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ANALYSIS OF RATE OF FORCE DEVELOPMENT, MAXIMAL FORCE AND TIME TO MAXIMAL FORCE DURING CLOSED KINETIC CHAIN UPPER EXTREMITY STABILITY (CKCUES) TEST

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SUMMARY

The CKCUES Test is a functional test performed in a push-up position [1]. To date, there have been no studies evaluating any biomechanical metrics of this test. Understanding key kinetic parameters is important to evaluate the performance requirements of the test and its potential utility as a functional shoulder performance test. The objective of this study was to evaluate the rate of force development (RFD), maximal force (MF), and the time to maximal force (TMF) during the CKCUES Test. Fifteen subjects performed the test which required them to reach from hand to hand while maintaining a pushup position within a specific time period. Vertical Ground Reaction Force (VGRF) was obtained using a forceplate. Based on VGRF, RFD, TMF and MF force were calculated. Results indicate that there were no differences in the RFD, TMF and MF between analyzed touches. Thus, for this population, these kinetic variables were consistent all over the 15 seconds of test performance.

INTRODUCTION

The CKCUES Test is a functional upper extremity test performed in a push-up position that can be used as an additional tool in the clinical rehabilitation for people with shoulder impairments or can be used as complementary outcome to evaluate upper extremity stability function in athletes [1]. To our knowledge, no studies have described any biomechanical parameters during the CKCUES Test. Moreover, there were not found studies that evaluated the MF and RFD when CKCUES Test is being performed. The purpose of this study was to evaluate some kinetic parameter as performance indicators during the CKCUES Test. We hypothesized that there would be no differences in kinetic variables over the timed test.

METHODS

The study included 15 males, with [mean (SD)] age of 24.98 (2,45) years, height of 175 cm (0,5), and weight of 81,99 kg (12,58). Inclusion criteria included being right-hand dominant, sedentary, and healthy. The study was approved by the ethics committee of the Cuiabá Health and School Center of the Ribeirão Preto Medical School at the University of São Paulo.

The CKCUES test is performed during 15 seconds with the person assuming a push-up position with hands at 91.44 cm apart (36-inch). Then, the subject leans over one hand and picks up the opposite hand reaches over to touch hands and then returns the hand to the starting position. This sequence is repeated with the opposite hand as fast as possible. Each volunteer performed three trials, with 45 seconds of rest between trials.



Figure 1. CKCUES Test initial position.

Because each subject did a different number of touches during CKCUES Test, the second, the middle and the final touches were analyzed to represent the subject's performance at three different time periods. Data analysis was only performed on for the dominant side. During the test one hand started on a forceplate, which was used as an event marker. Each touch analyzed was divided into load and swing phases in accordance to hand contact on the forceplate or not, respectively (Figure 2).

Assuming the dominant hand on the forceplate, the load phase was the time it took for the non-dominant hand to reach over to touch the dominant hand and then return. The swing phase for the dominant arm was then the time it took for the dominant hand to leave the forceplate and reach to

touch the opposite hand and then return to the forceplate initial position.

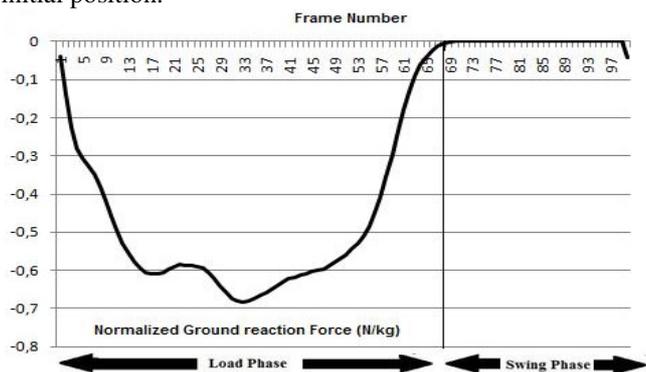


Figure 2: Graphic representation NGRF during a touch.

Vertical Ground Reaction Force (VGRF) on CKCUES Test was obtained using an AMTI (Advanced Mechanical Technology Inc., MA – EUA) force plate with sampling rate set at 240Hz. Data were sampled using The Motion Monitor Software™ (Innovative Sports Training, Inc., IL, USA). Rate of force development (RFD), maximal force (MF) and time to maximal force (TMF) were the kinetic variables chosen for analysis and those were calculated based on VGRF normalized by body weight (NVGRF). MF was defined as the highest NGRF before finishing load phase. The RFD was determined by dividing the difference between the maximal force and the minimum force between the impact force and the maximum force by the time to maximum force. The TMF was defined as the percentage the total cycle where the subject reached the maximum force. Total time of a touch was defined as 100% and time to maximal force was calculated as a percentage of it. Statistical analyses were done using mean and standard deviation. The significance level was set at $p < 0,05$. Linear mixed effect model analysis was used to compare RFD, MF and TMF between initial, middle and final touches.

RESULTS AND DISCUSSION

There were no differences in the values of RFD, MF and TMF when initial, middle and final touches were compared (Table 1). Thus, the hypothesis of this study was confirmed. This could be explained by the fact that subjects had to be able to keep their performance constant, which forced them to maintain the VGRF similar over time. The lack of differences might also be explained by the relative athleticism of the healthy subjects. However, if the test had been performed by a person with upper extremity muscle weakness or shoulder injuries, greater variation might have been observed.

Performance depends on the capacity that a subject has to generate power with repeated submaximal muscular contractions [3]. Performance depends on the capacity that a subject has to generate power with repeated submaximal

muscular contractions [3]. The CKCUES is used as a functional performance test; however no performance parameters other than time have previously been evaluated. Our study is the first to look at the basic GRF responses as additional potential metrics for the test. A previous study [3] evaluated similar kinetic responses for a 3 types of plyometric push-ups and showed that RFD and MF was higher for countermovement push-up that is performed with elbows extended, than for two other types of push-ups performed with elbow flexed. Results cannot be compared directly because our data was normalized and in the other study not. However, it is important to point out that CKCUES Test is performed essentially a high plank position or extended push-up position so, based on the cited study; greater level of VRFD can be developed.

To evaluate RFD is important because it is a measure of the rate at which a force is developed and it has importance when fast and forceful short time muscle contractions are done as in a fast movement because increases in RFD allows a muscle to develop a higher level of force in the initial phase of muscle contraction [4]. Thus, results showed that CKCUES Test can generate a great level of VRFD, which can be helpful for develop a higher force level in short contraction as those done in a performance exercises. However this study has some limitations. Only healthy males were studied. Thus, these results cannot be extrapolated to a population with shoulder impairments. Thus, precautions should be taken on using this test for a person with shoulder dysfunctions.

CONCLUSIONS

There were no differences in the RFD, TMF and MF between analyzed touches. Thus, for this population, these kinetic variables were consistent all over the 15 seconds of test performance. Moreover, further studies are needed to determine the limitation and precautions of this test in a population with and without shoulder injury.

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Table 1: Mean (standard deviation) values of rate of force development, maximum force and time to maximal force (n=15).

	Initial Cycle	Middle Cycle	Final Cycle
Maximum Force (N/kg)	0,691 (0,035)	0,683 (0,040)	0,675 (0,044)
Time to maximum force (% cycle)	16,73 (4,51)	17,73 (1,94)	17,00 (6,06)
Rate of force development (N/kg/%cycle)	0,0064 (0,0024)	0,0064 (0,030)	0,0067 (0,0024)

n= number of subjects per group; N= Newton; kg= kilogram