Progress in Nutrition 2020; Vol. 22, N. 3: e2020028 DOI: 10.23751/pn.v22i3.9334

Original article

Gender-related Differences on Physical Fitness Parameters After Core Training Exercises: A Comparative Study

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Summary. *Objective:* In this study, the effects of 8 weeks of core training by gender on strength, muscle endurance, flexibility, dynamic balance and body composition were examined. *Methods:* Twelve females (F) (Age: 20.66 ± 1.82 years, height:165.96 ± 6.98 cm, body weight: 53.25 ± 7.11 kg) and twelve young males (M) (Age: 20.75 ± 2.63 years, height:172.38 ± 4.48 cm, body weight: 67.40±8.05 kg) participated voluntarily for the study. Body composition compartments, Y balance test (YBT), flexibility tests, isometric strength, back endurance, and sit up tests were tested before and after the core training of 3 days per week for 8 weeks period. "Two repeated measures" (group x time) was used for differences of pre- and post-training for all parameters at two groups. *Results:* The findings of the present study showed significant increases in all parameters, except body composition between pre and post-training results in both groups. However, between genders, there were not statistically significant differences all parameters except dynamic balance. Following the training, female group achieved more increase in percentage change of leg strength (+16.38%), back strength (+15.07%), Biering-Sorenson test (+38.65%), sit and reach test, spine ROM test, and posteromedial balance results. Differently, the percentage change of male group results for sit up (+37.94%), right-left lateral flexion (+16.40%, +17.03%), and anterior-posterolateral balance tests demonstrated increased more. *Conclusions:* This study investigated differences the effects of core training with unstable surfaces by gender on the physical fitness parameters. The results showed that gender does influence dynamic balance parameter but not body composition, flexibility, strength and muscular endurance parameters for 8 weeks of core training.

Keywords: core strength training - gender - motor skill- BOSU ball - Swiss ball.

Introduction

Achieving and maintaining optimal body composition, changing nutritional habits and/or exercise behaviors were recent approaches for improving the quality of life and achieving well-being (1,2). Physically active men and women had superior body composition including bone mineral density (3), physiological values (4), and cardiovascular values (5). Therefore, optimizing lifelong physiological process for a healthy body weight and improving physical fitness parameters become inevitable for all age and sex groups. Recent studies demonstrated that core training affected on muscle activation for both genders (6) and physical fitness parameters were also improved for specific athletic groups (7,8). The "core" has been used to refer to the trunk or more specifically the lumbo-pelvic region (9). Working muscles in this region involves deeper muscles such as the transversus abdominis, obliquus internus abdominis, quadratus lumborum, and superficial muscles, the rectus abdominis, obliquus externus abdominis, erector spinae, gluteus maximus, hamstrings, and rectus femoris could (10). Core training programs contain muscle strengthening and motor control of the core muscle system (11,12). These are joint stability exercises, contraction exercises, balance training, proprioceptive training, plyometric exercises and sport-specific skill training (13,14). Core muscle

strength training is thought to cause more effective use of shoulder, arm and leg muscles and more maximum power. Thus, the positive effects of athletic performance results in body composition compartments (lean body mass and fat mass) and physical fitness parameters of speed, agility, power and aerobic endurance as well as reduced risk of injury (11,15,16). Improved core stability and neuromuscular control of the lumbopelvic-hip region has been shown to decrease the risk of knee injuries, especially in females (17).

Core region muscular training were recently examined by diversifying intensity, volume, frequency for different level of athletes and sedentary subjects (18,19). A study demonstrated that stabilizer muscles, dynamic exercise of concentric and eccentric contraction movement, and/or isometric exercise of no movement of core region, not only improve performance of athletes but also helps daily activities for all age groups (18). Moreover, including core region stability exercises to training plan promoted total body complementary or/and integrative effect to exercising individuals to achieve potential sports performance (20) or increase life quality for different population (4,5,21) for different level of athletes including beginner to elite (7,8). In the rehabilitation sector, core stability and core strength terms were used to improve performance for a patient with low back pain to perform everyday tasks pain free, whereas in the sporting sector, an improved core strength results were characterized by improving sporting technique and performance (14,21).

