Isokinetic quadriceps peak torque, average power and total work at different angular knee velocities

Khaled Takey ,Olfat A. Kandil, and, Shimaa N. Abo Elazm

Dept . of physical therapy for internal medicine its surgery and geriatrics , Basic Sciences Dept. (Biomechanics) , Basic Science Dept. 1, 2,3 Misr University for science and technology,

Abstract

Isokinetic dynamometry offers distinct advantages, both clinically and for research, in the evaluation and treatment of muscle performance .previous research has reported a high level of correlation between peak torque and work and between peak torque and power in the muscles surrounding normal and selected pathological knees. No research to date has examined whether such similarities exist in clients with no pathology to the knee in elderly with certain testing conditions. **The purpose** of this study was to investigate the relationship between the isokinetic parameters of peak torque PT, work, and power for the extensor muscle groups of elderly female. The main aim was to ascertain how the angular velocity can affect the relation between peak torque, average power and total work. **Subjects, materials and methods**: Isokinetic data were collected from 60 females; mean age 68.6 years on a Biodex isokinetic testing and training dynamometer at the speeds of 60, and°180, /sec. suggest that peak torque is representative of work and power and may be the only necessary parameter for isokinetic muscle performance testing of the extensor muscles of the knee in elderly.

Key words : Isokinetic , peak torque , power , work, muscle performance

Introduction

Assessment of muscle strength is a vital component of diagnosing and treating patients in which muscle weakness is present(24).A variety of methods has been be used to test quadriceps strength .The two most common methods used in the clinical testing are manual muscle testing and Isokinetic testing .Manual muscle testing is easier to use ,however results are less objective when a person is able to generate high force . On the other hand , Isokinetic testing offers the benefit of objective measurement, but there is controversy about which is the most clinically significant testing speed (16). Isokinetic strength testing gained a great deal of popularity throughout 1980 in rehabilitation settings ,primarily because it provides an objective means of quantifying existing levels of muscular strength(20).

The use of isokinetic testing as a mean of measuring dynamic muscle strength has increased considerably. Results of Isokinetic measurement were shown to be highly reproducible .Nowadays ,Isokinetic devices have been extensively used for the assessment and evaluation of muscle function ,rehabilitation, training and assessments of muscle strength and injury(1). The advantage of time saving testing or training protocol, and relative cost, an economical and efficient means of providing meaningful information for clinical analysis of patients give rise to its use (22).

Although an isokinetic assessment can be made for any muscle group in the body, the knee is probably the most commonly tested joint(11). Muscle strength must be quantitated in order to adequately describe weakness as well as prescribe and evaluate the success of rehabilitation. This can be done through isometric, isotonic, or isokinetic techniques (7).

A patient who can produce sufficient torque at very slow speeds but has difficulty generating torque at faster speeds may have difficulty in generating torque quickly enough to produce an effective postural response .This may give rise to the importance of an isometric muscle testing (9).

The improvement in slow muscle torque is significantly greater than that in fast muscle torque. In elderly subjects, high speed Isokinetic exercise produced greater torque at high speed in two weeks training and sharp rise after. On the contrary slow -speed exercise frequently causes knee stress and inability of some elderly to continue (15).

Isokinetic dynamometry provides objective measures of concentric dynamic strength. It provides optimal and efficient loading of muscles and joints through range, thereby minimizing potential risk for injury. By isokinetic dynamometry, strength evaluation is not limited to the weakest point in the range, since the resistance is accommodating. An isokinetic evaluation can identify muscle weakness at certain point in the range. Specific targeting of this range when designing an exercise protocol may reduce treatment time (13).

The Hamstring to quadriceps ratio has been used as a measure of knee muscle balance and hence linked to increased stress and injury susceptibility. Also, it was previously found that the ratio increases with increasing velocity (23). More specifically clarified that hamstring to

quadriceps ratio steadily increased from zero to 180 degrees per sec. with no further increase at 300 degrees / sec.(1).

Considering that work is done by the rotation-producing force which is equal to the torque generated by the force times the angular displacement of the body. The rate at which work is done is known as power. Both reflects the energy “work energy theorem" (21)

Subjects , materials and method
Subjects

Sixty elderly females participated in this study, their age ranged from 65 to 75years old. The participants were selected from El Hussein Hospital,El Azhar University .

Exclusion criteria includes subjects with marked postural abnormalities, severe neurological and musculoskeletal defects, uncontrolled hypertension , unstable angina pectoris or other medical conditions that would interfere with testing. Subjects should be able to follow simple commands ,their intelligence within the level that enables the elderly to follow instructions of the researchers.

