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RESEARCH ARTICLE

THE INFLUENCE OF BMI ON CORE STABILITY IN HEALTHY ADULTS

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ABSTRACT

Background: Assessment of core stability (CS) in subjects with high body mass index (BMI) is critical for prognosis and for designing a core stabilization program. ***Objectives:*** Investigation the effect of BMI on core stability in healthy adults, and to compare the outcome between female and male healthy adults. ***Subjects:*** 90 healthy students with the right dominant lower limb admitted in this study based on the inclusion criteria, with the age of 19 to 25 years. Subjects have been distributed into three groups; Group I: 30 individuals with BMI<25 kg/m^2. Group II: 30 individuals with BMI =25–30kg/m^2. For group III: 30 individuals of BMI>30 kg/m^2. 15 male and 15 female students were involved in each group. ***Material and Methods:*** Electronic scale of weight and stadiometer device: calculation of BMI percentage. Prokin system: to measure the motor control of CS by balance tests (static& dynamic). ***Results:*** There were significant differences in MLSD, AFBS, AMLS, and PE parameters of bilateral open and close eye static balance test in group III than other groups (*p=<0.05)*. Also; COPX of right foot static balance test increased significantly in subjects of group III. Male subjects showed a significant increase in bilateral and unilateral static balance tests than females in group I&II, and in all groups for dynamic balance. ***Conclusion:*** The effect of BMI on CS is significant, and this could be used for preventive programs to improve motor performance.

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INTRODUCTION

BMI is known as a standard measurable method of obesity, which is defined as a ratio of body weight/height. BMI is used to assess overweight and obesity clinically as well as for epidemiological purposes because of ease measurement (Keys, 2014; Pasco, 2014). The general effect of obesity on the risks of injury and illness has been investigated; studies assessed the impact of obesity on muscle performance, focusing primarily on the strength of lower extremity, with little attention to handgrip and low back strength and endurance. Obesity-related effects on functional performance for tasks are still understudying, including assessments of endurance, balance, and acute fatigue effects, as these factors are essential to understand general impairments of muscle function (Cavuoto, 2014). It has been evidenced that fatigue-induced reductions in functional performance due to high BMI. It may affect numerous work-related tasks and daily activities that involve upright standing positions (Berrigan, 2006). These adverse effects of high BMI may influence CS and foot posture index. CS depends on the musculature of lumbopelvic-hip. These muscles bear compressive forces on the spine. Also; it returns the body to equilibrium after perturbation. It is using core strength, endurance, power, balance, as well as coordination of the spinal, abdominal, and hip musculatures (Willson, 2005; Cowley, 2008). Spine stability is supported and controlled by three systems: neural control, passive, and active systems. The neural system contains neural control centers, motion and force of muscles, ligaments, and tendons. The passive system includes mechanical passive properties of skeletal muscles, spinal ligaments, joint capsules, vertebrae, facet articulations, and intervertebral discs. The active system is consisted of dynamic forces of skeletal muscles and its tendons, which are acting on the spinal column (Panjabi, 2003). The core muscles are twenty-nine pairs within the active system considered as the core 'box.' The anterior aspect consists of abdominals, and the posterior is glutei and paraspinal muscles. The roof is composed of the diaphragm, while; the base contains hip girdle musculature and pelvic floor muscles (Hibbs, 2008; Faries, 2007). Cooperation between these muscles will control the position and motion of the spine over the pelvis and lower limbs during the functional movements (Fredericson, 2005; Kibler, 2006). Studies found that endurance and balance provided by the core musculatures are more important rather than the strength to maintain stability during tasks of daily living (McGill, 2001; Lehman, 2006). Assessment of balance (static and dynamic) is an integral element of core stability (Gribble, 2003).The efficient function of core musculatures will provide neuromuscular control, particularly for dynamic balance which is necessary for complex weight-shift activities in standing (Akuthota, 2004). Neuromuscular control of balance is detrimental for optimal core stability in addition to muscle capacity, including endurance and balance, this process provides muscular response against internal and external destabilizing forces to control body position and movement (Silfies *et al.,* 2015; Zazulak, 2007). Studies focused on measuring CS elements in athletes and low back pain patients, with a lack of investigation of the benefits for healthy adults (Faries, 2007; Kibler, 2006; Peate, 2007; Stanton, 2004; Marshall, 2011; Hamlyn, 2007). Also; CS training effects widely examined in the research. The impact of BMI on CS has not been evaluated extensively with its known effect on balance during static positions and dynamic activities (AlAbdulwahab, 2016). Previous researches have been applied many testing procedures with a high degree of the variation among them to measure the core stability performance including evaluation methods of strength as ultrasound activation of stabilization muscles (Johanne, 2000), isokinetic measure of strength (McGill, 1999), pressure biofeedback unit,[26] in addition to number of using clinical tests. Studies clarified that the measurement of core stability is difficult as a result of defect and variation in the reliability and validity of the testing method (Faries, 2007; Fredericson, 2005; Akuthota, 2004; Aggarwal, 2011). There is a knowledge gap in understanding CS because most clinical measures of CS have not been validated against lab-based biomechanical measures (Butowicz, 2016). Understanding the parameters that contribute to CS, or related to it indirectly will help to define CS (Waldhelm, 2012). Accordingly; the current research objective is to identify the relationship between BMI and CS during measurements the neuromuscular control of dynamic and static balance using Prokin device, and investigation the difference between nonathletic male and female subjects.

