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Isokinetic Dynamometry in Measuring Bilateral Shoulder Peak Torque: Comparison and Prediction

قياس عزم عضلات الكتف الثنائية: مقارنة وتنبؤ

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Abstract

Background: The shoulder joint is the main joint responsible for upper limb movements. Pathology of the shoulder joint creates an imbalance in its bilateral and unilateral movement, in addition to balance and coordination of other joints and movement of the upper limb. Conflicting facts exist in the literature about whether bilateral comparison of shoulder strength is possible and how the dominant and the non dominant shoulder muscle strength relate to each other. **Objective:** To investigate whether flexion/extension and horizontal abduction and horizontal adduction on the shoulder dominant side are significantly different from the non dominant side, and whether a bilateral comparison between muscle strength can be made. **Methods:** Concentric flexion/extension and horizontal abduction/horizontal adduction shoulder movements were measured in 23 health male participants using the ISOCOM® dynamometer. Performing five repetitions of each synergetic movement, peak torque values were used for data analysis using the ANOVA variance test along with correlations and linear regression. **Results:** There was no statistically significant difference between dominant and non dominant flexion, horizontal abduction and horizontal adduction ($p< 0.05$). Poor to excellent correlations were found between movements. A linear regression made between the dominant and the non dominant shoulder movements resulted in equations which could predict a shoulder's movement strength from its contra lateral one. **Conclusions:** The study showed that bilateral comparison is possible and can be of help in shoulder pathology rehabilitation as it helps quantifying strength and weakness of the shoulder movements, and is able to predict recovery level and rehabilitation outcomes of the injured shoulder.

Keywords: Isokinetic dynamometry, shoulder, peak torque, rehabilitation.

ملخص

الخلفية العلمية: يعد مفصل الكتف مسؤولا بشكل كبير عن حركات الأطراف العلوية. تخلق أمراض مفصل الكتف خلل في توازن الحركات الثنائية والأحادية الجانب للطرفين العلويين. بالإضافة الى المشاكل في التوازن والتناسق في باقي مفاصل الأطراف العلوية. تختلف الحقائق المتوافرة في الأدبيات السابقة عن وجود دلائل كافية فيما إذا يستطيع المهنيين الصحيين المقارنة بين الطرفين العلويين من حيث القوة وفيما إذا كان هناك ترابط بين الطرف المهيمن والطرف غير المهيمن. **الأهداف**: التحقق من إذا كانت حركات الكتف في الثني والمد والابعاد الأفقي والتقرب الأفقي من مركز الجسم Horizontal abduction/Horizontal (adduction)، مختلفة بشكل احصائي من الطرف المهيمن لغير المهيمن، والتحقق فيما إذا هناك مجال للمقارنة الثنائية لقوى الأطراف العلوية معا. **الوسائل:** تم قياس قوة الانقباض العضلي في الحركات السابق ذكرها لدى ٢٣ شاب ليس لديهم أمراض في مفصل الكتف، باستخدام جهاز قياس الانقباضات العضلية مرتبطة السرعة والوقت (ديناموميتر، ايسوكوم). حُللت قيم العزم المطلقة (قوة الكتف مقاسة بالنيوتن/متر) باستخدام فحص الأنوفا الاحصائي المتخصص في مقارنة المعلومات، كما وتم استخدام تحليل العلاقات المترابطة والتراجع الخطي. **النتائج:** أثبتت النتائج عن عدم وجود فرق ذات قيمة احصائية ما بين قوة عضلات الكتف المهيمن وغير المهيمن من ناحية الثني والابعاد والتقارب الأفقيات (ح<٠.٠٥). تراوحت الترابطات بين الحركات كلها ما بين الضعيفة والممتازة. بعد حساب التراجع الخطي، تم التوصل إلى معادلات خطية توصف و تنبيء بقوة عضلات كل حركة كتف في الطرف المهيمن مع الحركة المقابلة لها في الطرف غير المهيمن. **الخاتمة:** أوضحت الدراسة أن المقارنة الثنائية ما بين عضلات مفصل الكتف واردة ويمكن أن تساعد في تعريف كم القوة والضعف العضلي في الكتف والعلاقة بينهما قادرة على التنبؤ بمقدار واحدة منها من الحركة المقابلة لها في الطرف الآخر.