Instrumentation
-Weight and Height Scale :A valid and reliable weight and height scale, with a range of 1 to 150 Kilograms for weight, and 1 to 200 Centimeters for height.

- Biodex Isokinetic dynamometer: (Biodex corporation, Shirly,New York).

Biodex Isokinetic resistance accommodates to Pain, Fatigue and musculoskeletal leverage. The resistance that subject may encounters is in direct proportion to the effort exerted. Subjects were well secured during testing by the attachments and isolation straps of the machine, (Fig. 1).

The system is provided with a computer (IBM) compatible device that collects displays, stores the data and control the movement of the dynamometer.

Fig.1*Biodex Isokinetic dynamometer

Testing protocol

-Preparation :

The steps of the test were explained for each subject to allow the subject to be oriented and familiar with the testing protocol. Calibration of the unit was performed prior to use according to the manufacturer guidelines.

Subjects were tested by Biodex Isokinetic dynamometer at two angular velocities for the knee extensor group during isometric contraction. Arrangement includes testing the subjects, where the resistance pad is placed on a level with the inferior part of the pad immediately above the medial malleolus .

Isokinetic knee strength at 60, and 180 degrees per second were measured with the subject's hips at slightly reclined posterior for about 10 to 15 degrees, and knees flexed 90 degrees (12).

- Apparatus adjustment

Before performing any test on the system, the apparatus was adjusted and set up ready for use. Proper stabilization techniques were applied to restrict motion to the area of interest. Maximal stabilization and minimal stabilization have no significant difference effect on the maximal torque produced by the quadriceps during concentric contraction (10).Instruct

participant to cross arms over chest to minimize involvement of upper body musculature.

- Knee testing protocol:

A warm up specific for the muscles to be tested prepares the muscles for the demands of testing and prevents injury.

Knee warm up exercises:

*Two light contractions of extension at 180 degrees per sec.
*Two medium contractions of extension at 180 degrees per sec.
*Repeat five sequence contractions at 120, 90, 60 degrees per sec.

Knee test:

*Five repetitions of extension at 60degrees per sec., and thirty seconds rest.
* Five repetitions of extension at 180 degrees per sec, and thirty seconds rest (4).

The subjects were positioned sitting at the machine and were asked to move their legs forwards using maximal effort against the accommodating resistance at a preset speed and for a preset number of test repetitions. The extensor muscle groups were tested repeatedly for three measurements of muscle performance; peak torque, total work, and average power.

Statistical analysis: Mean, standard deviation and Pearson's correlation test (correlation coefficient) to test a positive or negative linear relationship between peak torque and average power and peak torque and total work at the determined angular velocities.

Results

Sixty elderly females were included in the study , ,their age ranged from 65 to 75 years old , with a mean value of (68.17±2.82).

In table (1), the general characteristics of subjects were represented including age, weight ,and height.

Table (1) General characteristics of the subjects:

Variables	Value
Age range (years)	65-75
Mean ±SD	68.17±2.82
Weight(kg) range Mean ±SD	64-88 74.27±5.28
Height(Cm) Mean ±SD	156-174 165.27±4.77

Concerning the findings of this study as shown in table 2 and presented in figure 2 , at 60/ sec the right peak isokinetic torque was 67±1.84, the total work was 228 ±2.63 and average power of 46±1.32. There was a significant difference between right (Rt) and left (Lt)with a t value was at $p < 0.05$. The mean value for peak torque was 52± 2.33, total work117± 1.56 and average power 31.32 ±1.02.

Table (2) peak torque, total work &average power at 60°/sec. for RT & LT knee extensors

Variable	Peak Torque		Total work		Average power	
	Rt	Lt	Rt	Lt	Rt	Lt
Mean	67	52	228	117	46	31.32
SD±	1.84	2.33	2.63	1.56	1.32	1.021