MATERIAL AND METHODS

90 male and female of healthy students, having an age of nineteen to twenty-five years old and right lower extremity dominant involved in the study. The Dominancy of the lower limb was determined by kicking a ball. Subjects were distributed based on BMI into three groups: Group I (normal): 30 individuals with BMI lower than 25 kg/m2. Group II (overweight): 30 individuals with BMI ranged from 25 to 30 kg/m2. Group III (obese): 30 individuals with BMI more than 30 kg/m2. Each group has consisted of 15 female and 15 male students. Subjects have been known the potential risks and benefits and signed a consent form to be admitted. The research unit of the university approved the study. The research unit of the university approved the study. Exclusion criteria were: foot pain, decreased foot sensibility, previous injury or surgery of back or abdomen, plantar fasciitis, neuropathy, and patellofemoral pain. Also; lower limb discrepancy, tibialis anterior or posterior dysfunction, back pain and musculoskeletal disorders about six months before the study (AlAbdulwahab, 2016).

Instrumentation used for measurement: Prokin System (Prokin-PK 212 –252-Techno Body-Italy): was used to perform Static and dynamic balance measurements (Fig.1) (Salavati, 2007).

A Calibrated stadiometer, including an analog scale (Invicta, London, UK): was used to measure the height of subjects. Breuer electronics scale (0.01 kg of precision): was used for measuring the weights of participants.

Assessment Procedure: A brief orientation session about the study nature was provided to each participant. All subjects received the familiarization trials of the testing procedures. The data recording was done by the same physiotherapist, in the same settings within two days after the trial session.

Body mass index assessment and calculation: A calibrated stadiometer with an analog scale was used to examine the participants' heights. Weights of participants' were assessed using the Breuer electronics scale. The BMI was determined by dividing weight over/ height squared (kg/m^2) for each participant (De Oliveira Pinheiro, 2004).

