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Comparison of Isokinetic Testing to Upper Extremity Closed Kinetic Chain Testing in Recreational College Athletes

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Abstract

Background: Clinicians utilize various techniques during the rehabilitation process to ensure that patients can successfully recover from injury. Isokinetic testing and Closed Kinetic Chain testing have both been utilized during this process by various health care practitioners. Through the utilization of data gathered from these tests, clinicians can develop strengthening programs to target specific areas of weakness on the patient. However, there has not been extensive information in the literature regarding if the results from these two modalities correlate and share commonality with each other. **Purpose**: The purpose of this study is to discern whether data gathered from Isokinetic testing of internal and external shoulder rotational strength correlates with data gathered from the Closed Kinetic Chain Upper Extremity Test in the recreational athlete population. The information gathered from this study can be utilized by health care clinicians in the future to determine how to implement these modalities as part of a rehabilitation protocol for the upper extremity. **Methods**: Convenience sampling resulted in 14 recreational college-aged athletes who participated in this quantitative study. Informed consent was obtained from each participant upon the initial testing day. The subjects were then guided through the Isokinetic or Closed Kinetic Chain testing protocol depending on which testing session was being conducted. Isokinetic measurements were ascertained from testing speeds of 60 and 180 degrees per second while Closed Kinetic Chain data was gathered from three timed trials of 15 seconds each. Once all the data has been collected from the testing protocols, correlational and regression analyses will be performed to determine whether these two modalities share a commonality. **Results**: Correlation and Regression analyses determined that there was no statistically significant relationship between Isokinetic and Closed Kinetic Chain Testing. Additionally, hand dominance was proven to have no statically significant relationship with Isokinetic measurements. However, bodyweight was shown to have a statistically significant relationship with Isokinetic measurements. Also, through comparisons with established normative data, it was observed that most of the subjects in this study exhibited above average values on both testing modalities. **Discussion**: The lack of a statistically significant relationship between the two testing modalities contradicts previous literature gathered on these two tests. However, it is likely that the small sample population of this study played a role in affecting this correlational outcome. Despite this finding, it is clear that these modalities are strong indicators of shoulder strength and stability through the comparisons between subject data and literature normative values. **Conclusion:** These testing modalities can be utilized by clinicians to determine whether their patient possesses optimal upper extremity strength and stability. Through the measurements gained from these tests, the attending clinician can adequately develop a rehabilitation program for their patient. These tests allow the clinician to gain an understanding of the patient's weak areas and plan accordingly on how to optimally target these areas and make improvements.

Keywords: isokinetic, closed kinetic chain, recreational athlete

Introduction

Background

Clinicians utilize various techniques during the rehabilitation process to ensure patients are able to successfully return from injury. Isokinetic testing and Closed kinetic chain testing have both been utilized during this process by various health care practitioners in the medical world. These tests allow the clinician to assess strength and stability of particular musculature in order to determine whether weaknesses are present and if these weaknesses are causing particular ailments in a patient.

The term isokinetic refers to muscular contractions performed at a constant speed. In most cases, clinicians utilize peak torque and peak work values gathered from testing to properly interpret testing results. Peak torque in terms of isokinetic methodology refers to an absolute strength value of the musculature being tested while peak work refers to a functional assessment of muscular performance. These two values in concert allow the clinician to gain an understanding of the tested muscle's overall strength and functionality. Isokinetic testing has several advantages in the rehabilitation setting including the ability to isolate a certain muscle through the testing protocol as well as being able to analyze that muscle's strength and stability at a constant contractile speed.

The Closed Kinetic Chain refers to exercises performed in which the distal segment of the body meets external force in a fixed position. During the Closed Kinetic Chain Upper Extremity Test, the shoulders are placed within the closed kinetic chain due to the patient's hands being fixed in the pushup starting positioning during the administration of the test. Closed Kinetic Chain testing also has tangible benefits including the ease of testing administration and the ability to determine possible deficits in the functionality of the extremities in the closed kinetic chain, as well as noting proprioception and neuromuscular control.

Through the utilization of data gathered from these tests, clinicians can develop strengthening programs to target these specific areas of weakness that the patient exhibits. These tests allow for a more advanced means of diagnosing injury and a more revolutionary process of developing injury prevention strategies targeted for specific imbalances that the clinician's patients are affected by. However, there has not been extensive information in the literature regarding if the results from these two testing modalities correlate with each other. More specifically, it has not been examined whether the Closed Kinetic Chain Upper Extremity Test is able to predict individual's performance on the Isokinetic testing of the upper extremity. The purpose of this literature review is to discuss the background of these tests, provide frameworks for how they are each used in the rehabilitation setting, and to compare the efficacy and rationale behind these two clinical examinations.

Literature Review

Isokinetic Testing

In the strength training world, the term isokinetic refers to a muscle working at a constant rate and speed over the duration of a muscular contraction. Prescribing this method of testing allows the clinician to ascertain various objective measurements which are useful when developing individualized rehabilitation and strengthening programs catered to the patient's needs (Ellenbecker & Davies 2000). In particular, the application of isokinetic testing in the upper extremity has proven to be useful due to the increased demand placed on this system by sport-specific events, the increased range of motion associated with the glenohumeral joint, and the need of stabilization in the shoulder girdle to ensure proper function (Ellenbecker & Davies 2000).

Within the literature, there are a variety of ways to administer isokinetic testing for the upper extremity. In one study, all of the subjects were instructed to lie in the supine position on the isokinetic dynamometer with the shoulder positioned at a 90-degree angle due to the similarities in the abduction angle for throwing sports (Ellenbecker & Mattalino 1997). However, in a different study conducted by Ellenbecker & Davies, two different positioning protocols were utilized by the researchers to test shoulder strength (Ellenbecker & Davies 2000). One of the protocols used during this study required the subject to remain in the standing position while the glenohumeral joint was positioned at 30 degrees of abduction and 30 degrees of flexion in the scapular plane with 30 degrees of diagonal tilt of the dynamometer head in the transverse plane, also known as the modified base position (Ellenbecker & Davies 2000). The researchers indicated that this positioning protocol for testing has a few benefits due to its avoidance of possible suprahumeral impingement and its overall positive tolerance within the patient population (Ellenbecker & Davies 2000). However, it was also indicated that the modified base position testing protocol may lead to compromises in glenohumeral joint isolation as well as test-retest reliability of the data due to the standing patient position required for this protocol (Ellenbecker & Davies 2000).