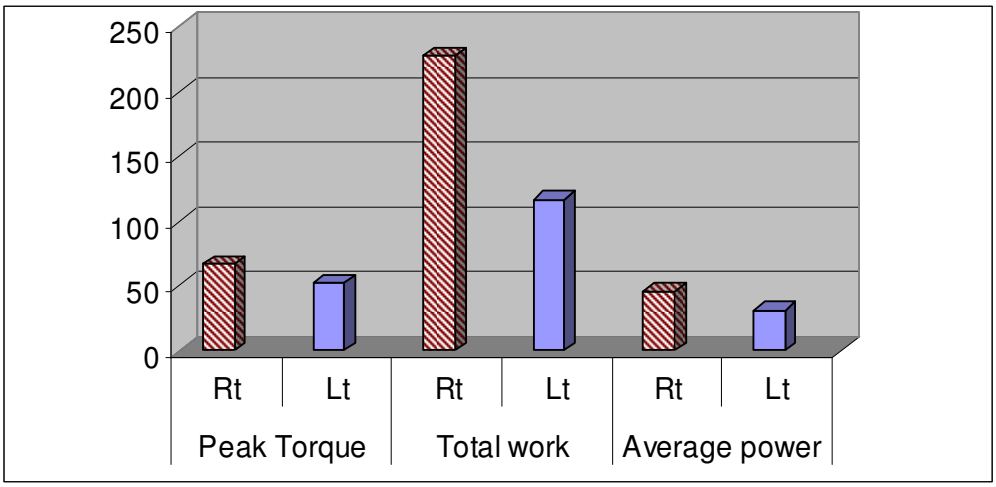


Fig. (2) Mean values of peak torque, average power and total work for right and left knee at 60°/ sec

With regard to the results at 180/ sec the right peak isokinetic torque was 45±2.13; the total work was 178 ±3.68 and average power of 32.3± 1.823. These results demonstrate significant decrease in all values except for the total work for the left side.

It was significant difference between right (Rt) and left (Lt)with at value was 4.35 at $p < 0.05$. The mean value for peak torque was 45±3.26, total work which significantly increased to 200± 2.58 and average power 24 ±2.213.

Table (3) peak torque, total work &average power at 180°/sec. for RT & LT knee extensors

Variable	Peak Torque		Total work		Average power	
	RT	LT	RT	LT	RT	LT
Mean	52	45	178	200	32.3	24
SD±	2.13	3.26	3.68	2.58	1.823	2.213

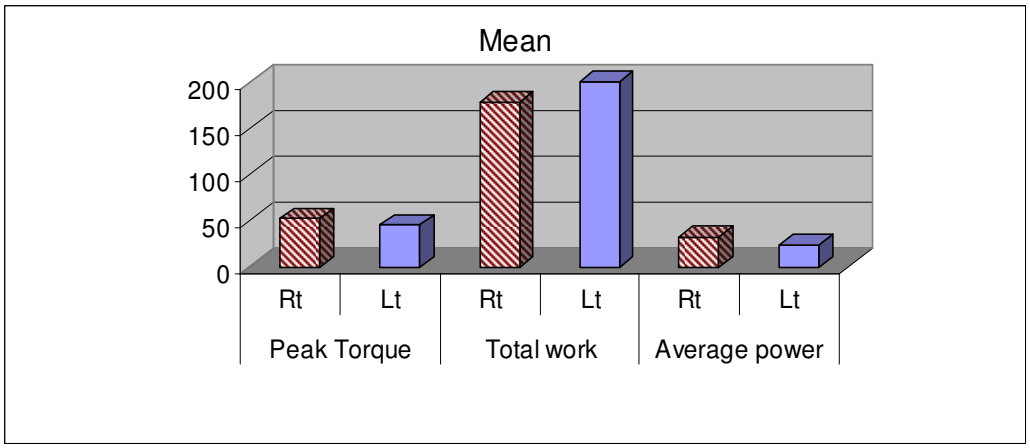


Fig (3) Mean torque, total work and average power at 180°/ sec for Rt and Lt

The findings for the Right side are summarized in table 4 and illustrated in figure 4. On the other side the data for the left side for the two velocities are shown in table 5 and figure 5.

Table (4) RT knee extensor peak torque, total work and average power at 60°/sec & 180°/sec.

Variable	Peak Torque		Total work		Average power	
	60°/sec	180°/sec	60°/sec	180°/sec	60°/sec	180°/sec
Mean	67	52	228	178	46	32.3
SD±	1.84	2.13	2.63	3.68	1.32	1.823