Instability resistance training can be created by Swiss ball, BOSU ball, foam roller, wobble board to utilize for performance enhancement, rehabilitation, and overall musculoskeletal health (22). Some research studies found higher core muscle activity were obtained with resistance exercises by using Swiss ball compared with flat surface exercises (22,23), but the findings of the other studies were resulted in higher muscle activity with resistance exercises by using BOSU ball (9,23). Occasionally, gender-related research Studies have examined whether age and/or studies that were associated with hypertrophy and strength after resistance exercises (22,23,24). One of the gender-related body composition comparative study determined findings of after 12 weeks of strength training in the Abe et al. (2000) study was found increase in muscle thickness (by measured by ultrasound) in male and female groups (24). Furthermore, another core training study demonstrated no differences between genders in postural control improvement (25). However, by gender-related comparison of core training on physical fitness parameters and body composition were not examined specifically.

Consequently, it is important to criticize how much core training affects with the same intensity, volume, and frequency by gender on body composition and some physical fitness parameters by gender. Therefore, the aim of this study was to determine the effects of 8-weeks core training that performed at unstable surfaces, on body composition, strength, muscle endurance, flexibility, and dynamic balance.

Materials and methods

Participants

Twenty-four university students (12 males and 12 females) between the ages of 18 and 25 years with no history of back or leg pain were recruited. The study was approved by the Ethics Committee of Medicine Faculty in Mustafa Kemal University, and informed consent was obtained from the participants.

Measurements

Anthropometric Measurements: Height was measured by using stadiometer (SECA, France) and waist and hip circumferences were measured with a non-stretching tape. Body mass index (BMI) was calculated as body weight (kg) divided by squared height (m^2). Body weight (BW), percentage of body fat (%BF), and lean body mass (LBM) assessed by bioelectric impedance analysis using the Tanita TBF-418 Body Fat Analyzer (Tanita Corp., Tokyo, Japan), were calculated.

Isometric Leg and Back Strength Measurement: Takei Kigi Kogyo dynamometers (Tokyo, Japan) were used to measure static strengths of the leg and back muscles. The participants performed two trials with a 1-minute rest intervals between the trials, and the best score was recorded as result (26).

Sit-up and Back Extension Test: The number of maximal repetitions for sit up and back extension tests were used to measure muscular endurance (27).

Back Extensor Endurance Test (Biering-Sorensen Test): The participants lied prone over the end of a treatment couch with anterior superior iliac spine supported on the bench edge. The duration in second during which the patient keeps to hold the upper body straight and horizontal were measured recorded (16, 28).

Dynamic Balance Test: Y-Balance Test was used to determine the balance of anterior, posteromedial, and posterolateral directions which were tested twice for both legs (29).

The Sit&Reach Test: The participants seated on the floor with knees fully extended and the feet against the box. Best result was recorded from two trials (27).

Lateral Bending Measurements: Measured minimal fingertip-to-floor distance in full lateral flexion with a tape meter without flexion, extension or rotation of the trunk or bending the knees (30).

Spine ROM Measurement: Thoracic and lumbar spine ROM for flexion and extension were measured using inclinometer (bubble inclinometer, enterprises Inc. USA). The spinous processes at T12-L1 and L5-S1 marked by palpation with the participants standing upright and inclinometer were located. Measurements were taken first in neutral, then in maximum flexion, and finally in a maximum extension position. Once full movements were completed, inclinometer was recorded (31).

After anthropometric measurements were completed, the participants performed warm-up and stretching exercises prior to all physical fitness parameter measurements.