Introduction

Movement of the human body relies on many body systems and structures. The musculoskeletal system is the foundation of body movement; bones, joints, and muscles create the static and the dynamic elements of movement. While bones and ligaments provide the foundation, stability and strength, muscles provide mobility, strength and function. Not forgetting to mention a sound neurological system to provide innervations to these systems in order to perform movements.

Muscle contraction is the mechanism by which a limb segment moves in a linear or a rotational dimension or maintains a certain position. Muscle contraction is divided into two contraction categories; isometric and isotonic contraction (Åstrand & Rodahl, 1986; Marrieb & Hohn, 2004; Roberts & Falkenburg, 1992; Tortora et al. 2003). Isometric contraction occurs when the muscles do not lengthen or shorten, but the muscle tension maintains a certain position or movement (Marrieb & Hohn, 2004; Roberts & Falkenburg, 1992; Tortora et al. 2003).

Isotonic contraction is divided to eccentric and concentric contraction. Concentric contraction is the active mode of muscle shortening as it overcomes an amount of external resistance, while eccentric contraction is the active mode of muscle lengthening as it is overcome by an external resistance (Dvir, 2004). In exercise eccentric and concentric contractions are most common. In addition to exercise and strengthening programmes, muscle testing is carried out for many purposes of investigation, or identifying muscle strength properties and weaknesses. Isokinetic testing is a part of a method where muscle strength is measured when exerting a force against a resistance resulting in the movement of the limb segment around its joint (Åstrand & Rodahl, 1986).

Isokinetics and isokinetic testing is commonly used in medicine, rehabilitation and sports studies (Dvir, 2004; Baltzopoulos, 2008). The aim of Isokinetics is either evaluation of muscle and joint strength and function or the strengthening and exercise of upper and lower limbs.

Among the joints of the body a major complicated joint which involves a massive amount of movement; the shoulder. The shoulder is a complex joint made up of many articulations capable of a wide variety of motions. The shoulder complex is made up of the clavicle, the humerus, the sternum, the scapula, the ribs, and the vertebral column (Rybski, 2004). The distinctive feature about the shoulder is that it is tied and connected to the whole body and interacts with back and chest muscles. The shoulder joint consists of a combined and coordinated movement of four distinct articulations - glenohumeral, arcomioclavicular, sternoclavicular, and scapulothoracic - which allow the arm to be positioned in space for efficient function (Nordin & Frankel, 1989). The four articulations of the shoulder joint complex acting together to provide the nearly full range of motion found in the shoulder, the sum of which is greater than the motion available at any single articulation. Of the four articulations, the glenohumeral joint bears the greatest load (Nordin & Frankel, 1989). The mobility of the shoulder joint is a result of motion in both glenohumeral joint and scapulothoracic-gliding plane (Veeger & Van der Helm, 2007).

In sports several injuries might create a problem for an athlete's career and well-being (Downer & Sauers, 2005). Throwing sports such as baseball and volleyball are very physically demanding. The throwing movement of the shoulder requires a sequential and coordinated muscle contraction (Perko, 2003). However, the repetitive throwing movement had shown to cause many disabilities in the throwing shoulder (Cooper et al. 2004), such as degenerations in the joint capsule, neurological disabilities, arterial and venous thrombosis, and impingement and instability of the glenohumeral joint.

In rehabilitation, stroke, spinal cord injury, head injury and other upper limb trauma cases also affect the shoulder joint. Upper limb injuries are common and can affect people of all walks of life (Baxter & McKenna, 2002). Clinicians such as health care professions aim at restoring the function and movement to the affected upper limb.

