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Effects of Closed and Open Kinetic Chain Exercise Induced-Localized Fatigue on Static and Dynamic Balance in Trained Individuals

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Abstract

Background: As balance impairment induced by fatigue is implicated in injury occurrence, the aim of this study was to evaluate the effects of closed and open kinetic chain exercise-induced localized fatigue on static and dynamic balance in trained individuals.
Methods: 30 healthy boys with mean age of 19.75 $\pm$ 1.20 years, participated in this research. Static and dynamic balance were measured before and after open and closed chain fatigue protocol. Static and dynamic balance were measured respectively using the Balance Error Scoring System (BESS) and the Star Excursion Balance test (SEBT) in eight directions. The data was analyzed by two-way repeated measures ANOVA at the significance level of $P \leq 0.05$.
Results: The results indicated that both static and dynamic balance changed significantly following the study intervention ($P \leq 0.05$). In addition, a statistically significant difference was found after fatigue protocol in the static and dynamic balance between open ($P = 0.003$) and closed ($P = 0.001$) kinetic chains and respectively.
Conclusions: Localized fatigue in both open and closed kinetic chain has affected the static and dynamic balance. Although, localized fatigue in the closed kinetic chain has a more devastating effect on static balance, in the open kinetic chain, the more deleterious effect influenced the dynamic balance.

Keywords: Fatigue, Exercise, Static, Dynamic

1. Background

One of the key objectives of coaches and professional athletes is to maximize the athletic and health-related performance in daily living and competitions; hence, it seems necessary to find the possible ways to increase the athletic potentials. A growing literature supports the positive effects of aerobic exercise (1-3), high intensity interval training (HIIT) (4), aquatic exercises (5) on physical fitness and health-related factors in different age groups. On the other hand, high prevalence of injury caused by a variety of exercises has been reported. In this regard, resistance exercises with the intention of increasing physical fitness have been often utilized by athletes. Moreover, the development of fatigability during this type of exercise is epidemic that disturbs the motor control, especially in balance power (6-8). There are several studies reporting that lower extremities fatigue would reduce postural control. Shanbehzadeh et al. stated that functional fatigue-induced alterations of motor control can be found in males and females (9). In contrary, no relationship was found between muscular fatigue and balance in other research (10, 11). It was also suggested in a study that body composition changes at the age of 19 - 21 years could decrease the physical fitness that necessitates the importance of strength training (12). Given the importance of making the athlete powerful in motor control, closed and open kinetic chain exercises are commonly applied by coaches and trainers. Closed kinetic chain (CKC) exercises refer to those activities where the distal part of the lower limb is fixed, while in open kinetic chain (OKC) condition, distal segment of the limb is free to move (13). Given the role of fatigue on balance impairment, which may lead to injury, the study was to investigate the effects of closed and open kinetic chain exercise-induced localized fatigue (lower body muscles) on static and dynamic balance in trained individuals.

2. Methods

30 healthy boys with mean age of 19.7 $\pm$ 1.2 years participated voluntarily in the experimental study with pre and post-test design. Subjects were randomly divided into two

groups including OKC (n = 15), and CKC groups (n = 15). The inclusion criteria were lack of lower limb injury and no history of physical and physiological limitations hampering the training protocol.

Static and dynamic balance were measured by the Borg Fatigue Scale and measured before and after open and closed chain fatigue protocol. Fifteen in Borg scale shows 75% to 85% of the maximum oxygen consumption, considered approximately as the threshold of lactate (14). Static and dynamic balance were measured using the Balance Error Scoring System (BESS) the Star Excursion Balance test (SEBT) in eight directions respectively (11, 15). OKC and CKC fatigue protocols are seen in Table 1. One-repetition maximum (1RM) was used by Equation 1. 60% of 1RM was intervened in both OKC and CKC as exercise intensity (14, 16).

$$1RM = \frac{Weight}{1 - 0.02\,(Rep)} \quad (1)$$

The study was approved by the ethics committee board of Imam Khomeini International University (ID: 17628). Informed consent was signed by subjects prior to the beginning of study. The Kolmogorov-Smirnov test was used to examine the data normality and the data was analyzed using two-way repeated measures ANOVA comparing pretest and posttest scores among all groups and conditions at the significance level of $P \leq 0.05$.