The second testing protocol mentioned by the researchers in this study requires the subject to be positioned in either the seated or supine position with the glenohumeral joint at 90 degrees of abduction (Ellenbecker & Davies 2000). This form of the test positioning is associated with several benefits including increased stabilization of the glenohumeral joint due to the positioning of the subjects as well as the commonality of the shoulder abduction angle with the common overhead throwing position utilized in various sporting events (Ellenbecker & Davies 2000).

Other studies found within the literature utilized unconventional testing protocols to test the reliability and validity of new positions for isokinetic testing. One of these studies in the literature was conducted by Falkel, Murphy, and Murray (1987), which utilized prone positioning on the dynamometer to test internal and external shoulder rotational strength. These researchers compared supine and prone positioning with the shoulder abducted at 90 degrees in the swimmer population, finding that prone positioning was more beneficial in the swimmer population (Falkel, Murphy, & Murray 1987). Despite these intriguing results, the prone position would only be experimentally beneficial in the swimming population due to the amount of time that swimmers spend in the prone position during their time in the water.

Like the aforementioned studies, experimentation conducted by Forthomme, Dvir, Crielaard, and Croisier (2011) compared methods of positioning for testing the external and internal rotational strength of the shoulder. These researchers utilized three different test positions during their experimentation, including two supine positions with the glenohumeral joint at either 45 or 90 degrees of abduction and one seated position with the shoulder moving in the scapular plane (Forthomme, Dvir, Crielaard & Croisier 2011). Through experimental data obtained through the various positions, the researchers determined that isokinetic testing for the internal and external rotators of the shoulder should be conducted in the supine position with the arm positioned at either 45 or 90 degrees of abduction for research purposes only, due to increased reliability (Forthomme, et. al 2011). However, this supine position places the shoulder in a vulnerable position, thus proving it unsafe for utilization in rehabilitation settings. Therefore, through examination of the various literary information assembled, it can be determined that the optimal positioning for isokinetic testing of the internal and external shoulder rotators for the purpose of this study is seated with the glenohumeral joint positioned at either 45 or 90 degrees of abduction.

There are also differences in the testing speeds utilized by researchers within isokinetic testing protocols. In the Ellenbecker & Mattalino study, the testing speed utilized by the researchers was 210 and 300 degrees per second (Ellenbecker & Mattalino 1997). Within the protocol, the 210 degrees per second speed was utilized first followed by the 300 degrees per second speed to acclimate the subjects to a moderate rate of speed initially and then transition to the higher speed in order to examine data at both moderate and high-speed levels (Ellenbecker & Mattalino 1997). In comparison, both testing protocols utilized in the Ellenbecker & Davies study discussing normative measures of the test, used testing speeds of 60 degrees, 180 degrees, and 300 degrees per second (Ellenbecker & Davies 2000). However, the fastest speed of 300 degrees per second may prove difficult for subjects to match, especially those in rehabilitation programs for upper extremity injury. Therefore, 60 and 180 degrees per second are the most optimal testing speeds for rehabilitation programs.

Normative interpretation of shoulder strength movement data collected from isokinetic testing has been indicated through one major study in the literature. Within this study conducted by . . ., the researchers indicated that there was no major statistical strength difference between dominant and non-dominant shoulders, however, a general pattern of increased strength in the dominant shoulder of the subjects was observed (Ivey, Calhoun, Rusche, & Bierschenk 1984).

Also, it was discovered that internal rotation strength was greater than external rotation strength in the subjects by a 3:2 ratio for both fast and slow testing speeds (Ivey, et. al 1984). This knowledge is beneficial for future testing practices in order to establish a baseline to compare future experimental data and determine whether the subject is exhibiting normal muscle strength ratios within the shoulder girdle. However, there are several problems with this study that need to be addressed. Primarily, the sample population of the study was rather small, thus calling into question the validity of these results. A much larger sample population needs to be utilized to establish accepted normative data criteria. Also, this isokinetic study was conducted three decades ago, so the equipment utilized during the actual testing may not be as accurate as the dynamometers in circulation today. However, when scouring the literature for normative data, this was the only article available that produced a solid background to base future experimentation on.

Isokinetics in Rehabilitation

Isokinetic testing has been utilized in the rehabilitation setting by various health care practitioners and clinicians to ascertain patient strength and stability. It is also utilized in some cases to determine when athletes can return to normal sport specific activities post injury. However, the clinician must know the stage of the healing process that the patient is in before prescribing isokinetic exercise as a part of their rehabilitation in order to prevent aggravation of the injury or possible increased damage to the afflicted area.

For example, in a sample rehabilitation program developed by Ellenbecker and Davies (2000), the researchers suggest initially prescribing submaximal, multi-angle isometrics and then progressing to more complex exercises depending upon reassessment of the patient’s signs and symptoms. The researchers sought to establish a framework of isokinetic rehabilitation progression by listing out the stages that the patient should progress through in order to ensure proper safety and optimal benefits from the prescribed isokinetic rehabilitation protocol. The optimal progression of isokinetic rehabilitation according to Ellenbecker & Davies requires the patient to initially progress through multiple angle isometric submaximal exercises and then finish the protocol with full range of motion, maximal isokinetic exercises (Ellenbecker & Davies 2000).