The ability to predict limb strength by using the same movement of the contra lateral limb helps clinicians create a base line to refer to in order to reach or set a goal for rehabilitation and recovery after an injury. Isokinetic testing was shown to be reliable in providing correct measurements of muscle strength (Dvir, 2004). Bilateral comparison of peak torque was found to be the most appropriate outcome parameter to distinguish patients and healthy persons (Meeteren et al. 2004).

This research aimed to investigate differences between the dominant and non dominant shoulders in shoulder flexion, extension, horizontal abduction and horizontal adduction in a healthy, male population, 18-35 years old at a 95% confidence limit. The research strived at understanding whether a comparison of the right and left (dominant and non dominant) above mentioned shoulder muscle groups can be made. This understanding might help the rehabilitation process whenever an injury of a shoulder muscle groups occur.

Studies of healthy populations have helped in finding some identifiable parameters to be investigated when researching shoulder isokinetic parameters.

Methods

The study recruited a convenience sample of 23 healthy male students of the University of Southampton, where the researcher conducted the research. The participants had to be male students of the University of Southampton between the ages of 18 to 35 years old with no present or previous shoulder injury in which complications are still persistent, no shoulder injury or fracture six months prior to the study, and no athletic activity of a national level, nor exercising in the gym for more than four times a week.

Materials and procedure

The ISOCOM® dynamometer (Eurokinetics Limited, UK) was used in the study (figure 1). The ISOCOM self calibrates itself whenever started and it has advantages over the Cybex® and the Biodex® by constantly checking its' two speed torque sensors (Spencer-Wimpenny, 2008 per comm.). Testing protocol used in the study was in accordance with other studies and other dynamometers used in similar studies (Cahalan, 1989; Skhlar & Dvir, 1994; Dauty et al. 2003).

The supine position was chosen in accordance to the experimental purpose of the study (Mayer, 2001). In this study an angular velocity of 60° per second was used with five repetitions which are advised for research purposes (ISOCOM manual).

The ISOCOM® was calibrated every time it was started. Four concentric movements at the preset angular velocity of 60° degrees per second were performed by participants; dominant/non dominant flexion/extension, dominant/non dominant horizontal abduction / adduction (figure 2, 3) The flexion extension movement is the movement where the arm is fully extended and adjacent to the trunk. Then the arm moves up parallel to the trunk as flexion and back down as extension. Flexion/extension was performed in the sagittal plane.

Figure (1): The ISOCOM® dynamometer (Eurokinetics Limited, UK) used for the study (Own collection, 2008).

Figure (2): horizontal abduction/ horizontal adduction movement performance on the ISOCOM ®, note alignment of the dynamometer and the shoulder joint axes (Own collection, 2008).

Figure (3): Flexion/extension movements performed using the ISOCOM®, note alignment of the dynamometer and the shoulder joint axes (Own collection, 2008).

All four movements were performed in a supine position with support given to the lumbar area by appropriate placement of a towel. The axes of the shoulder joint were always aligned with the dynamometer axis.

A pilot study with two volunteers took place before starting data collection in order to check the procedure and make sure the test can be made with no external or internal major errors. The study resulted in changing the testing position from sitting to supine as it was more feasible to use the dynamometer and it gave more stabilized position to conduct the movement although it meant a less functional movement (Ellenbecker, 2002).

Participants presented at the Human Performance Laboratory in the School of Education, Highfield Campus, University of Southampton. They were asked to give us approximately an hour of their time.

Upon arrival, each participant was given full details of what he would be asked to do; participants were familiarized with the ISOCOM ® and the researcher explained how the dynamometer worked. Then participants had the chance to ask questions regarding the procedure or any concerns they had. Each participant signed a consent form before starting the testing.

A checklist of general demographic data was filled before the testing procedure. It included age, weight, height, hand dominance determined by the hand participants used for writing, and an alias random number that was given for each participant. Before each movement participants familiarized themselves with the machine until Isokinetic ROM was set by the dynamometer in order to determine the maximum ROM they can achieve within their own safe limit. Mechanical stops were then located to prevent hyper movement that might injure the participants.

