.02	0.84
Mass (kg)	-0.18	0.11
BMI (kg/m ²)	-0.20	0.08
Year in School	0.16	0.16
Division of School	0.12	0.30

Abbreviations: r= Pearson Correlation Coefficient, BMI= Body Mass Index

**Figure 2. Plot of Touches by Position, displayed as mean (error bars indicate 95% confidence intervals).**

ity to perform the test. Linebackers recorded more touches (29.7) than offensive linemen (24.8) ($p = 0.03$). Additionally, linemen as a group (25.7) had significantly fewer touches compared to all other positions as a group (28.1) ($p < 0.01$). The difference found may be partly explained by variations in height and mass across positions, as each role has distinct physical and functional demands. In the current study, a trend was observed towards a weak negative correlation between both BMI and mass with touches. While not statistically significant, future studies with larger sample sizes may detect a stronger association between touches and

subject characteristics, offering further insight into positional differences.

In the collegiate football population, those with less than 21 touches during pre-season testing had an increased risk of injury during season.¹³ Additionally, sedentary patients with subacromial pain were found to have fewer touches when compared to healthy individuals.² No study has considered whether a history of upper extremity injury should change expectations on touches in NCAA football players. Our findings suggest there were no differences in touches for football players with a history of upper extrem-

Table 3. Bonferroni-corrected p-values for differences between positions

	DL	K	LB	OL	QB	RB	TE	WR
DB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DL		1.00	0.84	1.00	1.00	1.00	1.00	1.00
K			1.00	1.00	1.00	1.00	1.00	1.00
LB				*0.03	1.00	1.00	1.00	1.00
OL					1.00	0.24	0.58	1.00
QB						1.00	1.00	1.00
RB							1.00	1.00
TE								1.00

Abbreviations: * Statistical significance, DB= Defensive Back, DL= Defensive Line, LB= Linebacker. OL= Offensive Line, WR= Wide Receiver, TE= Tight End, QB= Quarterback, RB= Running Back, K= Kicker

Table 4. Touches per upper extremity injury status, reported as mean (95% CI)

Upper Extremity Injury	Yes	No	p value
Touches	26.6 (24.6-28.5)	27.6 (26.6-28.5)	0.30

ity injury and those without. The lack of relationship between the history of upper extremity injury and touches could be explained by the ability of collegiate athletes to rehabilitate well or to compensate for injuries. The CKCUEST test replicates aspects of the high-paced, competitive nature of sports, potentially enabling athletes to perform well despite a history of injury, underscoring the need for comprehensive testing before returning to play.

An athlete's upper extremity strength influences CKCUEST performance, as it strongly correlates with grip strength and shoulder internal rotation and external rotator isokinetic and isometric strength.⁷⁻⁹ These factors may be improved in athletes through increased years of participation in the collegiate level or differences in training styles seen between teams and through the various divisions of NCAA athletics. Previous studies on collegiate football players did not examine if years in school impacted number of touches or assess if different divisions alter the number of touches performed during testing. We found no significant differences related to either year in school or division, indicating that the various environmental factors from years in college or specific division do not influence the number of touches.

Internal validity is a limitation of this study as data were collected at three sites with different researchers. To reduce this risk, video instructions were sent to participating researchers as well as over the phone discussions on follow up questions to provide consistency with collecting data between sites. With different facilities being utilized for collection, different flooring may have had an effect on the number of touches. Flooring like carpeting may have allowed for less slipping compared to tile thus affecting scoring. Lastly, some positions had insufficient sample sizes,

resulting in underpowered comparisons of touches between positions.

Future research should examine the impact of injury severity and number of touches on the CKCUEST, as this study did not differentiate based on these factors. Incorporating height and mass is another area of research that should be expanded on. Information on this area of research may help further explain scoring differences, particularly between position groups. Goldbeck and Davies highlight the use of height and mass to calculate normalized and power values for the CKCUEST.¹ Applying these metrics could offer greater insight into how variations in subject characteristics across positions influence performance outcomes, specifically the difference between the grouped linemen and all other positions grouped together. Lastly, research with more subjects would allow better stratification based on positions, expanding on the results found in this study.

CONCLUSION

In this cross-sectional study of NCAA football players, the mean number of touches for the CKCUEST was 27.3. A change of at least two touches would indicate a measurable change in testing. No differences were found when considering the year in school, division of school, subject characteristics, or history of upper extremity injury with the CKCUEST. Linemen may produce less touches than other positions when returning to sport.

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