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ORIGINAL REPORT

EFFECT OF ISOKINETIC TRAINING ON QUADRICEPS PEAK TORQUE IN HEALTHY SUBJECTS AND PATIENTS WITH BURN INJURY

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Objective: **To evaluate the improvement rate of quadriceps muscle peak torque in healthy subjects and patients with burn injuries after an isokinetic training programme.**
Subjects: **Thirty male volunteers, 15 healthy and 15 subjects with burn injury after complete healing, participated in the study.**
Methods: **Concentric and eccentric torque of quadriceps was measured for both groups using an isokinetic dynamometer before and after 6 weeks of isokinetic training. The tests were performed at angular velocities of 30°/s and 90°/s.**
Results: **There was a significant increase in the quadriceps peak torque for both groups at both angular velocities after isokinetic training. During eccentric contraction at angular velocities of 30°/s and 90°/s the percentage improvement in the burned group was higher than in the healthy group ($p=0.003$ and $p=0.0008$, respectively). During concentric contraction at an angular velocity of 30°/s the percentage improvement in the burned group was higher than the healthy group ($p=0.020$). However, during concentric contraction at an angular velocity of 90°/s there was no significant difference between the groups ($p=0.742$).**
Conclusion: **The isokinetic training programme was effective in increasing the concentric and eccentric peak torque of the quadriceps muscle for healthy subjects and patients with burn injuries.**

Key words: burns; muscle contraction; concentric training; eccentric training.

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INTRODUCTION

Severe burn injury leads to persistent and extensive skeletal muscle catabolism and weakness (1), confounded by prolonged physical inactivity (2). Muscle wasting is a characteristic hypermetabolic response in patients with, and animal models of, burn injury (3–7). Increased protein degradation following burn injury has been postulated to be a major contributor to muscle wasting (8).

Various therapeutic approaches have been investigated in burn care to ameliorate the adverse effects. Exercise is one of the therapies that have been reported to improve functional outcome of burn patients (9). Suman et al. (10), in a prospective, controlled, randomized study, demonstrated increases in muscle strength and lean body mass of severely burned children in response to a 12-week exercise programme. Standard physical and occupational rehabilitation therapy targets improvement in overt physical changes associated with burn injury, such as uncomfortable scarring, range of motion (ROM) limitation, and contractures (11).

Muscles are known to function in a variety of different ways and do not merely contract and relax to move the various joints of the body. Muscle work is classified into 3 distinct functions: motor "concentric contraction", stabilizer "isometric contraction", and shock absorber "eccentric contraction" (12–14). All voluntary muscles are capable of the performance characteristic of each category. The ability to perform these 3 functions is essential to all functional motor activities (12).

The appropriate use of eccentric principles and procedures in the fields of medicine and allied health will produce more profound adaptive changes in skeletal muscle than those obtained from concentric work (15–17) and, as a result, the patients return to normal levels of functioning as quickly and physiologically as possible without significant risk of re-injury (18).

Unlike isometric and isotonic contraction, isokinetic contractions provide muscle training throughout the ROM of a joint at a pre-set constant speed of contractions. When a specific speed is reached, the device will automatically accommodate to give resistance to each point of the ROM, allowing the specific speed to be maintained. This type of training is considered to be safe. When the subject applies force, the device provides resistance. If the force stops, the resistance stops automatically. Force changes caused by muscle length/tension relationship, skeletal leverage, pain or fatigue are then easily accommodated (19).

One advantage of isokinetic testing is that it provides numerous objective parameters that can be used to evaluate and analyse a patient's or athlete's performance. Isokinetic testing data frequently used to analyse muscular performance include peak torque, time rate of torque development, total work, and mean power (20). The peak torque is used most often because of its high reliability (21). Isokinetic training may be helpful in the rehabilitation regimens of burned patients (22).

Earlier studies (19, 20) have shown the effect of isokinetic training on the muscles of healthy subjects, but its effect on

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the muscles of patients with burn injuries is not known. Thus, the main objective of the study was to evaluate the improvement rate of quadriceps muscle peak torque in healthy subjects and subjects with burn injury after an isokinetic training programme at two different angular velocities.