A two to three minute break was given to the participants between each movement until the ISOCOM® was ready for the next movement. The four movements were carried out by all 23 participants with no data missing. Unusual errors occurred in different testing stages to different participants where the dynamometer had to be recalibrated, but the test itself was not affected and everything was completed with no problems.

Data sheets obtained from the ISOCOM® after each test contained peak torque values, peak torque values to body weight and a percentage of muscle strength between the synergy of extension/flexion, horizontal abduction/horizontal adduction.

To investigate dominance effect on muscle strength in bilateral peak torque values of the shoulder, an ANOVA test of variance was chosen; as it best fits the repeated measures data collected in this study (Field, 2005).The ANOVA test investigated a probability value of 95% of dominance and movement being involved in determining muscle strength in shoulder movements. A further post hoc paired p t-test was conducted to confirm results accordingly.

A correlation with Pearson's Correlation Coefficient and a linear regression was conducted which investigated the relationship between the variables. All tests were conducted using SPSS 16.0.

The study was approved by the School of Health Professions and Rehabilitation Sciences Ethical Committee (SHPRS-ETHICS-08-018, and sponsored and insured by the Research Governance Office (RGO) of the University of Southampton (RGO-REF 5845).

Results

The study included 23 male participants with mean age of 24.83 years (19-33), mean mass (weight) of 75.848 kgs, and a mean height of 179.391 cm. All participants were right handed; 70-90% of people around the world are right handed (Holder, 2001).

Muscle groups peak torque mean values (figure 1) shows the descending order of their strength as the following: extension (69.00 Nm), horizontal adduction (58.44 Nm), flexion (53.75 Nm), and horizontal abduction (49.38 Nm).

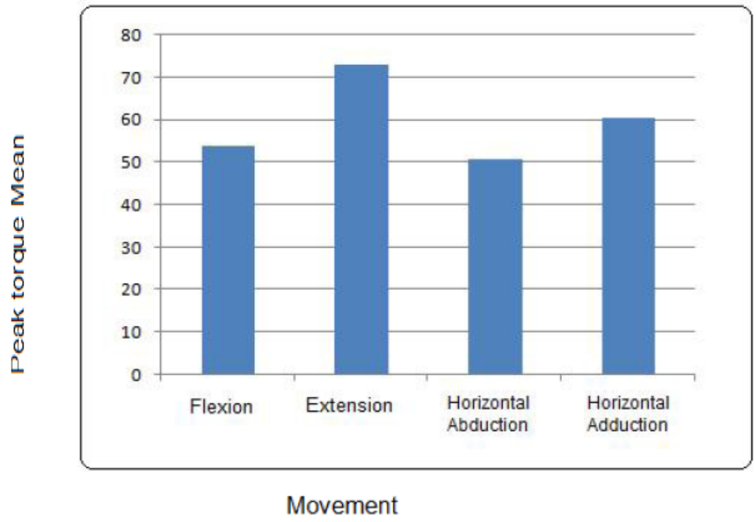

Figure (1): Peak torque values of flexion, extension, horizontal abduction, and horizontal adduction muscle groups.

ANOVA Test of Variance

For the first synergetic movement flexion/extension, there were no significant differences ($p \leq 0.05$) between the dominant and the non dominant arm when flexion/ extension. However, there was a significant difference between agonist/antagonist movement i.e. flexion/extension ($p \leq 0.05$). But then the test showed a statistical significant difference between movement and dominance ($p = 0.026$). A post hoc paired t-test was conducted for the dominant/non dominant extension torque values using the SPSS 16.0, which revealed a statistical significant difference of $p = 0.021$ between them. As a result, extension on the dominant side showed to be statistically different from the non dominant one.