Initially, the patient must complete static, isometric exercises and then progress to short arc submaximal isometric, short arc isotonic, and short arc maximal isokinetic exercises (Ellenbecker & Davies 2000). These short arc exercises are the primary means of transition for the patient into future dynamic isokinetic movement later in the rehabilitation program. The specified range of motion and contraction velocity (60-180 degrees per second) of these short arc movements promote the avoidance of the afflicted area as well protection of soft tissue healing processes (Ellenbecker & Davies 2000). Isotonic movements should also be mixed into this rehabilitation progression due to their ability to promote muscular loading at the weakest point in the range of motion (Ellenbecker & Davies 2000). This weak point loading is beneficial for building consistent strength throughout the range of motion which will translate to improved movement and increased stability of the upper extremity.

Finally, the patient must progress through full range of motion submaximal isokinetic, full range of motion isotonic, and full range of motion maximal isokinetic exercises (Ellenbecker & Davies 2000). These full range of motion isokinetic exercises are important to utilize at the end stage of the patient’s rehab progression due to the utilization of various functional movement patterns which can work to strengthen and increase the patient's range of motion during the end stage of isokinetic rehabilitation (Ellenbecker & Davies 2000). Also, increased contractile speeds can be utilized during this stage of the progression which hold several benefits including decreased joint compressive forces and increased neurophysiologic motor learning response (Ellenbecker & Davies 2000).

In a different study conducted by Ellenbecker, isokinetic rehabilitation was also discussed but the focus was more on the reliability and validity of the protocol. Within this study, Ellenbecker sought to test the relationship between manual muscle testing and isokinetic strength measurements of the internal and external shoulder rotators (Ellenbecker 1996). Comparing the validity of isokinetic testing in the rehabilitation setting to a popular component of the rehabilitation processes is beneficial to determine whether the use of isokinetic testing and exercise should be prescribed by clinicians. The researcher indicated that the results from the experimentation proved that isokinetic internal and external rotation testing found muscular strength discrepancies in patients who were deemed to possess normal internal and external rotator strength by licensed physical therapists according to manual muscle testing guidelines (Ellenbecker 1996). Therefore, isokinetic measures are a useful tool for clinicians to utilize when determining optimal rehabilitation plans and progressions for the upper extremity. Despite differing focal points, the two rehabilitation studies discussed from the literature shed light on proper isokinetic rehab techniques as well as the reliability and validity of the practices in a rehabilitation setting.

Closed Kinetic Chain Testing

Closed Kinetic Chain testing is another technique being utilized by clinicians in order to test whether their patients have optimal shoulder stability and functionality as well as adequate proprioception and motor control (Oliveira, Pitangui, Nascimento, da Silva, dos Passos, & Araújo 2017). This form of testing can be also utilized post injury as a part of the rehabilitation process to determine if the patient has regained stability and proper function in the injured extremity. It is also beneficial because it is easy for the clinician to administer due to the lack of equipment needed to accurately administer the test.

Before the test begins, tape with a width of 1.5 inches is placed on the ground 36 inches apart from each other (Lee & Kim 2015). The subject participating in the test then must assume a pushup position with one hand on each piece of tape (Lee & Kim 2015). There was a discrepancy between the Lee study and the Oliveira, et. al study regarding starting positioning for the female population. Lee stated that females should perform the test in the same position as male subjects while Oliveira, et. al discussed that females could assume a modified pushup position for the testing (Lee & Kim 2015 (Oliveira, et. al 2017). However, in a study conducted by Roush, Kitamura, & Waits that discussed reference values for the test, females were instructed to start the test in a modified pushup position. Therefore, this is the preferable method of testing for female participants (Roush, Kitamura, & Waits 2007). Next, from this starting position, the subject must reach across their body and touch the piece of tape on the opposite side and then return to the starting position (Lee & Kim 2015). The same movement is then conducted for the opposite side of the subject's body (Lee & Kim 2015). The subjects are allowed a total of 15 seconds to record as many touches as they can while maintaining proper form in their back and shoulders (Lee & Kim 2015). As simple and practical as this test seems, there have not been many studies conducted to test the validity of the results ascertained from this form of testing, so more information is needed before this modality becomes a more common staple of rehabilitation programs.

There were a few studies present in the literature that sought to experimentally determine whether the Closed Kinetic Chain Upper Extremity Test is a valid and reliable entity. One such study conducted by Lee & Kim, examined whether the test was a reliable measure among male and female members of the Korean population. The researchers sought to compare the results taken from the testing to maximum grip strength as well as peak torque values of internal and external shoulder rotation (Lee & Kim 2015). These modality comparison points are like a different study conducted by Oliveira, et. al in which the researchers compared the validity of the test to maximum grip strength and peak torque values of the internal and external shoulder rotators in the adolescent population (Oliveira, et. al 2017). Both sample population sizes in these studies were rather small for testing which could affect whether the data gathered from this test is valid and reliable. The Lee & Kim study used 40 healthy Korean males and females while the Oliveira, et. al study only used 25 healthy adolescents. This is one of the major drawbacks of a lot of the reliability studies conducted on the Closed Kinetic Chain Upper Extremity Test because a much larger sample population is needed to properly establish whether the data gathered from the test is valuable. In comparing the resulting information from these two studies, the study by Lee & Kim indicated a high level of reliability for the Closed Kinetic Chain Upper Extremity test due to a high positive correlation comparison with hand grip strength and isokinetic shoulder internal and external strength (Lee & Kim 2015). However, the Oliveira, et. al study found that the test exhibited moderate to excellent reliability values when compared to the other two modalities due to fluctuations in the testing data attributed to the adolescents only performing one familiarization session with the testing protocol (Oliveira, et. al 2017).

Normative values were discussed in an article by Roush, Kitamura, and Waits. The researchers themselves did not establish these values but they sought to compare these prior established values to testing values obtained from 77 collegiate baseball pitchers (Roush, et. al 2007). These reference values were discussed as being 18.5 touches for male subjects and 20.5 touches for female participants instructed to start off in the modified pushup position (Roush, et. al 2007). However, when comparing these values to the experimental scores obtained from the testing protocol, each category of positions among the collegiate baseball players recorded much higher than 18.5 touches (Roush, et. al 2007). However, these increased values make sense due to the testing being conducted on an athletic population rather than a population comprised of "average participants". The researchers of this study also discussed several concerns that they established regarding the Closed Kinetic Chain Upper Extremity test. One of the main concerns that the researchers discussed was the excessive loads of force presented upon the wrist, elbow, and shoulder joint (Roush, et. al 2007). If a patient has a history of multiple upper extremity issues, it may not be suitable for them to participate in the test due to possible risk of reinjury. Another concern with the test is that a sufficient amount of core strength and stability is needed in order successfully complete the test (Roush, et. al 2007). The researchers were also skeptical regarding the older population attempting this test due to increased risk of fractures and overall lack of stability as age increases (Roush, et. al 2007). The clinician needs to be made aware of these possible concerns and risk factors when prescribing this treatment to their patient population.