Training program

Both groups participated for the core training program 3 times/week for 8 weeks. Training consisted of 2 sets of 15 repetitions of first 4 weeks of duration, and 3 sets of 20 repetitions for the second 4 weeks of duration (Table 1). The 8 weeks program was included four Swiss ball and two BOSU ball exercises (Figure 1). The participants rested for at least 20 seconds between sets, and 90 seconds between the exercises. After 8 weeks core training duration, all measurements were repeated under the same environmental conditions and using the same procedures.

Table 1. Core Exercise Training Program for 8 weeks

Core Exercises	**First 4 weeks**	**Second 4 weeks**
Warm-up and stretching	*10 min walk + static stretching for major muscles*	
1.Two legs rises from side on BOSU ball	*2×15 repeats ((both sides)*	*3×20 repeats ((both sides)*
2.Cross sit-up on BOSU ball	*2×15 repeats*	*3×20 repeats*
3.Back extension on BOSU ball	*2×15 repeats*	*3×20 repeats*
4.Quadruped opposite arm-leg raise on BOSU ball	*2×15 sec (both sides)*	*3×20 sec (both sides)*
5.Dynamic glute bridge on Swiss ball	*2×15 repeats*	*3×20 repeats*
6.Static plank on Swiss ball	*2x15 sec*	*3x20 sec*

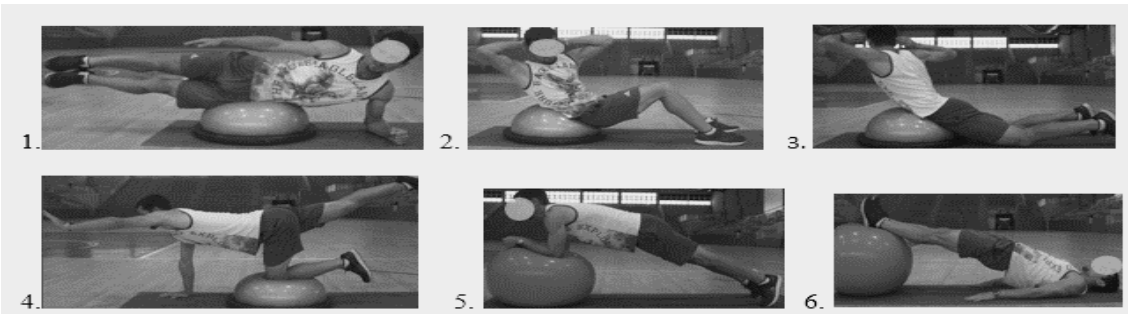

Figure 1. Core Exercises.

Statistical Analysis

The descriptive data were presented as mean and standard deviation ($\bar{x} \pm SD$). The normality of distributions and the homogeneity of variances were assessed by Shapiro–Wilk and Levene's tests. "Two way repeated measures ANOVA" (group x time) was used to determine the differences between pre- and post-training for all parameters in both genders. Pearson's correlation coefficients were used to test the relationships. $p<0.05$ was considered significant.

Results

The means and standard deviations for physical fitness parameters according to groups were presented in Table 2. All pre-training parameters of groups were analyzed by using independent sample t-test. There were significant differences between both groups except for age. The means, SD, and % changes in body composition measurements were presented in Table 3. At the end of 8 weeks, there were a few increases in all body composition results between pre- and post-test values in both groups except for a few neglectable decrease in male waist circumference and LBM ($p>0.001$). Furthermore, there were significant differences for all body composition parameters except trunk fat and hip circumference for both pre- and post-test in between genders.