For the second synergetic movement horizontal abduction/adduction the same was done. The ANOVA test revealed no significant difference between the dominant and the non dominant horizontal abduction/horizontal adduction arm movements ($p \leq 0.05$). A statistical significant difference, however, was found between the agonist and antagonist movement i.e. horizontal abduction/horizontal adduction ($p < 0.05$). This means that the dominant horizontal abduction and horizontal adduction movements were not statistically different from the non dominant horizontal abduction and horizontal adduction.

Anecdotally, the dominance/movement interaction for horizontal abduction and horizontal adduction showed no statistical difference ($p= 0.615$). This means that statistical difference exhibited only between horizontal abduction and horizontal adduction in the same side but not between the contra lateral sides. Since the ANOVA test showed no significance between the movement and dominance interaction, no further investigations were needed.

Correlations

Very good to strong correlations were found between flexion and extension in both dominant and non dominant side. Dominant flexion correlated strongly with non dominant flexion ($r= 0.762$), and with the dominant and non dominant extension ($r= 0.734$ and 0.770), respectively. The dominant extension had a good correlation with the non dominant extension ($r= 0.648$) and with the non dominant flexion as well ($r= 0.626$). The non dominant extension showed a strong correlation with the non dominant flexion ($r= 0.787$). On the other hand, dominant horizontal adduction correlated poorly with the dominant abduction, and good to very good with the non dominant horizontal abduction and the non dominant horizontal abduction ($r= 0.609$, 0.704), respectively. Moreover, dominant horizontal abduction correlated fairly with the non dominant abduction ($r= 0.469$), and the non dominant horizontal adduction ($r= 0.511$). A strong correlation was seen between the non dominant horizontal abduction and the non dominant horizontal adduction (0.794).

Regression

A linear regression was conducted between the dominant flexion and non dominant flexion, the dominant extension and non dominant extension, the dominant and the non dominant horizontal abduction, and the dominant and non dominant horizontal adduction.

Table 3.6 Linear regression results; coefficients, constants, and regression predictors for each movement

Movement	Coefficient	Constant	Predictors
Non Dom Flex	0.691	16.482	Constant, Dom Flex
Non Dom Ext	0.452	32.030	Constant, Dom Ext
Non Dom HorAbd	0.352	31.068	Constant, Dom HorAbd
Non Dom HorAdd	0.783	9.298	Constant, Dom HorAdd

Dom: dominant **Flex: flexion** **Abd: abduction**
Ext: extension **Hor: horizontal** **Add: adduction**

The linear regression was conducted to find a relationship between the non dominant shoulder movement, which was the independent variable, and the dominant one which was the predictor of the first one.

The constants and the coefficients were used to compose equations that defined the predictive relationship between movements. The equation was as follows:

Non dominant Movement peak torque = Coefficient X dominant flexion peak torque + constant

Using this equation, each movement's strength can be predicted from its contra lateral one;

Non dominant flexion (Nm) = 0.691 x dominant flexion (Nm)+ 16.482 (figure 4)

Non dominant extension (Nm) = 0.452 x dominant extension (Nm) + 32.030 (figure 5)

Non dominant horizontal abduction (Nm) = 0.352 x dominant horizontal abduction + 31.068 (figure 6)

Non dominant horizontal adduction (Nm) = 0.783 x dominant horizontal adduction + 9.298 (figure 7)

These equations were applied on dot scatter plots for each bilateral movement that showed the amount of agreement between their muscle strength values. After that, studying the plots with the equations, the equations were applied to each movement plot's minimum value of agreement, which was identified by being the farthest dot from the equation line on the plot, and the maximum value, which was also identified by being the closest dot to the equation line.

Prediction results obtained from the equations showed that the equations were able to predict muscle strength values of 71% - 100%, 72% - 100%, 69% - 100%, and 66.2% - 100% for flexion, extension, horizontal abduction and horizontal adduction, respectively.