MATERIALS AND METHODS

Subjects

Thirty volunteer male subjects participated in this study. Subjects provided informed consent to the Faculty of Physical Therapy, Cairo University. They were sequentially allocated into two groups: (*i*) a healthy group of 15 normal male subjects with right-side dominance. Their demographic data are shown in Table I. Subjects were excluded if they had any musculoskeletal injuries or symptoms or equilibrium disorders. Their occupational and recreational activities did not change during the present study, and none of them was involved in any other training programme to improve muscle strength, as it may have affected the outcomes of the study; (*ii*) a group of 15 male subjects with burn injuries. Subjects were included if they had a second-degree burn on the anterior thigh (deep partial thickness of thermal injury), as a burn to the posterior thigh will lead to knee flexion contracture, which affected the function of the quadriceps muscle. They were selected from the burn unit at Om El-Masryeen Hospital. Total body surface area (TBSA) for the burns ranged from 30% to 40% (more than this percentage would affect other areas more than the lower limb, e.g. the abdominal or chest wall). Subjects commenced the training programme after complete wound closure. The time to enrolling in the study ranged from 21 to 25 days after burn injury. The demographic data for the patients is shown in Table I. The patients had received the same physical therapy programme during the acute stage, and were excluded if they had any neurological, orthopaedic, renal, cardiovascular or malignant conditions.

Study procedures

Measurements included height and weight, and medical records were examined for date of injury and associated injuries. The subjects warmed up for 5 min on a cycle ergometer (75 W). Then, the right and left quadriceps, hamstrings and calf muscles were stretched 3 times, with a 30 s stretch and a 30 s rest.

Measurement procedure

The eccentric and concentric torque of the quadriceps (Nm) was measured, for the healthy subjects and for patients with burn injuries, using an isokinetic dynamometer (Biodex multi-joint system 3, Shirley, NY, USA) before the training programme (Pre) and after 6 weeks of isokinetic training (Post). Four maximal contractions were recorded at each speed, with a 2-min rest period between each set. A mean was calculated of the best 3 of the 4 contractions. The eccentric and concentric torque of subjects with burn injury was compared with the eccentric and concentric torque of healthy subjects at angular velocities of 30°/s and 90°/s. Ichihashia et al. (23) concluded that there is variation in peak torque value at different angular velocities, as the peak torque during low angular velocity of 30°/s is higher than the peak torque at an angular velocity of 90°/s. The concentric-eccentric programme was used to evaluate the knee extensor muscles.

Table I. *Demographic data for healthy and burned groups*

	Healthy, $n=15$ Mean (SD)	Burned, $n=15$ Mean (SD)
Age, years	24.8 (2.5)	24.4 (3.4)
Weight, kg	69.2 (4.3)	70.4 (4.9)
Height, cm	166.9 (3.9)	168.5 (3.7)

SD: standard deviation.

Isokinetic training programme

Each subject underwent tests to measure isokinetic muscle strength at the knee while performing extension movement of right quadriceps muscle (dominant side). The measurements were carried out using Biodex multi-joint system 3, with the backrest reclined 5° from vertical, and straps fixing the trunk, waist, and distal thigh. The lateral femoral epicondyle was used as the body landmark for matching the rotation axes of the knee joint and the lever arm of the dynamometer. The dynamometer strap was then fastened around the leg 5 cm proximally to the medial malleolus and the subjects performed a series of 3 submaximal contractions for familiarization. The subjects then performed 3 series of 10 consecutive maximal concentric and eccentric isokinetic contractions (24). The knee was moved by the dynamometer through the ROM from 90° to 20° of knee flexion at an angular velocity of 30°/s and 90°/s (Fig. 1). Blazevich et al. (25) proved that the greater ROM during isokinetic training is essential because it increases peak torque and changes the architecture of the muscle, in terms of shifting the torque-angle relationship of the muscle by a greater length regardless of the contraction mode. Each series was preceded by 3 min rest, and there were no pauses between the 10 contractions (26).

During the programme, the subjects were verbally encouraged to exert maximal efforts. A 20-min rest was allowed between the 2 angular velocities. The training was performed twice a week for 6 consecutive weeks, totalling 12 sessions. The extensor muscles of the right knee were trained during each session, the testing and training procedure was conducted from 13.00 h to 17.00 h for both groups.

Data analysis

Data was analysed using the Statistical Package for Social Sciences (SPSS version 16). Repeated-measures analysis of variance (ANOVA) was used to investigate the effect of isokinetic training on quadriceps eccentric and concentric peak torque at angular velocities of 30°/s and 90°/s for healthy and burned groups. The level of significant was set at 0.05 for all statistical tests.