In this study, both male and female groups showed statistically significant increases ($p<0.05$) in strength and endurance values after the training period (Table 4). There were significant differences between the genders in both the pre- and post-training, for back strength and leg strength measurements ($p<0.00$). However, there were no significant differences between the genders in the pre and post training at the other muscle endurance parameters. Especially, the percentage change of all strength and muscular endurance results of female group showed more improvement than male group, except for sit up test (25.92% and 37.94%, respectively). Pre- and post-training measurements of the flexibility parameters were presented in able 4. Statistical analysis showed significant differences between pre- and post-test results for sit & reach test, right lateral and left lateral flexion in both groups. It was found that there was more improvement at left and right bending in male than female. But this difference was not significant between male and female participants. Although, the spine extension ROM of the females was greater than that of the males for pre-training, both groups showed a significant improvement especially at spine extension ROM results than flexion ROM results for post-training. The results of extension ROM for female participants increased approximately 13.81% in L5-S1 in and 17 % in T12-L1, whereas, increase in flexion that of the spinal ROM improved only 5.88% and 7.68%, respectively. Although, there were significant increase in female groups than male groups at all flexibility parameters except lateral bending results, there were no significant difference between the flexibility results between the genders. As described in Table 5, significant differences were found for the pre- and post-training measurements of all parameters of the Y-balance test for both genders. Especially, while the increase at anterior and posterolateral directions were found greater in males than that of females, moreover, increase at posteromedial direction were found greater in females than that of males for both support legs. Besides, relationships between the reaching anterior direction at balance for each support leg and height were r=0.43 (left foot) and r=0.52 (right foot). Relationships between reaching posterolateral - posteromedial directions at balance and leg strength values were statistically significant (r = 0.51; 0.49 for left leg and r = 0.52; 0.47 respectively $p<0.05$) (Table 6).

Table 2. Descriptive Data of Participants Characteristics

Groups	Age (years) $\bar{x} \pm SD$	Height (cm)** $\bar{x} \pm SD$	BW (kg)* $\bar{x} \pm SD$	BMI (kg/m²)* $\bar{x} \pm SD$
F (n=12)	20.66 ± 1.82	165.96 ± 6.98	53.25 ± 7.11	19.24 ± 1.82
M (n=12)	20.75 ± 2.63	172.38 ± 4.48	67.40 ± 8.05	22.33 ± 2.00

***p<0.05, **P<0.01*

Table 3. Body Composition and Anthropometric Measurements of the Participants

Parameters	*Groups*	*Pre* x̄ ± SD	*Post* x̄ ± SD	% *Change*	*Between measurements*		*Between Genders*	
					F	*p*	*F*	*p*
BW (kg)	F	53.25 ± 7.11	53.85 ± 7.05	+1.12	2.336	0.141	19.629	***0.000***
	M	67.40 ± 8.05	67.54 ± 8.54	+0.14				
BMI (kg/m^2)	F	19.24 ± 1.82	19.46 ± 1.68	+1.14	3.739	0.066	16.253	***0.001***
	M	22.33 ± 2.00	22.60 ± 2.14	+1.20				
BF (%)	F	19.75 ± 5.14	20.52 ± 4.73	+3.89	0.561	0.462	11.905	***0.002***
	M	12.48 ± 5.73	12.57 ± 6.54	+0.72				
LBM (kg)	F	42.46± 3.78	42.50 ± 4.28	+0.05	0.000	0.989	93.880	***0.000***
	M	58.66 ± 4.28	58.61 ± 4.20	-0.05				
Trunk Fat (%)	F	15.49 ± 7.12	16.64 ± 6.05	+7.42	1.364	0.255	1.283	0.270
	M	12.82 ± 6.61	13.15 ± 7.46	+2.57				
Waist Circumference (cm)	F	67.00 ± 4.32	67.04 ± 4.80	+0.06	0.265	0.612	16.184	***0.001***
	M	77.45 ± 6.75	76.83 ± 8.50	-0.80				
Hip Circumference (cm)	F	91.83 ± 5.14	92.08 ± 4.55	+0.27	0.047	0.831	1.269	0.272
	M	94.83 ± 6.56	94.41 ± 6.90	-0.44				

Table 4. Values of Flexibility, Strength and Muscle Endurance Parameters of the Participants