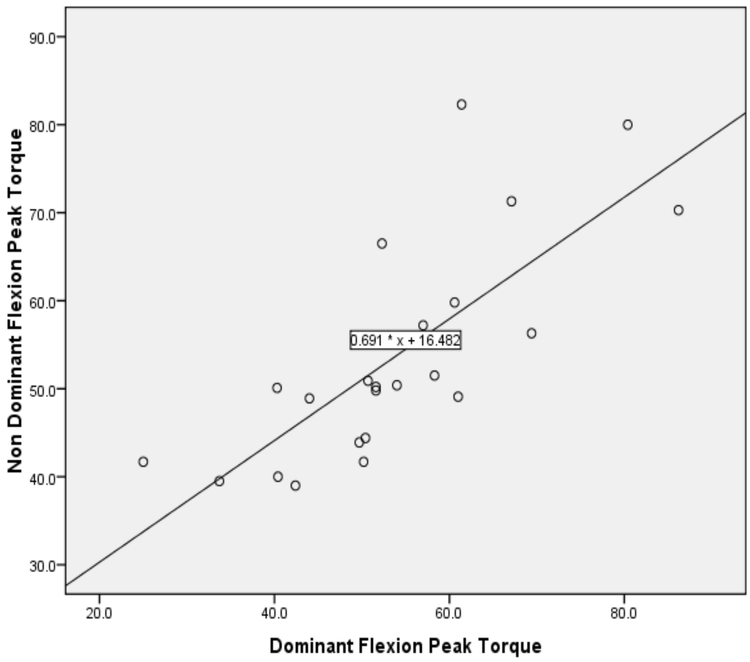

Figure (4): Scatter plot of Dominant and non dominant flexion peak torque values with the equation applied.

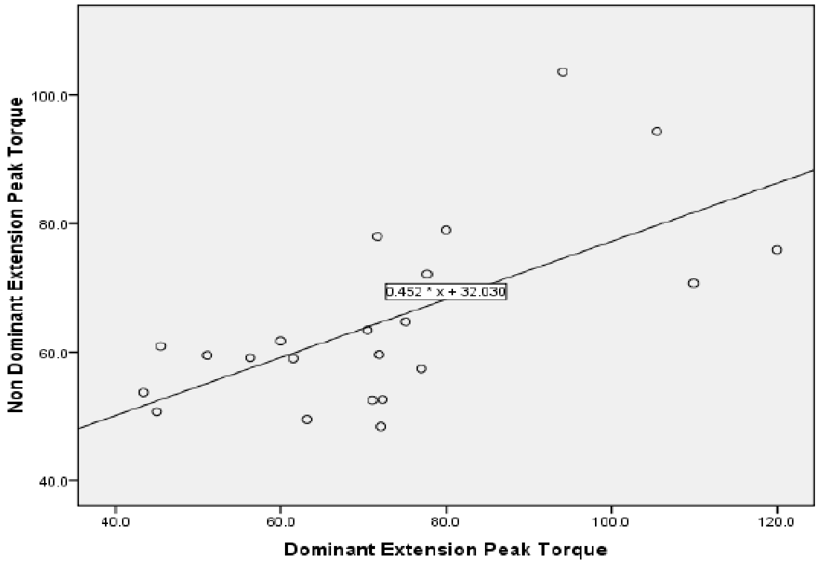

Figure (5): Scatter plot of Dominant and non dominant extension peak torque with the equation applied**.**