Closed Kinetic Chain Testing in Rehabilitation

Closed Kinetic Chain rehabilitation of the upper extremity has begun to gain popularity among health care practitioners due to the noted benefits attributed to its implementation in rehabilitation programs for the lower extremity (McGee, Kersting, & Davies 1998). However, more research needs to be conducted to accurately determine whether this aspect of closed kinetic chain framework can become an integral part of rehabilitation programs designed for the upper extremity. Several studies in the literature discussed instances in which closed kinetic chain methodology have been utilized in rehabilitation programs with noted success.

One of the studies from the literature sought to compare a standard rehabilitation program to a rehabilitation program combined with closed kinetic chain exercises to determine whether closed kinetic chain movements made a difference in enhancing the rehabilitation process in patients with upper extremity issues (Mcgee, et. al 1998). Separately, a different study conducted by Lephart & Henry sought to discuss the physiological framework behind utilizing open and closed kinetic chain movements as a part of rehabilitation programs for the upper extremity (Lephart & Henry 1996). Researching programs that utilize the methodology and purpose behind closed kinetic chain efficacy is beneficial to clinicians and future clinicians seeking to incorporate new applications into their rehabilitation protocol for the upper extremity. It also provides clinicians with proper framework for the necessary progression to administer to their patients when participating in a rehabilitation program with closed kinetic implementation. This progression of closed kinetic chain exercises was discussed in one study in the literature conducted by Sciascia & Cromwell to properly dispense knowledge on the framework and background of kinetic chain movement (Sciascia & Cromwell 2012). These phases discussed in the literature include initial acute stage which is classified by protecting healing tissue and reducing pain as much as possible in the afflicted area (Sciascia & Cromwell 2012). Next, the patient must progress through the recovery phase which promotes muscle reeducation, particularly in the core muscles which are essential for proper performance of most kinetic chain movements (Sciascia & Cromwell 2012). This is then followed by attempts to stabilize the scapula and strengthen glenohumeral efficacy in patients (Sciascia & Cromwell 2012). It is essential to have a firm understanding of these progressions as a clinician in order to safely prescribe kinetic chain movements as a part of a patient's upper extremity rehabilitation plan.

Importance of the Tests and Future Endeavors

Both testing practices have multiple benefits that can be utilized in the rehabilitation setting as illustrated through the various examples discussed from the literature, such as assessment of neuromuscular imbalances as well as determination of rehabilitation program efficacy. Isokinetic testing is a more historically tested modality; therefore, its usage and validity is more well documented than Closed Kinetic Chain testing. However, if more research can be conducted on rationalizing and validating the data gathered from Closed Kinetic Chain testing, it could become more commonly implemented in clinical settings as not only a rehabilitation tool but a method of testing whether patients are capable of returning back to normal activities post upper extremity injury. In the literature, there were a few studies comparing the Closed Kinetic Chain Upper Extremity test to isokinetic testing as a benchmark for validity and each of these studies illustrated that the methods and data seemed to possess a strong correlation. However, most of these studies were conducted many years ago with different sampling populations.

Previous studies have not adequately compared these two modalities directly, in terms of evaluating whether one modality can predict the other (i.e. Closed Kinetic Chain testing predicting performance on Isokinetic Testing) or if these modalities share any relation at all. The need for this evidence is the reason behind why this current study was conducted, to examine whether data obtained from the Closed Kinetic Chain Upper Extremity (CKCUET) test correlated with data obtained from Upper Extremity Internal and External Isokinetic assessments among average recreational college athletes. Also, this study examined whether the participating subjects achieved scores on both testing modalities that fell within the normative range established by previous analyses within the documented literature.

Methodology

Participants

The 14 subjects who participated in this study were non-student athletes at Merrimack College in the Undergraduate and Graduate programs. The subjects were at least 18 years of age and had no prior or current history of upper extremity injuries or conditions. Individuals were recruited for participation via acquaintances made at the college as well as through verbal education. Once the potential subjects expressed interest in the study, they signed a letter of consent which formally recruited them as a participant in the study.

Instruments/Measures

On the initial testing day, baseline measurements were taken from the subjects including age, height, weight, hand dominance, and gender. Once these measurements were recorded, the subject utilized the Upper Body Ergometer to warm up before the actual testing began. The subjects then participated in the isokinetic assessment first, conducted through the Cybex Isokinetic Dynamometer machine in the Athletic Training room in the Volpe Complex on campus. The measurement that was taken from this physical test for assessment was peak torque of the internal and external rotators of the shoulder girdle. On a separate day, the subjects participated in the Closed Kinetic Chain Upper Extremity Test. The only equipment that was needed for this test is athletic tape, a stopwatch, and a counter. The measurements that were taken from the CKCUET were the total amount of touches recorded by the subjects in the pushup testing position. Once these statistics were recorded, the average number of touches for each subject was utilized for data analysis.

Procedures

Before any tests or measurements were conducted, IRB approval was achieved through Merrimack College. Once this approval was granted, subjects were asked to set up a schedule for both testing days required for the study through a google sheet.