Parameters	*Groups*	*Pre* x̄ ± SD	*Post* x̄ ± SD	% *Change*	*Between measurements*		*Between Genders*	
					F	*p*	*F*	*p*
Isometric Leg Strength (kgf)	F	77.25 ± 15.53	89.91 ± 18.19	+16.38	28.104	***0.000***	37.771	***0.000***
	M	133.92 ± 33.98	152.29 ± 27.00	+13.71				
Isometric Back Strength (kgf)	F	76.04 ± 14.54	87.50 ± 11.81	+15.07	22.619	***0.000***	53.685	***0.000***
	M	132.17 ± 28.14	147.50 ± 23.42	+11.59				
Sit-up (max. number/min)	F	38.58 ± 13.28	48.58 ± 12.41	+25.92	31.689	***0.000***	1.842	0.188
	M	42.83 ± 13.80	59.08 ± 17.83	+37.94				
Back Extension (max number)	F	43.00 ± 15.98	54.75 ± 24.87	+27.32	19.307	***0.000***	0.890	0.356
	M	52.50 ± 23.78	62.00 ± 24.33	+18.09				
Biering Sorensen (sec)	F	146.83 ± 59.13	203.58 ± 80.13	+38.65	26.601	***0.000***	1.525	0.230
	M	136.08 ± 31.93	161.92 ± 37.54	+18.98				
Sit & Reach (cm)	F	24.25 ± 6.94	26.79 ± 5.18	+10.47	20.452	***0.000***	0.695	0.414
	M	26.58 ± 8.59	29.20 ± 7.32	+9.85				
Lateral Bending (Right) (cm)	F	27.50 ± 6.55	30.16 ± 6.52	+9.67	35.978	***0.000***	0.019	0.892
	M	26.95 ± 5.20	31.37 ± 6.19	+16.40				
Lateral Bending (Left) (cm)	F	26.70 ± 5.91	30.79 ± 5.77	+15.31	24.859	***0.000***	0.055	0.817
	M	26.95 ± 5.79	31.54 ± 5.02	+17.03				
L5-S1 Flexion (deg)	F	68.00 ± 10.51	72.00 ± 9.64	+5.88	17.122	***0.000***	1.144	0.296
	M	71.66 ± 9.85	76.41 ± 8.28	+6.62				
L5–S1 Extension (deg)	F	38.00 ± 6.13	43.25 ± 5.17	+13.81	18.737	***0.000***	0.364	0.552
	M	37.00 ± 5.89	41.75 ± 5.98	+12.83				
T12-L1 Flexion (deg)	F	99.83 ± 6.53	107.50 ± 8.85	+7.68	21.102	***0.000***	0.385	0.541
	M	102.17 ± 10.93	109.33 ± 9.62	+7.00				
T12-L1 Extension (deg)	F	56.33 ± 11.03	65.91 ± 12.11	+17.00	22.881	***0.000***	2.490	0.129
	M	52.41 ± 7.60	58.41 ± 7.15	+11.44				

Table 5. Y-Balance Test Results of Males and Females

Parameters	*Support Leg*	*Groups*	*Pre* Mean ± Sd	*Post* Mean ± Sd	*% Change*	*Between Measurements*		*Between Genders*	
						F	*p*	*F*	*p*
Anterior (cm)	Left	F	83.00 ± 5.13	89.33 ± 4.84	+7.62	27.751	***0.000***	1.582	0.222
	Left	M	85.83 ± 5.30	92.41 ± 9.52	+7.66				
	Right	F	84.16 ± 4.60	89.66 ± 4.51	+6.53	27.370	***0.000***	9.333	***0.006***
	Right	M	87.58 ± 5.59	98.58 ± 9.18	+12.55				
Posteromedial (cm)	Left	F	80.50 ± 8.75	89.41 ± 6.97	+11.06	21.634	***0.000***	16.389	***0.001***
	Left	M	89.91±6.35	98.25 ± 6.22	+9.27				
	Right	F	77.83 ±10.57	90.16 ± 9.62	+15.84	75.197	***0.000***	4.458	***0.046***
	Right	M	84.50 ± 7.83	97.75 ± 7.72	+15.68				
Posterolateral (cm)	Left	F	86.25 ±11.01	95.33 ± 7.79	+10.52	35.805	***0.000***	9.510	***0.005***
	Left	M	94.41 ± 7.47	105.92 ± 7.40	+12.19				
	Right	F	91.33 ± 9.68	98.83 ± 8.05	+8.21	26.620	***0.000***	3.641	0.070
	Right	M	95.83 ± 9.00	106.67 ± 9.30	+11.31				