RESULTS

Healthy group

During eccentric contraction at angular velocities of 30°/s and 90°/s there was significant improvement in healthy group quadriceps peak torque ($p<0.001$).

On the other hand, during concentric contraction at angular velocities of 30°/s and 90°/s there was significant improvement in healthy group quadriceps peak torque ($p<0.001$), as shown in Table II.

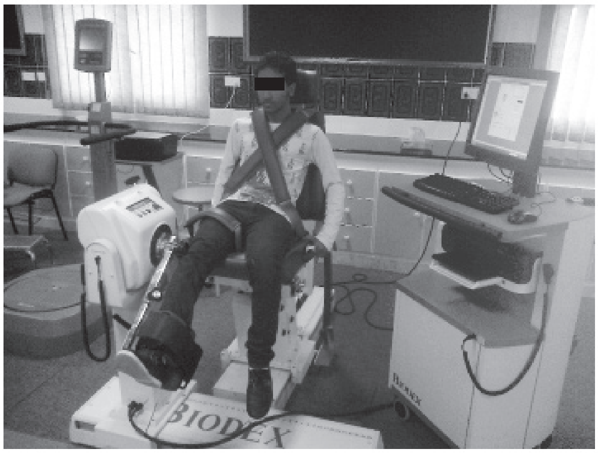

Fig. 1. Subject position during isokinetic training.

Table II. *Descriptive statistics for healthy and burned groups quadriceps peak torque (Nm)*

	Concentric contraction (Nm)				Eccentric contraction (Nm)			
	Healthy subjects, $n=15$		Burned subjects, $n=15$		Healthy subjects, $n=15$		Burned subjects, $n=15$	
Test statistics	Pre Mean (SD)	Post Mean (SD)	Pre Mean (SD)	Post Mean (SD)	Pre Mean (SD)	Post Mean (SD)	Pre Mean (SD)	Post Mean (SD)
30°/s	188.0 (6.9)	241.3 (7.7	121.5 (6.2)	170.8 (9.0)	201.7 (3.4)	260.8 (5.4)	127.0 (5.7)	180.5 (6.2)
90°/s	122.3 (2.6)	147 (3.1)	113.3 (2.4)	137.5 (2.2)	205.0 (6–0)	262.0 (3.2)	130.2 (4.0)	181.4 (5.0)

SD: standard deviation.

Burned group

During eccentric contraction at angular velocities of 30°/s and 90°/s there was significant improvement in burned group quadriceps peak torque ($p<0.001$). On the other hand, during concentric contraction at angular velocities of 30°/s and 90°/s there was significant improvement in burned group quadriceps peak torque ($p<0.001$), as shown in Table II.

Comparison between healthy and burned groups

During eccentric contraction at an angular velocity of 90°/s there was a significant difference between healthy group and burned group peak torques ($p=0.008$), the percentage improvement in the healthy group was 27.80%, and the percentage improvement in the burned group was 39.38%.

During concentric contraction at an angular velocity of 90°/s there was no significant difference between burned and healthy group peak torques ($p=0.742$), the percentage improvement in the healthy group was 20.22%, and the percentage improvement in the burned group was 21.36%.

During eccentric contraction at an angular velocity of 30°/s there was a significant difference between healthy group and burned group peak torques ($p=0.003$), the percentage improvement in the healthy group was 29.30%, and the percentage improvement in the burned group was 42.22%.

During concentric contraction at an angular velocity of 30°/s there was a significant difference between healthy group and burned group peak torques ($p=0.020$), the percentage improvement in the healthy group was 28.39%, and the percentage improvement in the burned group was 40.69%.

The percentage quadriceps peak torque improvement of healthy and burned groups during concentric and eccentric contraction at angular velocities of 30°/s and 90°/s are shown in Table III.

DISCUSSION

In recent years, researchers have examined the effect of isokinetic training on peak torque of healthy subjects, but there is a limited research in burned populations. The present study was undertaken to examine the effect of concentric and eccentric isokinetic training on quadriceps peak torque in burned patients compared with healthy subjects, and to compare the percentage improvement between the two groups. The results indicate that isokinetic training is an effective method for increasing the concentric and eccentric peak torque of the quadriceps muscle for subjects with burn injury at angular velocities of 30°/s and 90°/s.