Core stability measurement:

Motor control test /balance tests (Static and dynamic):

- Warm-up activity was done for 5-minutes by training on a treadmill with self-selected speed before each testing session.
- The tests were explained. Then; the therapist calibrated the device and entered the data of height, weight, and age. The feet of the participants were placed bare on the balance platform.
- Subjects have looked at the screen in front of them with a 10 cm distance between their feet while their arms were at sides and to keep them fixed at (0) point.
- The subject was allowed to take rest after completion of each test, for device calibration process.
- At the time of the measurements, no communication (verbal) was with the subjects.
- Static balance tests: was performed for 30 seconds;

Bilateral static balance test with closed eyes (EC), and opened eyes (EO) including the following: center of pressure in x-axis (COPX), center of pressure in y-axis (COPY), Forward/backward Standard Deviation (FBSD), Medio-lateral Standard Deviation (MLSD), Average Forward/backward Speed (AFBS), Average Medio-lateral Speed (AMLS), Eyes Open ellipse area (EOEA), ratio area of Romberg test (RTAR), Eyes closed ellipse area (ECEA), perimeter error of Eyes closed (ECPE), Eyes open perimeter error (EOPE), and perimeter ratio of Romberg test (RTPR). Unipedal static balance: static balance was measured respectively on the right foot, eyes open and the values in terms of COPX, COPY, FBSD, MLSD, AFBS, AMLS, PE, and EA were taken for a right foot. Dynamic (Equilibrium/ Disequilibrium test): In this test, the subject was standing on the right foot(dominant), and saw some galleries that come against. The subject's scope was to go through o those galleries while maintaining the tilting board firmly. Only one axis is used in this test, and absorbers of the force for other axis was hardening. It was in the coronal plane (mediolateral direction) just for sixty seconds and. In dynamic equilibrium-disequilibrium test; COPX, COPY, FBSD, MLSD, AFBS, AMLS, PE, and EA parameters were evaluated (Atilgan, 2013).

Statistical Results: Analysis of data was performed using version 20.0 of SPSS. The significance level of (0.05) was used. Data were screened for normality assumption initially. It was checked by Kolmogorov-Smirnov and Shapiro-Wilks

Table 1. One way of ANOVA for bilateral open eye static balance test

Variable	X±SD	D.F	*F* .value	*P. Value*	Sig.
*EO_COPX in:	2.36 ± 2.73	(2.87)		0.536	NS
BMI_Group I	2.17 ± 2.17		0.627		
BMI_Group II	3.07 ± 4.45				
BMI_Group III					
*EO_COY in:	10.40 ± 10.28		0.737	0.482	NS
BMI_Group I	8.80 ± 10.12				
BMI_Group II	11.96 ±9.90				
BMI_Group III					
*EO-FBSD: BMI_Group I	5.83 ± 4.11		2.24	0.112	NS
BMI_Group II	6.03 ± 4.08				
BMI_Group III	7.83 ± 3.88				
*EO-MLSD: BMI_Group I	2.76 ± 1.25		5.001	0.009	HS
BMI_Group II	4.06 ± 2.42				
BMI_Group III	4.56 ± 2.84				
*EO-AFBS:	7.80 ± 3.26		3.317	0.041	S
BMI_Group I	8.53 ± 2.68				
BMI_Group II	9.86 ± 3.45				
BMI_Group III					
*EO-AMLS:	5.60± 2.14		4.121	0.019	S
BMI_Group I	7.83 ± 3.94				
BMI_Group II	8.00 ± 4.36				
BMI_Group III					
*EO-PE:	303.00 ±288.27		3.49	0.035	S
BMI_Group I	436.23 ±416.36				
BMI_Group II	731.40±990.95				
BMI_Group III					
*EO-EA:	331.56 ±121.71		3.57	0.032	S
BMI_Group I	392.53±137.59				
BMI_Group II	429.73 ±167.80				
BMI_Group III					

*EO-COPX: Eye Opened center of pressure in direction of x axis. *EO-COPY: Eye Opened center of pressure in direction of y axis. *EO-FBSD: Eye Opened Forward/backward Standard Deviation. *EO-MLSD: Eye Opened Medio-lateral Standard Deviation. *EO-AFBS: Eye Opened-Average Forward/backward Speed. *EO-AMLS:Eye Opened Average Medio-lateral Speed. *EO-PE: Eye Opened perimeter. *EO-EA: Eye Opened ellipse area. BMI*: Body mass index. X: mean SD: Standard Deviation D.F. Degree of Freedom HS: Highly Significant NS: not significant. HS: Highly Significant S: Significant P: probability F value:F-test.