3. Results

General characteristics of subjects are presented in Table 2. No significant difference was found in general traits in baseline (independent *t*-test results) ($P > 0.05$).

The dependent variables were the BESS error scores and SEBT scores, and our independent variables were group, time, BESS and SEBT conditions. Analysis of BESS scores with the groups combined revealed significant time ($F_{1,29} = 112.3$, $P < 0.01$) and BESS condition ($F_{5,145} = 706.5$, $P < 0.001$) main effects and a time-by-BESS condition interaction ($F_{5,145} = 821.3$, $P < .001$).

As seen in Table 3, a significant difference was found between the pre-test (before fatigue) and the post-test (after fatigue) in static balance of both OKC and CKC. Furthermore, there was a significant difference between static balance of OKC and CKC in posttest. Localized fatigue in the CKC had a more negative effect on static balance.

Analysis of SEBT scores with the groups combined revealed significant time ($F_{1,29} = 244.8$, $P < 0.05$) and SEBT condition ($F_{7,203} = 841.1$, $P < 0.001$) main effects and a time-by-SEBT condition interaction ($F_{7,203} = 708.6$, $P < 0.001$).

According to Table 4, there was a significant difference between the pre-test (before fatigue) and the post-test (after fatigue) of both groups in the dynamic balance. Independent *t*-test also showed a significant difference between the two groups. Localized fatigue in OKC had a more negative effect on dynamic balance (Table 4).

4. Discussion

In the current study, changes of static and dynamic balance due to fatigue were studied in trained persons. Although the effect of fatigue on balance was studied before, there is no study examining fatigue effect on balance in OKC and CKC of trained individuals. In summary, different effects of exercises on balance may associate with intensity and duration of exercise, constant or variable intensity in exercise protocols, metabolic demands, metabolic acidosis, impairment in somatosensory and vestibular system, hyperventilation, and dehydration (17). The results showed that fatigue had deleterious effect on static and dynamic balance following OKC and CKC. The obtained results are in line with Mousavi et al. (18), Surenkok et al. (19) in terms of balance impairment after fatigue, while inconsistent with Zech et al. who found that fatigue had no effect on dynamic balance (20). However, the interesting point is that to the best knowledge of the authors, no study considered the effect of OKC and CKC induced fatigue on the static and dynamic blance of trained persons. In addition, the majority of research investigated the elite athletes, while we studied the trained people. One possible reason for disturbance of static imbalance following CKC could be attributed to weight bearing in this condition as the legs are in the position of bearing the weight on the ground (13). In the present study, the fatigue in OKC had a more negative effect on dynamic balance. Apparently, In OKC condition, fatigue occurrs due to putting the stress on joints which disrupts the normal functioning of the joints and functional muscles of the joint which results in a more negative effect on dynamic balance compared to the static one. There were a number of limitations to our study including the control of mental functioning, sleep and rest hours, nutrition and motivation in subjects. On the other hand, a larger study sample size across individuals with different levels of physical fitness is offered in future studies.

As a conclusion, it is highly recommended that coaches and athletes should be aware of the possible risks of incorporating the mere trunk and lower muscles training into programs owing to high possibility of injury caused by localized fatigue. Therefore, diverse training components of kinetic chains should be applied.