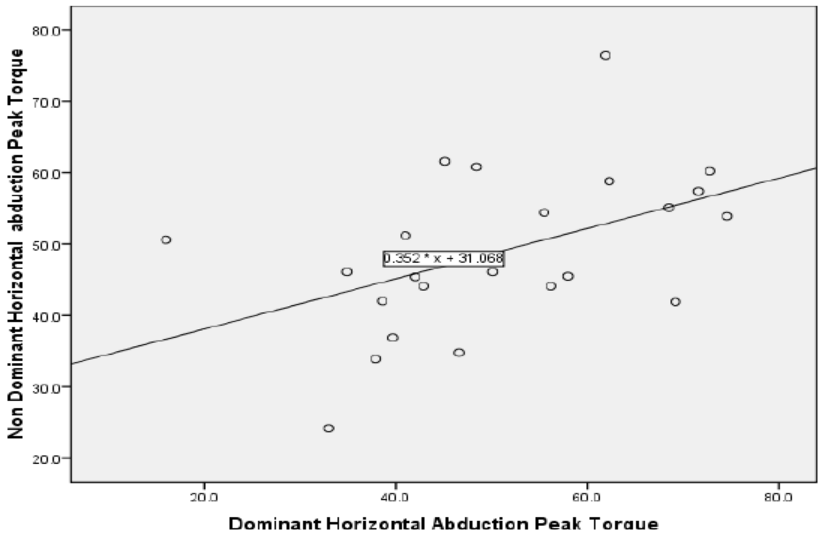

Figure (6): Scatter plot of Dominant and non dominant horizontal abduction peak torque with the equation applied**.**

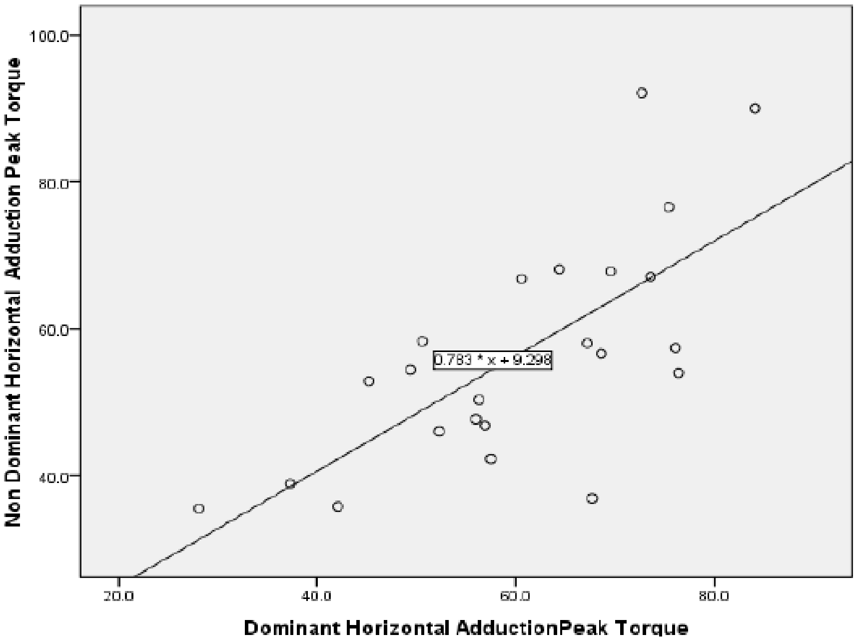

Figure (7): Scatter plot of Dominant and non dominant horizontal adduction peak torque with the equation applied

Discussion

The study tested 23 healthy participants from different backgrounds, physical activity level and with no asymmetrical shoulder activities. The age range of the sample was 19-33 years old and only males. The choice of a specific gender and age is attributed to the previously published studies stating a difference in isokinetic peak torque and shoulder strength values between younger and older individuals (Åstrand & Rodahl, 1986; Gaines & Talbot 1999; Murray et al. 1985), and between males and females (Ivey et al. 1985, Gaines & Talbot, 1999) although some other studies (Cahalan, 1989; Skhlar &Dvir, 1995) found inconsistent differences between males and females.

The results of the current study concurred in many aspects with previous studies (Cahalan et al. (1989), Shklar & Dvir (1995), However, dominance differences found in the study contradicted with what So et al.

(1995) and Lertwanich (2006) found. So et al. (1995) and Lertwanich (2006) found that there was a significant difference between the dominant and the non dominant sides ($p < 0.05$).

When health professionals are faced with shoulder pathology in rehabilitation a correction of muscular imbalances is assumed to be important in therapy (Mayer, 2001). But the question how is so? And how these imbalances and strength values could be identified, evaluated and predicted for recovery.