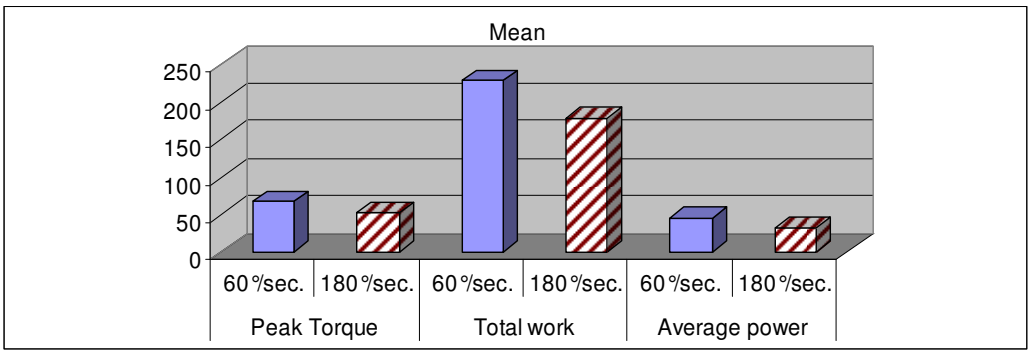
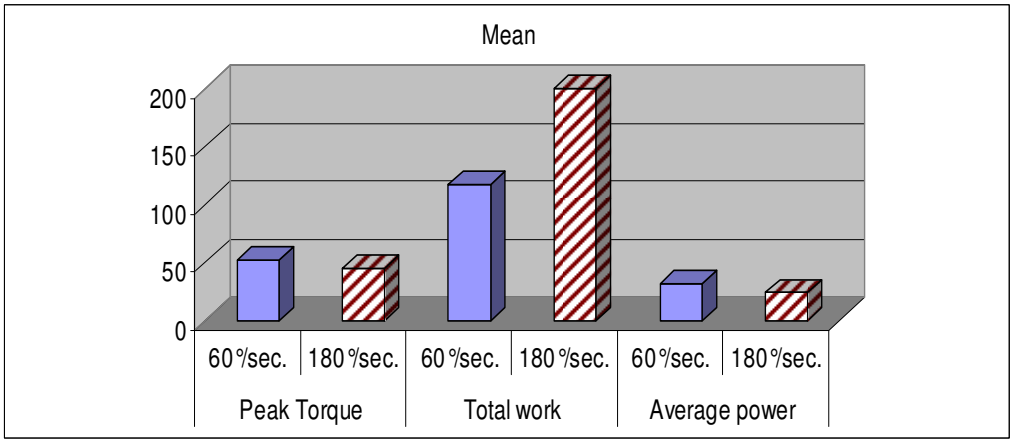


Fig (4) The Rt side peak torque, total work and average power at 60°,180° /sec velocities

Table (5) LT knee extensor peak torque, total work and average power at 60°/sec & 180°/sec.

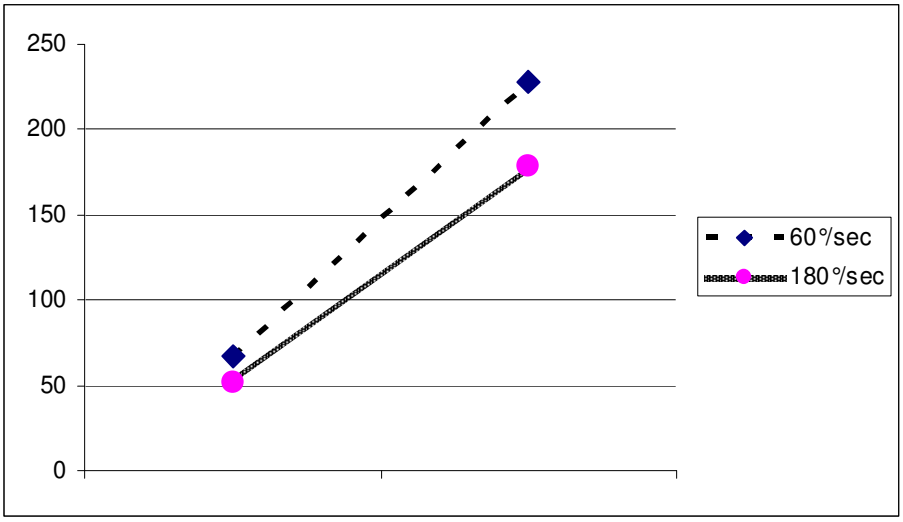
Variable	Peak Torque		Total work		Average power	
	60°/sec	180°/sec	60°/sec	180°/sec	60°/sec	180°/sec
Mean	52	45	117	200	31.32	24
SD±	2.33	3.26	1.56	2.58	1.021	2.213



Fig(5) LT knee extensor peak torque, total work and average power at 60°/sec & 180°/sec.

Concerning the correlation between Peak torque & Total work at 60°/sec and 180°/sec . for RT knee extensors is a direct relation as presented in fig 6 The ranges of Pearson correlations between PT and work and between PT and power were 0.75-0.96, 0.67-0.99 knee

extensors of right and left side at 60°/ sec , and 0.76-0.98 and 0.85-0.97 for right and left side at 180°/ sec . These findings suggest that peak torque is representative of work and power.