On the first scheduled day of testing, subjects signed a consent form that stated their willingness to participate in the study. Next, baseline measurements were taken for the subject including gender, age, height, hand dominance, and weight. Once these measurements were recorded, the subject was instructed to warm up for 5-10 minutes on the Upper Body Ergometer located in the Athletic Training room in the Volpe Complex on campus. As the subject was warming up, various adjustments were made to the Cybex Isokinetic Dynamometer to ensure proper functioning for testing procedures (See appendix for full set up specifications). Once the equipment was properly set up, the subject was instructed to sit in the chair and prepare for testing to begin. The subject then performed 5 maximal repetitions of internal and external shoulder rotation at 60 and 180 degrees per second with approximately a minute's rest between each speed trial. The subjects were also allowed three practice repetitions at each speed in order to acclimate to the testing speed.

On a separate day, subjects were scheduled to participate in the Closed Kinetic Chain Upper Extremity Test. Prior to the actual testing, subjects warmed up on the Upper Body Ergometer for approximately 5-10 minutes. As the subject was warming up, tape with a width of 1.5 inches was placed on the group approximately 36 inches apart. Once the subject was properly warmed up, they assumed a pushup position (modified pushup position for female participants). Once this position was achieved, the subject had 15 seconds to reach across their body, touch the piece of tape on the opposite side, return to the starting position, and then repeat the same process on the opposite side while they maintained proper form throughout. Each subject participated in three trials for the test with a minute's rest between each. Once all the trials were completed, an average of the data was utilized for analysis.

Data Analysis

Correlational analyses and regressions analyses were performed. These inferential analyses were chosen as a means to determine whether there was a relationship between the two variables (Isokinetic testing and Closed Kinetic Chain Upper Extremity testing). The correlation analyses were performed utilizing only the subjects that expressed right hand dominance due to the small percentage of left handed subjects within the sample population.

Results

A total of 15 participants agreed to participate in the study. One subject was unable to complete all the data collection procedures, therefore, data from this subject was excluded from the data analysis resulting in a total of 14 participants

There were 11 male and 3 female subjects recruited for this study. The average age of the subjects was 22.5 years old (SD=1.1). Average height and weight of the subjects was also collected and reported as 69 inches (SD=2.4) and 174.9 pounds (SD=27.2) respectively. Subjects also reported hand dominance with 12 identifying as possessing right hand dominance and 2 possessing left hand dominance.

Table 1: Correlational analyses comparing Isokinetic measurements to CKCUET

Isokinetic Measurements	Average CKUET Correlation
RIR (60)	-0.0632
LIR (60)	0.1446
RIR (180)	0.1614
LIR (180)	0.2604
RER (60)	0.2809
LER (60)	0.2145
RER (180)	0.4335
LER (180)	0.3377

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Note: *Correlation coefficient's closer to 1 indicated strong correlation*

CKCUET refers to the Closed Kinetic Chain Upper Extremity Test

*Reference- RIR (right internal rotation), RER (right external rotation), etc.… *

Table 2: Correlational analyses comparing Isokinetic Measurements

Isokinetic Measurements	Isokinetic Measurements	Correlation Coefficient
RIR (60)	LIR (60)	0.7897
RIR (180)	LIR (180)	0.9162
RER (60)	LER (60)	0.6895
RER (180)	LER (180)	0.5778

Note: *Correlation coefficient's closer to 1 indicated a strong correlation*
*Reference- RIR (right internal rotation), RER (right external rotation), etc.….

Table 3: Adjusted Regression analyses comparing Isokinetic measurements to Weight & CKCUET

Isokinetic Measurements	Average CKCUET Correlation	Weight Correlation Coefficient	Standard Error (CKCUET)	Standard Error (Weight)	P Value (CKCUET)	P Value (Weight)
RIR (60)	-.3034628	.2741583	.7794706	.1449114	0.704	0.085
LIR (60)	.2340353	.4044587	.5203416	.0967376	0.662	0.002
RIR (180)	.3262383	.2347766	.688283	.1279587	0.645	0.094
LIR (180)	.5493646	.3025638	.5793721	.1077111	0.363	0.017
RER (60)	.3058486	.1141565	.31555	.0586639	0.353	0.078
LER (60)	.2666702	.1068711	.3928057	.0730265	0.511	0.171
RER (180)	.5712906	.1133838	.3430122	.637694	0.124	0.103
LER (180)	.4029513	.1356639	.319515	.059401	0.233	0.043

Note: *Correlation coefficients indicated measure of association between variables*
* p value < .05 indicated data significance*
CKCUET referred to the Closed Kinetic Chain Upper Extremity Test
*Reference- RIR (right internal rotation), RER (right external rotation), etc.…

Table 4: Crude Regression analyses comparing Isokinetic measurements to CKCUET

Isokinetic Measurements	Average CKCUET Correlation	Standard Error (CKCUET)	P Value (CKCUET)
RIR (60)	-.1878654	.856523	0.830
LIR (60)	.4045732	.7991659	0.622
RIR (180)	.4252306	.7507796	0.582
LIR (180)	.6769391	.7246897	0. 369
RER (60)	.3539821	.3492002	0. 331
LER (60)	.3117319	.4098025	0. 462
RER (180)	.6190983	.3714783	0. 121
LER (180)	.4601533	.3702837	0. 238

Note: *Correlation coefficients indicated measure of association between variables*
p value < .05 indicated data significance
CKCUET referred to the Closed Kinetic Chain Upper Extremity Test
*Reference- RIR (right internal rotation), RER (right external rotation), etc...