Table 6. Relationships Between Y-Balance Test with Anthropometric and Strength Results ($p<0.05$).

Parameters (n:24)	Height	BW	Leg Strength	Back Strength
Left foot – Anterior	***0.43***	-	-	-
Left foot - Posteromedial	-	***0.41***	***0.51***	***0.47***
Left foot - Posterolateral	-	-	***0.49***	***0.42***
Right foot - Anterior	***0.52***	***0.48***	-	-
Right foot– Posteromedial	-	-	***0.52***	***0.51***
Right foot - Posterolateral	-	-	***0.47***	-

Discussion

Core region muscular endurance, balance strength, and body composition compartments were improved by core training in many studies demonstrated for different population of sedentary, older adults, athlete's rehabilitation and performance athletes for all sports with different duration. In the present study, the findings indicated that 8 weeks of core training effected significantly on physical fitness parameters except for body composition compartment results for males and females. In addition, the improvement in static strength and muscular endurance parameters were more in males than females and the improvement back extension and Biering-Sorensen test values also were improved differently more in females than males.

Pre-training, there were significant differences all body composition parameters except for trunk fat and hip circumference between males and females. Post-training results showed that body composition results did not significantly change for both genders. The reason of the absence of changes in body composition for both genders might be related to the core training which involves predominantly isometric type of exercises. Besides, the absence of changes in body composition also may have been related to frequency of core training and number of sets and repetitions of each exercise. Similarly, the study of Sekendiz et al., (2007) and Segal et al., (2004) findings were parallel with the results of the present study for female after core training (32,33). In the present study, body composition compartments of the both groups were different from each group at the beginning (Table 2). By 8 weeks of core training duration, body composition compartments were not changed significantly because number of sets and repetitions might not be enough to

decrease body fat percentage. In addition to that, the difference of the muscle mass at the beginning favoring the male group and total produced force for each sessions training effect could be expected to be different at the end of the training period, that means more impactful training upshot might have been explained than female group due to higher muscle mass content and fiber recruitment. For this reason, the findings of the study were not resulted as expected that the muscle mass compartment of body composition was not changed significantly pre- and post- training test results. Moreover, isometric leg and back strength results were not supported in theoretical that strength were improved significantly more in females that males by considering LBM increase (+0.05 % for females and -0.05 % for males). Besides, post-training test results of core training demonstrated that there were significant improvements in both strength parameters were found more in females than males (+16.38 % vs +13.71 % and +15.07% vs +11.59 % respectively). The comparison of the body composition with the total body mass results gave rise to the confusion should warn sport scientists and coaches, because we could interpret the results differently if we examined the regional body fat, regional muscle mass, and regional fat mass differences considering also total body water variations.

In the present study, by favoring the improvements in the females were more than males that Biering Sorensen (+38.65 % and +18.98 % respectively) and back extension test (+27.32 % and +18.09 % respectively) percentage change values significantly increased for both genders. Unlike this, Tse et al., (2005) did not find a significant increase in Biering-Sorenson test scores in his study of 45 male rowers after 8 weeks core training (15).