Fig(6) The correlation between Peak torque & total work at 60°/sec. and 180°/ sec. for RT knee extensors

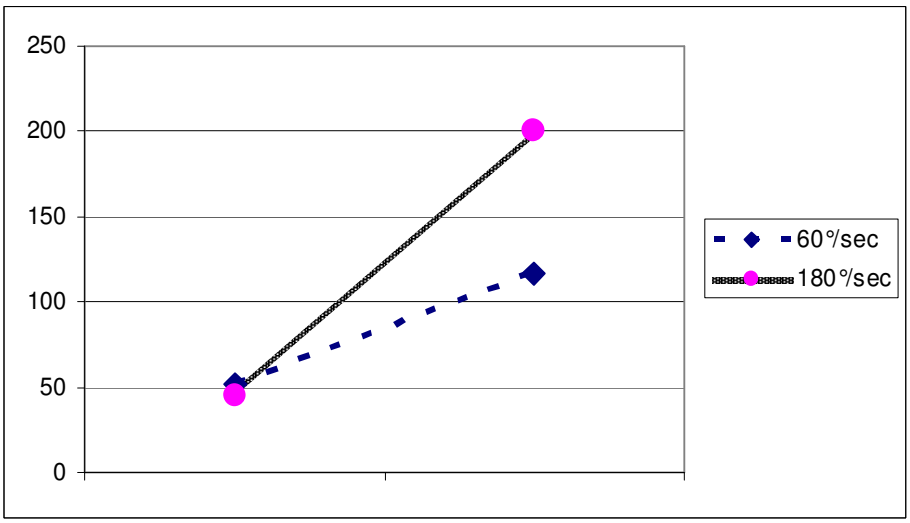


Fig.(7) The correlation between Peak torque & total work at 60°/sec. and 180°/ sec for LT knee extensors

Concerning the correlation between Peak torque & average power at 60°/sec. and 180°/sec for RT knee extensors as presented in fig 7 , both decrease as velocity increases .

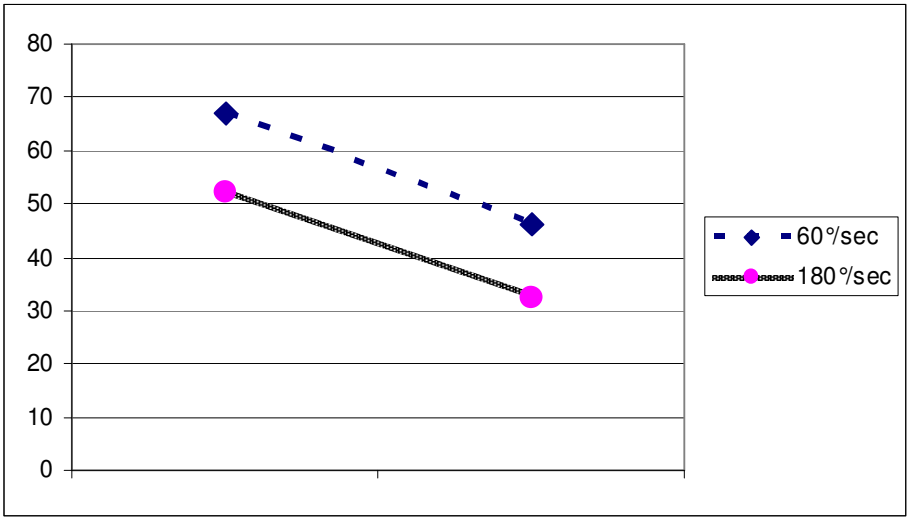


Fig. (8) Peak torque Vs Average power at 60°/sec and 180/sec for Rt knee extensor.

Concerning the correlation between Peak torque & average power at 60°/sec. and 180°/sec for Lt knee extensors, as presented in fig 9 , both decrease as velocity increase .