Table 5: Adjusted Regression analyses comparing Isokinetic measurements to CKCUET & Hand Dominance

Isokinetic Measurements	Average CKCUET Correlation	Hand Dominance Correlation	Standard Error (CKCUET)	Standard Error (Hand Dom.)	P Value (CKCUET)	P Value (Hand Dom)
RIR (60)	-.1549935	2.780064	1.214786	13.86647	0.902	0.846
LIR (60)	.3405708	13.52726	1.036518	11.83158	0. 751	0. 286
RIR (180)	.8283764	-1.936607	1.036455	11.83087	0. 447	0. 874
LIR (180)	.9261721	2.625658	.9864503	11.26007	0. 375	0. 821
RER (60)	.3270382	-1.109584	.4781503	5.457962	0. 513	0. 844
LER (60)	.2204012	6.792079	.4798345	5.477187	0.658	0. 250
RER (180)	.6740144	-4.540884	.5066184	5.782918	0. 220	0. 455
LER (180)	.4789643	4.0006	.4795479	5.473915	0. 347	0. 486

Note: *Correlation coefficients indicated measure of association between variables*
p value < .05 indicated data significance

Table 6: CKCUET Subject Data

Subject	CKCUET (Trial 1)	CKCUET (Trial 2)	CKCUET (Trial 3)	CKCUET (Average)
1	26	26	32	28
2	26	32	34	31
3	26	28	35	30
4	21	28	25	25
5	23	25	26	25
6	17	18	23	19
7	19	23	25	22
8	14	16	20	17
9	30	26	32	29
10	16	21	24	20
11	21	23	26	23
12	21	22	22	22
13	20	22	21	21
14	15	14	15	15

Note: * CKCUET referred to the Closed Kinetic Chain Upper Extremity Test

Table 7: Isokinetic Measurements Subject Data

Subject	Peak Torque (RIR60)	Peak Torque (LIR60)	Peak Torque (RIR180)	Peak Torque (LIR180)	Peak Torque (RER60)	Peak Torque (LER60)	Peak Torque (RER180)	Peak Torque (LER180)
1	27	37	26	29	20	9	26	10
2	34	46	32	34	20	24	17	19
3	41	40	38	37	26	24	21	21
4	50	65	42	51	30	27	23	27
5	75	56	63	54	29	26	27	21
6	28	28	23	16	14	15	10	9
7	25	27	22	23	16	12	12	8
8	44	35	30	28	20	20	15	14
9	27	27	28	26	12	21	8	15
10	21	20	8	9	12	10	7	5
11	22	25	17	18	11	6	8	5
12	46	57	30	36	19	27	10	20
13	38	31	30	21	16	19	12	14
14	42	42	36	34	16	17	10	13

Note: Peak Torque measured in Newton meters

Discussion

Interpretation

Through the utilization of the data analyses, this study discovered numerous information regarding these two testing modalities. In addition to determining that there was no statistically significant relationship present between the two tests, it was also discovered that hand dominance had no statistically significant relationship with Isokinetic measurements while body weight did possess a statistically significant relationship with the measurements obtained from Isokinetic testing. Also, through comparisons with normative data for both tests, it was observed that the majority of the subjects who participated in this study exceeded normative values with only three subjects exhibiting less than average values.

Through correlational analyses between Isokinetic testing and CKCUET exhibited in Table 1, it was determined from the values reported that there is no significant correlation between the two testing modalities in healthy college athletes. All correlations found through the analyses were insignificant, indicating that even the fairly weak correlations obtained from this experimentation could have been obtained through chance, meaning that the values could be different if the analyses were run a second time. Since no significant correlation was present between the two modalities, this indicates that there is no common relationship between the two. This finding conflicts with the information discussed in several studies in the literature including experiments conducted by Lee & Kim (2015) and McGee, Kersting, & Davies (1998). During these experiments in the literature, the researchers utilized Isokinetic testing on their subjects in tandem with the CKCUET in order to test the efficacy and reliability of the CKCUET. While no specific statistical measurements were mentioned in these studies, it can be interpreted that the researchers chose this methodology due to the perceived strength of the relationship between the two testing modalities. This discrepancy between previous research and this current study is most likely attributed to the small sample size that was utilized in the current study because there were not enough subjects to quantify significant data.

Through examination of several adjusted and crude regression analyses exhibited in Tables 3, 4, and 5, it was further determined that measurements taken from Isokinetic testing had no real relationship with the measurements gained from the CKCUET. Furthermore, it was established that hand dominance of the subjects had no significant relationship to the results obtained from the Isokinetic measurements. However, through examination of individual data from the subjects, it can easily be observed that the subjects' dominant arm tended to produce a greater amount of peak torque than the non-dominant arm.

This result is interesting because there are differing reports in the literature regarding the effects of hand dominance on Isokinetic testing results. For example, in a study conducted by Brown, Niehues, Harrah, Yavorsky, and Hirshman (1988), it was reported that increased levels of torque were produced by the participant's dominant arm in comparison to their non-dominant arm at all testing speeds. Conversely, a study conducted by Ivey Jr., et. al (1984) referencing normative data for Isokinetic testing reported no statistical difference between the subjects' dominant and non-dominant arm but observed consistent patterns of increased strength in the dominant arm (Ivey Jr., et. al 1984). Therefore, there is conflicting research in the literature related to hand dominance, a quandary that the current study does not particularly solve. However, most of the subjects in the current study were right handed, thus creating an experimental bias towards these right-hand dominant participants. Through this bias, the efficacy of these insignificant hand dominance results can be called into question. Through this limiting factor via the small sample size, hand dominance was ultimately determined to not have a significant effect on Isokinetic performance because none of the experimental p values registered as significant (value <.05). Future studies should aim to balance the sample population between right and left-hand dominance in order to develop a more accurate picture of the effects that hand dominance has on Isokinetic measurements.

Conversely, bodyweight was proven to have a significant impact on Isokinetic measurements gathered from the testing conducted during the current study. This result was expected because the more body weight that an individual possesses, generally will allow that individual to produce a greater amount of torque and force due to the increased level of mass present on that individual's body. This finding was confirmed through a study conducted by Zakas, Mandroukas, Vamvakoudis, Christoulas, and Aggelopoulo (1995). In this study, the researchers discussed that bodyweight had a positive effect on peak torque values gathered from testing of the quadriceps muscles of basketball players (Zakas, et. al 1995).