Table III. *Percentage quadriceps torque improvement for both groups*

Group	Concentric torque at 30°/s	Eccentric torque at 30°/s	Concentric torque at 90°/s	Eccentric torque at 90°/s
Burned	40.69	42.22	21.36	39.38
Healthy	28.39	29.30	20.22	27.80

Two major factors contribute to muscle deconditioning after major burn injury: bed rest and catabolic processes that lead to muscle atrophy. A serious burn injury results in the greatest hypermetabolic response in comparison with other physical traumas (27). This increased metabolic rate can persist until wound closure is achieved (28) and perhaps for 6–9 months after wound closure (29).

St-Pierre et al. (30) indicated that people with smaller burns did not differ with respect to muscle strength from a non-burned control group matched for age, sex, body mass index, and physical activity level. People with burns of 30% total body surface area (TBSA) or larger showed significantly less torque, work, and power in the quadriceps than control subjects. This was the primary cause of selecting burned subjects with 30–40% TBSA. It can be said that the cause of loss of muscle mass mainly by catabolic effect of burn injury in addition to other co-factors, such as pain and physical inactivity.

There was a difference in the concentric peak torque between angular velocities of 30°/s and 90°/s, with a higher improvement value for 30°/s than the improvement value for 90°/s (healthy and burned subjects). This result is confirmed by the findings of Ichihashia et al. (23), who revealed variation in peak torque value at different angular velocities, as the peak torque during a low angular velocity of 30°/s is higher than the peak torque at an angular velocity of 90°/s. For appropriate programming of the exercise format, Timm (18) stated that slow eccentric speeds are 30–60°/s, moderate speeds are 60–90°/s, and fast speeds are 90–120°/s on an isokinetic dynamometer. Faster velocities are not required, as research findings indicate that muscle eccentric force production reaches a functional plateau at the speed of 120°/s under isokinetic conditions.

The results of our study showed that eccentric training was effective in improving the eccentric torque of quadriceps at angular velocities of 30°/s and 90°/s. This finding is supported by the findings of Konishi et al. (31) and Miller et al. (32), who proved that training using eccentric contractions is more effective for muscle recovery because it promotes greater changes in neural activation and muscle hypertrophy. Moreover, loaded eccentric exercise is a potent stimulus for hypertrophy (33, 34) and increased muscle strength (35). Likewise, Poletto et al. (24) proved that the eccentric isokinetic training of the knee extensors increased the extensor torque.

The isokinetic eccentric exercise causes a change in the structure of the contractile motor unit of the muscle, which, in turn, results in an increase in the contractile tissue ability to generate force (2). This change in the contractile apparatus would enhance the overall performance efficiency of a muscle performance under eccentric conditions (12). That eccentric muscle activity incorporates both the contractile and the non-contractile tissues of the muscle is the reason why a muscle can generate more force as a shock absorber "eccentric contraction" than as a motor "concentric contraction". This means that a muscle can generate more force when acting eccentrically than it can concentrically, which has important implications for clinical rehabilitation (15).

The results of this study show that isokinetic training is beneficial in the restoration of muscle strength of normal and burned groups, the percentage improvement of subjects with burn injury was higher than the improvement of healthy subjects for all modes of contraction and speeds; except for during concentric contraction at an angular velocity of 90°/s there was no significant difference between healthy and burned groups. Therefore, isokinetic eccentric exercise stimulates a significant increase in muscle mass and strength (36), which gives a higher importance to the type of training in the overall rehabilitation programme of the burn patients.

There are some limitations of this study. First, the total study time was limited to 6 weeks, which could be extended to achieve a greater benefit of isokinetic training on muscle weakness after burn injury. Secondly, the gender in this study was limited to males only. Thus, the appropriateness of generalizing the results is confined to this specific population. Thirdly, the angular velocities of this study, 30°/s and 90°/s, may be considered as slow, and the results may be different if conducted at higher angular velocity. Finally, the only parameters examined in this study were concentric and eccentric peak torque. Other isokinetic parameters, such as power, work, and fatigue, were not considered.

In conclusion, the isokinetic training programme at different angular velocities proved an effective method for increasing the concentric and eccentric peak torque of the quadriceps muscle for healthy subjects and patients with burn injuries. Thus, isokinetic training can be advocated as a treatment modality in the rehabilitation of subjects with burn injuries.

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