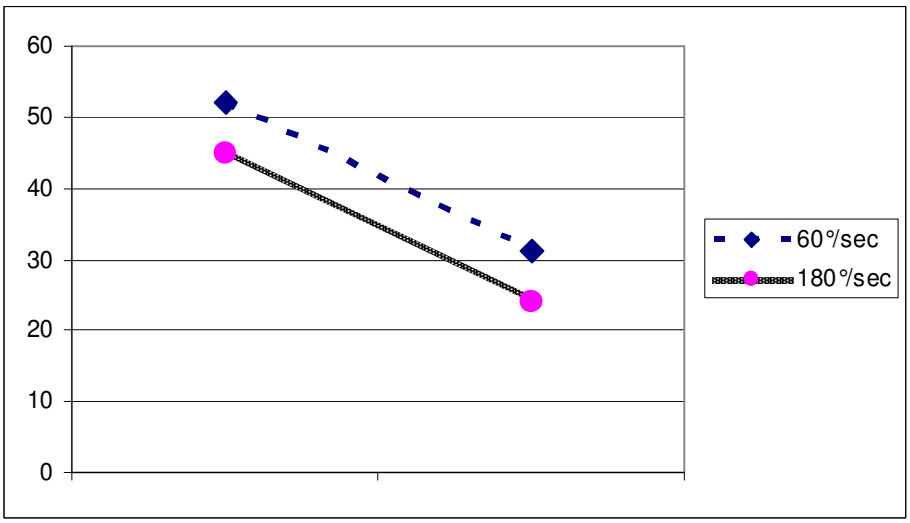


Fig. (9) Peak torque Vs Average power at 60°/sec and 180°/sec for Lt knee extensor.

Discussion

This result can be explained by the increased force at slow compared with fast angular knee extension velocities and the associated elongation of series elastic elements in the knee extensors. The force-elongation relationship of the series elastic components of the vastus lateralis and intermedius complex were studied in a separate experiment and confirmed this idea. The behavior of the human muscle shows that the torque velocity relationship during Isokinetic contraction at different angular velocity provided the rule is the force velocity relationship is indicated.. The muscle fiber lengths are not constant, even at identical joint angles, provided the muscle forces are different. This factor in some instances may be the cause of discrepancy between the force velocity and torque velocity relationships. The evidence for this has been studied for maximum quadriceps Isokinetic exertion. The peak torque has been shown to shift towards more extended positions and increasing angular velocity (15) . This in part is contradictory to what has been found in this study concerning the increase in the torque with the decrease in angular velocity. The decreased ratio of eccentric / concentric activity of the quadriceps muscle at 60 and 120 degree per second was reported in case of quadriceps inhibition due to high stresses((8).

With regard to the variables that may influence test findings , in a study to compare three different intervals for a between sets rest period during a common isokinetic knee extension strength-testing protocol of twenty older Brazilian The results showed that during a common isokinetic strength testing protocol a between set rest period of at least 30 seconds is sufficient for recovery before the next test set in older men(3). The isokinetic variables comparing the right and left body side in two sports group, with dominance on one or both legs, did not differ. No differences were recorded in the H/Q between the right and left legs for any of the subject groups (26). In a way to examine the relationship between muscle strength and functional test scores and subjective assessment in patients with patellofemoral pain it has been showed that both isokinetic dynamometry and functional tests must be done individually (8)

Peak torque expresses a point output which may, but does not always, correlate well with full range output measure as work or power especially if any factor exist as aging, injury or rehabilitation.(2).

Previous research has analyzed the relationship of peak torque with work and power on the muscles surrounding the knee with correlation coefficients being reported, ranging from 67 to 99 (25).

Isometric torque and isokinetic peak torque, total work, power, torque acceleration energy and acceleration time at 30, 120 and 240° · s^{-1} of the knee and elbow extensors and flexors were measured using an isokinetic dynamometer in 24 healthy women. Intra-session variation of the measurements was evaluated and the short-term and long-term reliability was assessed by repeating all procedures after averages of 2 and 30 days, respectively. The effect of learning on peak torque during a session was also evaluated. Moreover, the effect of general warming-up on knee extensor and flexor strength was examined on a separate day. Using correlations, numerous studies have indicated that muscle strength measurements are reliable. Correlations, however, are inappropriate and misleading in studies on reliability. In the present study reliability of each strength variable was expressed as the coefficient of variation (CV). With the protocol used, neither learning nor warming-up had any significant effect on strength. As expected, intra-session variation tended to be less than short-term and long-term inter-session variation. The CVs for strength variables measured 30 days apart exceeded 5% for all variables and raised to 107% for acceleration time. Substantial between-subject variation of individual CVs were found. The study demonstrated that muscle strength measurements may be highly unreliable in the individual subject, (1**8).**

This study evaluated at two different test sessions the normality and variability of the isokinetic peak torque (PT), peak work (PW), peak power (PP) and peak torque acceleration energy (PTAE) data outputs in healthy elderly females (n = 10). The quadriceps muscle was tested at the angular velocities of 60 deg/s (a slow speed test) and 180 deg/s (a high speed test). The predictability of the PW, PP and PTAE from the PT was also assessed. The results showed that the consistency of the total work and average power measurements were equal with that of the peak torque, this was due to equal (almost normal) data distribution, equal variability of the outputs, the coefficient of variation (cv) ranged from 14 to 29% in the PWs and PPs versus 16 to 29% in the PTs), and excellent predictability of the PW and PP from the PT (PTs accounted on an average 85% for the variation seen in the PWs and PPs). In the PTAE measurements, the results were much more inconsistent, especially during the slow speed of the dynamometer, compared with PT, PW and PP. In conclusion, the Isokinetic PW and PP measurements can be

recommended for clinical use, while the PTAE measurements should not be used routinely (14).