Data obtained from these two testing modalities were also used to compare to established normative data gathered from previous studies in the literature. Exhibited in Tables 6 and 7, these results were compared with normative data taken from studies conducted by Roush, Kitamura, and Waits (2007) and Ivey Jr., Calhoun, Rusche, and Bierschenk (1984). In the study conducted by Roush, et. al (2007), normative values were referenced for male and female participants of the CKCUET in comparison to results obtained from administering the test to collegiate baseball players (Roush, et. al 2007). These reference values were obtained from a separate study conducted by Ellenbecker, Manske, and Davies (2000) in which males were reported as achieving an average of 18.5 touches while females achieved an average of 20.5 touches in their designated modified pushup position (Ellenbecker, et. al 2000). Through comparing these reference values to the data obtained from the current study, all but two of the male participants in this study scored higher than the reported average of 18.5 touches. Similarly, all but one of the female participants in this study scored higher than the reported average of 20.5 touches. This is most likely due in part to the fact that all the participants in this study were healthy and had no previous history of upper extremity injury or discomfort.

The CKCUET is a testing modality dependent upon shoulder stability and health. Therefore, if a patient exhibits a history of shoulder issues, this test is going to prove rather difficult for the patient to complete due to the amount of stress placed on the shoulder joint during this movement, as well as the amount of shoulder stability needed to effectively perform this test. This modality can also be used as an indication of core strength due to the amount of core activation necessary to perform this test. This testing modality could prove useful during the initial evaluation stage of the rehabilitation process because it can give the clinician a chance to evaluate particular areas of weakness that the patient may possess. Also, this modality could be implemented at the end of a patient's rehabilitation program as a means to determine whether the patient is safe to return to normal activities and if the rehabilitation program that was implemented was successful.

Isokinetic upper extremity normative data was discussed in a study conducted by Ivey Jr., et. al (1984) via average volunteers. The main result discussed in that study that holds importance for the current study is the analysis of internal and external shoulder rotational strength. The researchers found that internal rotation strength was commonly greater than external rotation strength by a ratio of 3:2 (Ivey Jr., et. al 1984). This information correlates with the results observed within the current study because all subjects demonstrated increased internal rotational strength compared to external rotational strength values. This is most likely due to the majority of everyday movements involving the upper extremity occurring via internal rotation of the upper extremity. Muscles responsible for external rotation in the upper extremity are most commonly utilized as stabilizers, therefore, they are usually not as strong as muscles responsible for the main movement being enacted by the body. Like the CKCUET, this testing modality should be utilized by clinicians during the initial evaluation stage and end rehabilitation stage as a means to determine initial weak points on the patient and to track progress gained through the implementation of the designated rehabilitation protocol.

Limitations

There were several limitations in the study, the most prominent being the sample size. The 14 subjects who completed this study presented adequate data and some conclusions were able to be made from this data, however this is an insufficient sample size needed to truly answer the research questions presented in this study and to test for statistical significance. It is plausible that the small sample size of the current study affected the results gathered from the experimentation, particularly the correlation between the two testing modalities. Future studies of this area need to utilize much larger sample sizes in order to determine the efficacy of the results gathered from the current study.

Another issue that may have affected the results from the current study is that most of the participants were right-hand dominant. This created an imbalance when examining data obtained from dominant and non-dominant shoulders of the subjects. This discrepancy between right and left-hand dominance influenced results derived from this study, particularly the analyses comparing Isokinetic data and hand dominance of the study participants. Future studies of this area need to ensure even numbers of right and left hand dominant subjects in order to ensure accurate results between the two upper extremities.

The final major limitation that affected the results of this study is that the majority of the participants were male. This gender bias influenced the results pertaining to the Isokinetic measurements because males generally weigh more, thus translating to increased peak torque values as the literature discussed. Therefore, the findings related to bodyweight in this study could be disputed due to this gender bias.

Future/Practical Applications

Based on the information presented in this study, several conclusions can be made regarding these two testing modalities. Primarily, each of these modalities should be included during the rehabilitation process of the upper extremity due to the measured success in quantifying an individual's strength and stability in the upper extremity. For example, the CKCUET could be implemented either towards the end stages of the rehabilitation protocol or during the initial evaluation process because this test can be used as a means of identifying patient weaknesses as well as to track patient progress over the course of the rehabilitation program. This is corroborated in the literature through a study that stated that general closed kinetic chain rehabilitation exercises can and should be implemented during all stages of the rehabilitation process to promote muscle reeducation and soft tissue mobility, as well as stability and proprioception (Sciasia and Cromwell 2012).

Similarly, Isokinetic testing of the upper extremity should be implemented throughout the duration of the rehabilitation process. Through examination of the literature, it was determined that clinicians should utilize submaximal Isokinetic exercise prescription during the early stages of the rehabilitation protocol to encourage soft tissue healing (Ellenbecker and Davies 2000). Then as the patient progresses, the clinician should transition towards maximal isokinetic exercise prescription to promote strength in the affected area (Ellenbecker and Davies 2000). This maximal focused phase of the rehabilitation process is where the Isokinetic testing should occur as a means to assess whether the patient is making the gains necessary to return the afflicted area to a normative state.

While this study indicated that there is no significant relationship between the two testing modalities, it was evident that these tests do an adequate job of examining shoulder functionality and health within the sample population. Through comparisons made between the current study and normative data established through the literature, it was evident that the majority of this study's population possessed adequate shoulder health and functionality with only 3 out of the total 14 subjects reporting outside of normative values in the CKCUET, and all subjects meeting normative criteria for Isokinetic measurements. Future studies should attempt to examine whether this trend holds true for a sample population that has a history of upper extremity injuries. It would be interesting to observe these individuals' scores and compare them to the established normative data as a means of determining whether they have made improvements in their shoulder health or if they are still plagued by issues.

This study also presented some interesting results regarding factors that affected the measurements obtained from the Isokinetic test. Some of these results were contradictory to what was presented in the literature, mainly the hand dominance statistical insignificance. This anomaly could be worth researching in future studies with a larger sample size in order to determine whether this result from the current study is accurate or simply due to the lack of a sufficient sample population.

Conclusion

In summary, the most important finding exhibited through this study is that these testing modalities can be utilized by clinicians to determine whether their patient possesses optimal upper extremity strength and stability. Through the measurements gained from these tests, the attending clinician can adequately develop a rehabilitation program for their patient. These tests allow the clinician to gain an understanding of the patient's weak areas and plan accordingly on how to optimally target these areas and make improvements.