Table 2. Post hoc comparisons of COPX of right foot static balance test between the three groups.

Compared Groups	MD	95% CI	*P value*	Sig.
COPX:		(-6.90 to 0.09)	0.059	NS
BMI_Group I	-3.00		0.006	S
BMI_Group II		(-7.22 to -1.04)		
BMI_Group I	-4.13		0.658	NS
BMI_Group III				
BMI_Group II	-1.13	(-4.22 to 1.96)		
BMI_Group III				

MD: Means Difference 95% CI: 95% Confidence Interval for Difference P: probability

Table 3. Comparison of bilateral close eye static balance test between males and females in group II

Angle	Male			Female			*t value*	*P. value*	Sig.
	Mean	SD	95% CI	Mean	SD	95% CI			
COPX	5.1	2.8	(-1.70 to3.4)	4.2	4.0	(-1.72 to 3.5)	0.690	0.496	NS
COPY	11.3	9.8	(-12.5 to 3.4)	15.8	11.3	(-12.5 to 3.4)	-1.17	0.251	NS
FBSD	7.3	2.7	(-2.6 to 2.9)	7.2	4.5	(-2.7 to 2.9)	0.099	0.922	NS
MLSD	4.8	2.4	(-2.6 to 0.86)	5.7	2.3	(-2.6 to 0.86)	-1.02	0.314	NS
AFBS	12.3	3.1	(0.60 to 5.1)	9.4	2.9	(0.60 to 5.1)	2.594	0.015	S
AMLS	10.1	4.4	(-0.07 to 5.3)	7.5	2.4	(-0.11 to 5.3)	1.989	0.056	NS
PE	628.1	427.2	(-470.6 to 329.8)	698.5	624.5	(-472.9 to 332.2)	-0.360	0.721	NS
EA	530.4	165.6	(13.9 to 225.9)	410.5	112.9	(13.2 to 226.5)	2.316	0.028	S

SD: Standard Deviation T value: Paired t value P: Probability NS: Not Significant.

Table 4. Comparison of dynamic balance test between males and females in group III

Angle	Male			Female			*t value*	*P. value*	Sig.
	Mean	SD	95% CI	Mean	SD	95% CI			
*USPI	6.63	0.37	(0.12 to 0.65)	6.25	0.34	(0.12 to 0.65)	2.946	0.006	S
*USI	5.85	0.23	(-0.7 to -0.35)	6.39	0.23	(-0.7 to -0.35)	-6.235	0.000	HS

*USPI: upper stability index. *USI: under stability index. SD: Standard Deviation T value: Paired t value P: Probability HS: Highly Significant