In an in vivo angle - specific torque velocity relationship mostly gives confusing but consistent findings that the torque velocity relationship deviates from the normal curve at slow velocity, (5), which support the results of this study. This was attributed to that the length of muscle fiber is close to optimal.

The correlation between torque and power in this study is supported by many studies for different reasons .The large increase in torque and power was partly accounted by a significant increase in muscle cross sectional area developed through training(6).

Peak torque responses may not adequately reflect tension development through range of motion. Total work and mean power generated, on the other hand, are highly relevant measure (2). The findings of this study magnify this principle by the correlation between the three variables making it of strength way of performance evaluation to be based on Isokinetic peak torque.

The ability to reliably quantify the impact of peak torque on the level of performance in activity of daily living may enlighten the way to understand the neuromuscular functional limits in various clinical settings. The conditions that may have an influence on the peak torque are stated in a study conducted by Labarque et al. (17), these are post-orthopedic surgery patients, older adult and muscle diseases.

The inability of older adults to exert existing muscle strength in a timely manner greatly influences the risk of falls and function capability. The effect of power training is superior compared to strength training as a matter of functional adaptation in community with regard to the risk of fall.

Recommendations

That crucial to the future development of isokinetic technology is the confirmation of its usefulness and effectiveness in the overall patient care system, for example proving whether cost savings can be achieved with its applications. Further research should in particular be carried out in areas including the validity and specificity of different muscle actions such as eccentric actions and contraction, in relation to specific training

and rehabilitation programs; the metabolic characteristics of and adaptations to isokinetic training; the simplification and validation of sports-specific training programs; and the design of user-friendly machines to bring isokinetics closer to the rehab testing and training. Power training of elderly is a beneficial tool to safeguard against fall,(19).

References

1. AL angari AS,and AL-Hazzaa HM: Normal isometric and isokinetic peak torques of hamstring and quadriceps muscles in young adult Saudi males. Neurosciences ;Vol.,(3):165-170(2004).

2. Bandy W,and Timm K .: Relationship between peak torque , work, and power for knee flexion and extension in clients with grade I medial compartment sprains of the knee, Br J. Sports Med. 33(4) 250-254 (1999).

3.Bottaro, M, Russo, A , de Oliveira J :The effects of rest interval on quadriceps torque during an isokinetic testing protocol in elderly Journal of Sports Science and Medicine , 12; 2005

4. Brown LE: Isokinetics in human performance. 1st. edition, human kinetics pp.96-112, (2000).

5-Chino K. , Oda T. , Kurihara T, Nagayoshi, H, Kanehisa , S , Fukashiro , T , Fukunaga , and Kawakami Y :In vivo muscle fiber behavior of the triceps surae muscles during Isokinetic concentric and eccentric planter flexions , Journal of biomec. Sports Exerc. 7:206-213 , (2003).

6.Femi,A,Scaglioni G, Pousson M, Capodaglio P, Van Hoecke J, and Narici M: Strength and power changes of the human planter flexors and knee extensors in response to resistance training in old age, j neuron phys (7) 36- 46 ,(2002).

7.Fisher NM, Pendergast DR, and Calkins EC : Maximal isometric torque of knee extension as a function of muscle length in subjects of advancing age. Arch of Phys Med and Rehabil , (71):729-34(1990).

8.Goharpey S, Shaterzadeh M , Emrani A. and Khaesi V:
Relationship between functional tests and knee muscular isokinetic parameters in patiens with patellofemoral pain syndrome. ; j med sci. , 7 (8) : 1315-1319 , 2007

9.Guccione, AA: Geriatric physical therapy.2nded,Mosby,pp78-105(2000).

10.Hanten WP and Ramberg CL: Effect of stabilization on maximal Isokinetic torque of the quadriceps femoris muscle during concentric and eccentric contractions J Phys Ther. Vol 68, 2-9-222, (1988).

11.Holmes JR,and Alderink GJ: Isokinetic strength characteristics of the quadriceps femoris and hamstring muscles in high school students, Physical therapy;65(6):914-918(1984).

12. **Hughes MA, Duncan PW, Rose DK, Chandler JM and Studenski S A:** The relationship of postural sway to sensorimotor function, functional performance and disability in the elderly. Arch Phys Med Rehabil ; 576-572 (1996).