There was significant increase in sit up test results between pre- and post-training for both genders. Moreover, especially more improvement (37.94% vs 25.92%) was determined in male subjects, however, the increase was not statistically significant between genders. The reason of the result might be the duration of the training period. It could be recommendable that the improvement would be significantly different for longer-term training for both genders.

According to Table 4, there were significant increase between pre- and post-training measurements at all flexibility parameter results, whereas not statistically significant between genders. When we examined the increased parameters after training, spinal flexion-extension ROM values increased more in female than males, while lateral flexion values were have found to be higher in males than females. Increased trunk, back and hamstring flexibility in this study was supported by the Pilates studies of Segal et al. (2004) and Kloubec (2010) (33,34). Similarly, findings of Santos et al. (2010) also showed that resistance training improved flexibility in young sedentary women in 8 weeks (35).

The dynamic balance which is dependent on strength of the core muscles ensures that part of the body moves from one point to another while in motion, and stability is maintained (36). In this study, there was a relationship between the anterior direction reaching and the length (Left r=0.43, Right r=0.52), while the relationship between the posterolateral and posteromedial directions reaching and the leg strength (left r = 0.51; 0.49 and right r = 0.52; 0.47 respectively $p<0.05$). Therefore, the results of males were found to be higher in three directions before the core training, but not significantly different in Y balance scores between genders. Grippl at al. (2003) indicated that high correlations found between leg length and reach distance for three anterior directions on the Star Excursion Balance Test. They determined as raw data showed that men had significantly higher reaching data than women; however, they found no significant difference in gender after normalizing leg length (36). Before training, there was no significant difference between the genders that at all three directions with the right foot on the ground. But, after 8 weeks of core training, the significant differences in balance scores between genders were found to the anterior (in favor of males, 12.55%) and posteromedial (in favor of females, 15.84%) directions. From a different perspective, Gribble at al. (2009) found that due to the greater flexion angle of knee and hip, the balance results of females higher than males (37). Moreover, the findings of Akın et al. (2017) study supports the findings of the present study that the range of motion and the movement angle of the dorsi flexion and plantar flexion were impactful for balance improvement, the results of the

higher scores in favoring female might be the gender difference of plantar flexion and dorsi flexion movement angle and range of motion (38). Although, the results of the body composition favouring males with higher LBM than female provided an advantage for balance scores to males, correlation coefficient analysis between Y-balance posterolateral test and strength results were moderate significantly for total subjects. Therefore, there is a need to examine the effects of body composition compartments with mass and biomechanical details.

Conclusions

In conclusion, dynamic balance parameter but not body composition, flexibility, strength and muscle endurance parameters were influenced by gender. The compartments of LBM and % BF were not changed significantly pre- and post- training test results. Increasing the number of sets and repetitions with the duration of the core training could be more effective to change body composition compartments favoring to increase in LBM and decrease in %BF. Furthermore, at the beginning of the present study, males had high LBM, the muscularity of the subjects might affect their dynamic balance scores. In a study, even the children of dominant mesomorph group had very high dynamic balance scores, the findings of the study support the approaches of the body composition and dynamic balance relationships of the study (39).

Recommendations

It could be recommended that core training program might be used both genders training programme to improve physical fitness parameters for young female and male groups not to lose weight or gain LBM for 8-week of training. Furthermore, by longer duration and increasing the sets and number of repetitions could be suggested to get body composition aims for future studies. In addition to that it could be recommendable for sports which needs dynamic balance such as basketball, volleyball, tennis, to use balance after jumping, running, spiking etc. For future studies, the effects of core training by adding free weights, plyometric training and/or resistance training methods on body composition change and increase in performance parameters might be comparable in terms of methodological difference by gender. Longer periods of combined core training with following-up body composition by specific techniques including regional differences and hormonal changes could be examined to determine what causes a greater increase in which gender.

No potential conflict of interest relevant to this article was reported by the authors.

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