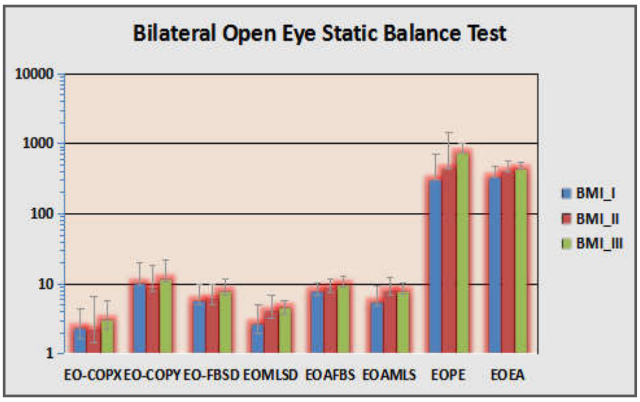

Figure 1. Means and ± SD of bilateral open eye static balance test

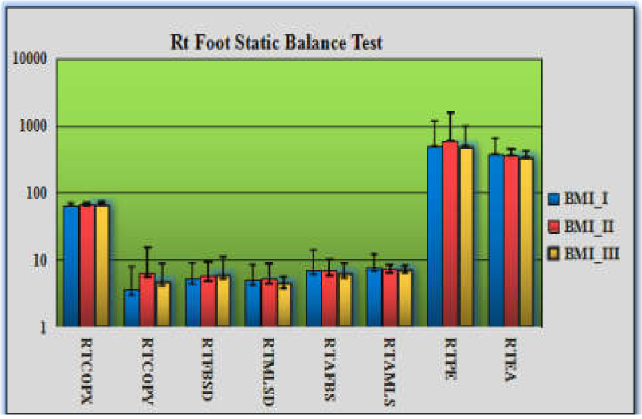

Figure 2. Means and ± SD of Rt foot static balance test

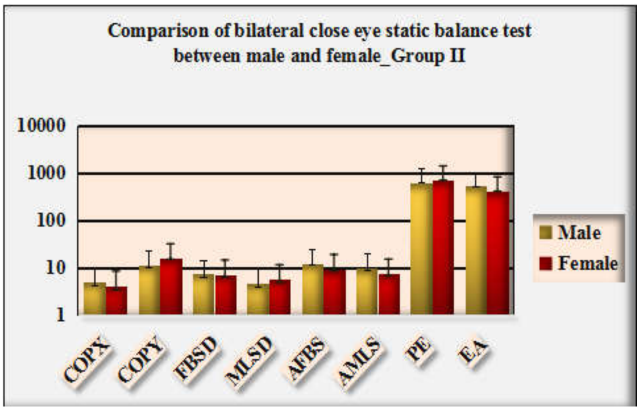

Figure 3. Comparison of bilateral close eye static balance test between males and females in group II

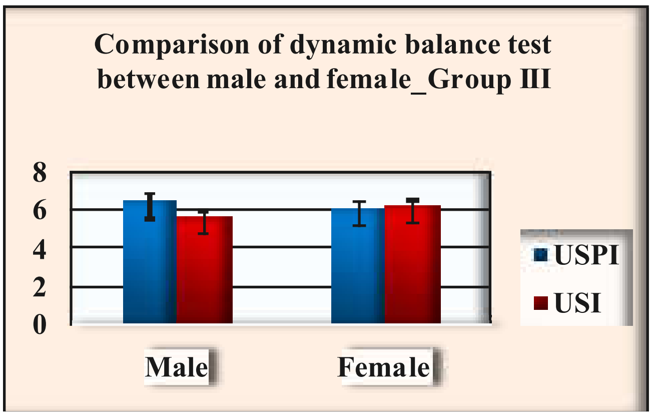

Figure 4. Comparison of dynamic balance test between males and females in group III

normality tests and also for testing the presence of extreme scores and significant skewness and kurtosis. Furthermore, data were assessed for variance assumption of homogeneity. A parametric analysis was conducted, as we found data not to violate the normality and homogeneity. Differences between the 3 groups of subjects for the variables of bilateral static balance, right foot static balance and test of dynamic balance were measured by one way of ANOVA. Also; T test (Unpaired) was used to examine the influence of BMI on core stability between female and male healthy adults in each group. A two-tailed probability value (P value) that was lower than (0.05) considered as statistically significant. Demographic data was for group I: age = 20.76 ± 1.41, weight = 57.00 ± 8.17, height = 161.6 ± 9.58, BMI = 21.655 ±2.058. Group II: age = 21.33 ± 1.71, weight = 72.40 ± 10.15, height = 162.67 ± 9.69, BMI = 35.54 ± 3.76. Group III: age = 20.87 ± 1.31, weight = 95.400 ± 16.21, height = 163.37 ± 9.65, BMI = 35.54 ± 3.76. There was no significant difference in variables of bilateral static balance test with the opened eye in three groups for EOCOPX, EOCOPY, EOFBSD by F value = 0.627, 0.737, 2.24, when P = 0.536, 0.482, and 0.112 respectively. On the other hand, there was significant difference between the means of the three groups for EOMLSD, EOAFBS, EOAMLS, EOPE, and EOEA of bilateral open eye static balance by F value = 5.001, 3.317, 4.121, 3.49, and 3.57, when P = 0.009, 0.041, 0.019, 0.035, 0.032 respectively (table 1, Fig. 1). It was apparent from post hoc comparisons for group III (BMI>30 kg/m^2); BMI had a highly significant effect on EOMLSD, EOAFBS, EOAMLS, EOPE, and EOEA than that of group I and II when p= 0.01, 0.0341, 0.031, 0.031, and 0.026 respectively.