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Appendix A: Informed Consent

MERRIMACK COLLEGE

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Consent to Participate in Research Study

Title of Study: Comparison of Isokinetic Testing to Closed Kinetic Chain Upper Extremity Testing in Recreational College Athletes
Investigator: Joe Bernardo, Exercise/Sports Science Graduate Student at Merrimack College
IRB Number: IRB-FY17-18-50

Introduction

You are being asked to be in a research study to test the reliability of two rehabilitation assessments for the upper extremity. You were selected as a possible participant because you are a student at Merrimack College and you do not have a previous or current history of injury to the upper extremity. We ask that you read this form and ask any questions that you may have before agreeing to be in the study.

Purpose of Study

The purpose of the study is to compare two types of upper extremity rehabilitation assessments in order to determine whether they are beneficial. This research could aid clinicians in developing more efficient rehabilitation protocols for the upper extremity. Ultimately, this research may be presented as a part of a final capstone requirement.

Description of the Study Procedures

If you agree to be in this study, you will be asked to do the following things: participate in isokinetic testing for approximately one hour and participate in closed kinetic chain testing for approximately 30 minutes on a separate day

Risks/Discomforts of Being in this Study

The study has the following risk. The subject may experience slight discomfort in the upper extremity during one of the testing protocols. However, both tests are conducted routinely in the rehabilitation setting, therefore the risk is very minimal in this population.

Benefits of Being in the Study

The benefits of participation are that the subjects will gain an understanding of their upper extremity strength and functionality and if there are any possible imbalances in their shoulder function.

Confidentiality

The records of this study will be kept strictly confidential. Research records will be kept in a computer only accessed by the researcher and once the testing and finalization of the data is completed, the records will be erased from the computer.

Payments or Compensation

There will be no payment or compensation for this study.

Right to Refuse or Withdraw

The decision to participate in this study is entirely up to you. You may refuse to take part in the study *at any time* without affecting your relationship with the investigators of this study, Merrimack College or any study partners. Your decision will not result in any loss or benefits to which you are otherwise entitled. You have the right not to answer any single question, as well as to withdraw completely from the interview or survey at any point during the process; additionally, you have the right to request that the interviewer not use any of your interview material.

Right to Ask Questions and Report Concerns

You have the right to ask questions about this research study and to have those questions answered by me before, during or after the research. If you have any further questions about the study, at any time feel free to contact me, Joe Bernardo at bernardoj@merrimack.edu or by telephone at (401) 644-6309. You may also contact the Merrimack College faculty supervisor of this research, Sarah Benes, at beness@merrimack.edu. If you like, a summary of the results of the study will be sent to you. If you have any other concerns about your rights as a research participant that have not been answered by the investigators, you may contact the Chair of the Merrimack Institutional Review Board at (9780 837-5280 or by email at irb@merrimack.edu.
If you have any problems or concerns that occur as a result of your participation, you can report them to the Chair of the IRB at the contact information above.

Informed Consent

Your signature below indicates that you have decided to volunteer as a research participant for this study, and that you have read and understood the information provided above. You will be given a signed and dated copy of this form to keep, along with any other printed materials deemed necessary by the study investigators.

Subject's Name (print): ______________________________

Subject's Signature: ______________________________ Date: __________

Investigator's Signature: ______________________________ Date: __________

Appendix B: Isokinetic Procedure

1. First, I will record the subject's height, weight, and gender as baseline information for testing.
2. Next, the subject will warm up on the Upper Body ergometer for approximately 5 minutes.
3. While the subject is warming up, adjustments to the equipment must be made in order to ensure proper testing arrangements.
4. First, the chair must be rotated to 35 degrees in order to ensure proximity to the dynamometer and then locked in place.
5. Next, the chair positioning must be moved to position 15 to ensure proper proximity to the dynamometer and then locked in place.
6. Once this is completed, the chair back translation needs to be set to 0.
7. The chair back needs to be set to 85 degrees and then locked into place.
8. The dynamometer tilt then must be set to 45 degrees and then locked into place.
9. Adjust the dynamometer height and rotation to position 9 and 5 degrees respectively and then lock into place.
10. Position the monorail and adjust the chair position to 75 and lock into place.
11. Install the elbow pad and the wrist shoulder adapter into the dynamometer and lock into place.
12. Instruct the subject to sit in the chair and then adjust the back translation for suitable comfort.
13. Instruct the subject to place their elbow into the stabilizer and then adjust the height o the dynamometer to ensure that the shoulder is in a neutral position.
14. Ensure that the subject's shoulder is positioned at 90 degrees of abduction
15. Position the hand grip into a comfortable position at the behest of the subject
16. Before initiating the test, secure the subject's arm with the forearm strap.
17. Check the axis of rotation of the shoulder and adjust the shoulder straps to ensure that the subject remains in place.
18. The testing will be performed at 60, and 180 degrees per second.
19. At each speed, the subjects will perform five maximal repetitions of internal and external rotation at each speed.
20. Subjects will be allowed a few practice reps at each speed in order to acclimate to the protocol
21. Subjects will be allowed one minute's rest between testing trials

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Appendix C: Closed Kinetic Chain Upper Extremity Test Protocol

1. First, I will record the subject's height, weight, and gender as baseline information for testing.
2. Next, the subject must properly warmup on the Upper Body Ergometer for 5 minutes.
3. While the participant is warming up, tape with a width of 1.5 inches is placed on the ground 36 inches apart.
4. Once the subject is properly warmed up, I will instruct the participant to assume a pushup position with one hand on each piece of tape (Females should assume the modified pushups position which consists of the female subject placing their knees on the ground).
5. Once the subject has assumed the proper positioning for testing, he or she will have a total of 15 seconds to reach across their body, touch the piece of tape on the opposite side, return to the starting position, and then repeat the same process on the opposite side while maintaining proper form throughout.
6. Each subject will participate in three trials for the test with a minute's rest between each trial.
7. Once all the data is collected, an average of the three trials will be utilized for data analysis.