13.Jones K ,and Baker K: Human movements explained .Butter worth Heineman Ltd,Oxford,Pp196-233(1996). .

14.Kannus P.Normality: variability and predictability of work, power and torque acceleration energy with respect to peak torque in isokinetic muscle testing: Int J Sports Med. Apr;13(3):249-56 (1992).

15.**Kawami,Y, Kubo, H. ,Kanehisa and Fukunaga T**.: Effect of series fiber elasticity on Isokinetic torque angle relationship in humans . Eur. J. Applied Physiology . 87: 381-387,(2002)

16. Keasays SL, Bullock SJ and Keasys AC: Strength and function before and after anterior cruciate ligament reconstruction . Clinical orthopedics and related research (373) : 174-183(2000)

17.Labarque , V.B., Teijnde T, and Leemputte M.V: Resistance training alters torque-velocity relation of elbow flexors in elderly men . Med. Sci. Sports Exerc. Vol. 34, pp. 851-856 (2002).

18.Madsen. O.R. :Torque, total work, power, torque acceleration energy and acceleration time assessed on a dynamometer: reliability of knee and elbow extensor and flexor strength measurements .European journal of applied physiology vol. 74 . no. 3 (1996).

19.Miszako ,T.A. , Cress, ME , Slade, JM , Covey, CJ, Agrawal , SK and Doeerr, CE : Effects of strength and power training on physical function in community-dwelling older adults . Journal of Gerontology ; Biology and medical sciences , 58, 171-175(2003).

20.Nicholas JJ : Isokinetic testing in young non athletic able bodied subjects . Arch Phys Med Rehabil.,70:210-215(1989).

21. Ozkaya N and Nordin M. : Fundamentals of Biomechanics ; equilibrium , motion ,and Deformation Van Nostrand Reinhold (1991).

22.Richards JG. and Cooper J.: Implementation of an on –line Isokinetic analysis system .JOSPT,vol.,4(1),36-38(1982).

23.Sudder NG : Torque curves produced by the knee during isometric and Isokinetic exercises .Arch Phys Med Rehabil ,61:68-71(1980).

24.The national isometric muscle strength data base consortium: Muscular weakness assessment :use of normal isometric strength data. Arch Phys Med Rehabil, 77:1251-1255(1996).

25.**Woodson C**, **Bandy WD**, and **Curis D**, **Baldwin D**: Relationship of isokinetic peak torque with work and power for ankle plantar flexion and dorsiflexion. J Orthop Sports Phys Ther. Sep;22(3):113-5(1995).

26. ZAKAS A: Bilateral isokinetic peak torque of quadriceps and hamstring muscles in professional soccer players with dominance on one or both two sides Journal of sports medicine and physical, vol. 46, pp. 28-35 38(2006)

ملخص بحث

العلاقة بين اقصى عزم للعضلة الرباعية و الشغل و الطاقة فى السيدات المسنات خلال سرعات دائرية مختلفة باستخدام جهاز الايزوكينيتيك

***د / خالد تقى **د / الفت عبد الرحمن قنديل ***د/ شيماء نبيل ابو العزم**

*مدرس بقسم ع.ط لامراض الباطنة و المسنين و جراحتها **مدرس بقسم العلوم الاساسية - وحدة الميكانيكا الحيوية *** مدرس بقسم العلوم الاساسية - كلية العلاج الطبيعى_ جامعة مصر للعلوم و التيكنولوجيا

تقدم اجهزة الايزوكينيتيك مميزات هائلة فى مجالات العلاج و البحث العلمى على حد السواء و ذلك لتقييم و علاج الاداء العضلىز و لقد اوضحت الدراسات السابقة وجود علاقة حتمية بين اقصى عزم, الشغل, و الطافة فى العضلات المحيطة بالركبة فى الحالات الطبيعية و بعض الحالات المرضية المختارة. لم تختبر اى دراسات هذه العلاقة فى السيدات المسنات بلا مشاكل فى الركبة

كان الغرض من هذه الدراسة هو اختبار العلاقة بيم اقصى عزم و الشغل و الطاقة فى العضلات المسئولة عن انبساط الركبة فى السيدات المسنات

تم تجميع النتائج من 60 سيدة مسنة بمتوسط عمر 68,6 سنة على جهاز Biodex بسرعة دائرية 180,60 درجة / ثانية

و قد اظهرت النتائج ان اقصى عزم يمثل الشغل و الطاقة و يمكن ان يكون هو المقياس اللازم لقياس الاداء العضلى بجهاز الايزوكينيتيك فى العضلات المسئولة عن انبساط الركبة فى السيدات المسنات.