Table 1. Open Chain and Closed Chain Fatigue Protocol

Kinetic Chain	Anterior Muscles	Type of Movement	Posterior Muscles	Type of Movement	RM, %	Sets	Rest, min
Open	Quadriceps	Leg extension	Hamstring	Lying Leg Curl	60	4 sets and each one is up to exhaustive	3
Closed	Quadriceps	Machine squat	Hamstring	Russian Leg Curls	60	4 sets and each one is up to exhaustive	3

Table 2. Individual Characteristics of Subjects in Baseline

Groups	Height, cm	Foot Length, cm	Weight, kg	Age, y
OKC	171.75 ± 4.74	64.5 ± 10.12	69.87 ± 6.24	18.37 ± 1.22
CKC	169.37 ± 5.57	61.5 ± 12.72	64.87 ± 7.01	19.02 ± 0.72
P value	0.112	0.091	0.147	0.251

Table 3. Balance Error Scoring System (BESS), Error Scores for Each Time Point by Group[a]

Surface and Condition	OKC		CKC	
	Pre-Test	Post Test	Pre-Test	Post Test
Firm				
Double leg	0.00 ± 0.00	0.09 ± 0.12[b]	0.00 ± 0.00	0.08 ± 0.20[b]
Single leg	2.36 ± 2.77	3.98 ± 1.09[b]	2.45 ± 2.61	6.22 ± 0.59[b,c]
Tandem	0.47 ± 0.81	0.96 ± 0.42[b]	0.54 ± 1.10	1.48 ± 0.84[b,c]
Foam				
Double leg	0.00 ± 0.00	0.52 ± 0.90[b]	0.00 ± 0.00	0.70 ± 0.98[b]
Single leg	4.20 ± 2.16	6.55 ± 1.96[b]	5.24 ± 1.66	9.98 ± 2.35[b,c]
Tandem	2.53 ± 3.45	4.72 ± 2.21[b]	2.71 ± 5.55	6.54 ± 2.32[b,c]
Total of firm surface	2.83 ± 3.10	5.53 ± 3.98[b]	2.63 ± 2.28	7.78 ± 1.44[b,c]
Total of foam surface	3.73 ± 5.13	11.29 ± 4.68[b]	7.98 ± 4.97	17.22 ± 5.87[b,c]
Total errors	9.56 ± 7.31	16.82 ± 6.14[b]	10.61 ± 8.76	25.00 ± 7.14[b,c]

[a]Values are expressed as mean ± SD.
[b]Significantly different from pretest.
[c]Significantly different from test group (OKC, CKC).

Table 4. Star Excursion Balance Test (SEBT) Values in Eight Directions (in Centimeter)

Directions	OKC		CKC	
	Pre-Test	Post Test	Pre-Test	Post Test
Anterior	75.70 ± 3.77	73.19 ± 2.70[a]	74.19 ± 0.70	75.45 ± 1.14[a,b]
Anterolateral	75.71 ± 1.65	72.01 ± 0.74[a]	74.01 ± 0.79	73.24 ± 1.16[a,b]
Lateral	78.38 ± 1.25	75.86 ± 1.26[a]	76.86 ± 1.10	77.95 ± 0.75[a,b]
Posterolateral	72.05 ± 0.77	70.09 ± 1.37[a]	84.90 ± 1.93	71.25 ± 1.34[a,b]
Posterior	82.70 ± 2.02	80.28 ± 1.45[a]	83.24 ± 1.66	81.94 ± 1.16[a,b]
Posteromedial	76.17 ± 1.45	74.78 ± 2.06[a]	75.71 ± 1.67	76.74 ± 0.78[a,b]
Medial	72.98 ± 1.54	71.04 ± 1.87[a]	73.83 ± 1.28	74.87 ± 1.02[a,b]
Anteromedial	74.97 ± 0.67	71.41 ± 2.22[a]	75.78 ± 0.97	73.54 ± 2.02[a,b]
Mean	76.08 ± 1.42	73.58 ± 1.01[a]	76.07 ± 1.14	75.26 ± 1.01[a,b]

[a]Significantly different from pretest.
[b]Significantly different from test group (OKC, CKC).

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