As functional activities needs muscle activity and a certain performance level from muscle groups and joints, impairments to the muscular strength will result in loss or deficit of functional movement (Bohannon, 1995). Research on functional activities and muscle strength has confirmed the relationship between muscle strength and physical performance (Bohannon 1995).

Predicting recovery and recovery level is a hoped use of isokinetic dynamometry in neurological patients besides the use of normal parameters and comparison between healthy population and patients and bilateral comparison in the patients themselves.

Isokinetic movements used in isokinetic testing are not normal movements seen in daily life activities (Perrin, 1993), so what we should ask ourselves is how isokinetic testing can be relevant to functional movement and activities of daily living.

There were some studies that have shown that there was a significant correlation between muscle strength and some particular functional activities in the gait (Bohannon, 1995), bed mobility (Bohannon, 1988a), transfers ((Bohannon, 1988b), and wheel chair propulsion (Tupling et al. 1986). Such functional activities delineate a patients' general functional capability, hence their recovery and performance level.

On the technical side, although many studies validated and have shown isokinetic dynamometry to be reliable in isokinetic testing in different fields of rehabilitation, medicine and sports, many limitations were identified that drew the line between correct and incorrect results obtained. In addition to gravity correction, calibration, and axes alignment, some other factors can produce measurement errors in isokinetic testing.

Isokinetic testing devices i.e dynamometers are not exactly available for all clinicians or rehabilitation teams; they are neither feasible nor applicable to use in daily practice. Aldernick & Kuck (1986) also stated that there is a great variance in the isokinetic measurements of the same individual in repeated isokinetic measures, which hence creates a big range of achieved peak torque or other isokinetic values obtained from dynamometry. Not to mention that when measuring isokinetic parameters, a zero in peak torque or torque value in isokinetic dynamometry does not mean that the patients or participants does not have a movement, but it means that they have the muscle power of 3 according to the manual muscle testing procedure, which means there is active movement but not against resistance (Dvir, 2004). These facts draw a line of where isokinetic dynamometry can be used; with individuals of a muscle power above 3.

Since only males were participants to this study from a certain age group were used, a comparison of the study results cannot be applied to females or older age considering established differences of isokinetic muscle strength in different age and gender (Gaines et al. 1999, Ivey et al. 1985, Murray et al. 1985).

Dominance in this study was 100% right side for all participants. Although not shown in studies but the results of this study might not be applicable for left-handed population unless proved otherwise.

The axes alignment during testing was not maintained perfectly as some participants shifted their head. Walmsley (1993) found that there was an arm elevation to about 8 cm during sagittal and frontal plane isokinetics testing, hence changing the glenohumeral position. Nonetheless, it is not possible to find a way to find a perfect correct way for axes alignment. A test re-test reliability study was not performed. A second isokinetic testing is advised as it shows it enhances the reliability of the test (Meeteren et al. 2004). Moreover, not all shoulder movements' were tested and only the concentric mode was tested as well.

Conclusion

The study concluded that shoulder extension is the strongest muscle group followed by horizontal adduction, flexion, and horizontal abduction among healthy male participants in isokinetic parameters. The dominant flexion, horizontal abduction and horizontal adduction are not statistically different in strength from their non dominant ones. Extension, however, is statistically stronger in the dominant side than in the non dominant one. Although there was no statistical difference in most dominant shoulder movements over the non dominant ones, all dominant muscle groups showed to be slightly higher than the non dominant. Poor to excellent correlations exhibited between flexion/extension and horizontal abduction/horizontal adduction and these correlations can be used in finding a relationship that connects them. Isokinetic testing can be used in the rehabilitation of shoulder impairments resulting from neurological conditions such as stroke, spinal cord injury, head injury and many others, as Isokinetic testing showed to be able to predict the recovery level of shoulder strength and provide a prognostic base line or a more realistic goal of shoulder movement rehabilitation.

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