In the bilateral static close eye test; EOCOPX, EOCOPY, ECFBSD, EOAMLS, and EOEA were not significant in the three groups of BMI when p = 0.631, 0.701, 0.260, 0.268, and 0.073 respectively. While; the means of ECMLSD, ECAFBS, and ECPE were significant in the three groups when p = 0.020, 0.010, and 0.047 respectively. Data from post hoc comparisons showed that there were significant increments in ECMLSD, and EC-PE during bilateral static close eye test in group III with high BMI in comparison with group I when P = 0.0190, and 0.037 respectively. Also; in groups III, there was an increase in ECAFBS than that of other groups when P = 0.012. ANOVA of right foot static balance test cleared that; there were no significant differences between the means of three BMI groups for COPY, FBSD, MLSD, AFBS, AMLS, ECPE and EA by *F value*= 1.38, 0.312, 0.425, 0.201, 0.231, 0.191, and 0.361 respectively when *P* = 0.256, 0.733, 0.655, 0.818, 0.794, 0.826, and 0.698 respectively, while there was significant difference in COPX by *F value*= 5.4, *P*=0.006 (Fig. 2). Post hoc comparisons in a table (2) showed that there was an increment in COPX in BMI group III more than that in groups II, and III of BMI when *P* = 0.006. ANOVA of dynamic balance test showed there were no significant differences between the means of three BMI groups for USPI (upper stability index) and USI (under stability index) by *F value*= 2.22, and 1.68 respectively when *P* = 0.115, 0.864 respectively. In the group, I; AFBS and EA during bilateral static balance eye open test were highly increased in males than in females by t value = 3.78, 3.019 when p = 0.001, 0.005 respectively. Regarding COPX, COPY, FBSD, MLSD, AMLS, and PE there was no statistically significant difference between male and female subjects by t value = -0.66, 0.921, 2.007, 1.33, 1.76 and 1.85, when p= 0.948, 0.365, 0.055, 0.194, 0.089, and 0.074 respectively.

For all variables of bilateral open eye static balance test; no difference has been found between male and female subjects in both group II and group III. During bilateral static balance close eye test, for the group (I), AFBS, and EA were highly significantly reduced in females than in males by t value = 3.092, and 2.709, when p = 0.0041, and 0.011 respectively. However; there were no differences in the remaining variables. AFBS and EA variables of bilateral static balance close eye test were increased in males than in females. It was in group II by t value = 2.594, and 2.316, when p = 0.0150, and 0.028 respectively. But; the other variables were not significant (table 3, Fig.3). For group III; no difference was found between female and male subjects. During the right foot static balance test; in group I; COPX had highly significantly increased in males than in females by t value = 3.518 when p = 0.002. In group II; COPX was highly considerably decreased in females in comparison with males by t value = 2.40 when p = 0.0230. There was no statistical variation in all the variables of unipedal test between female and male subjects in group II.
It was evident that there was strong effect of BMI in group I on the dynamic balance; where there was noticeable increase in the USPI in males than females by t value = 2.872, when p = 0.008, in contrast; there was increase in USI in females than males, by t value = -7.91 when p = 0.000. In group II; there was significant increase USPI in males than female subjects by t value = 2.232 when p = 0.034, also there was an increment in USI in females than male subjects by t value = -3.239, when p = 0.0030.Table (4) and fig (4) illustrated that in group III; USPI had reduced in females than male subjects during a disequilibrium balance test by t value = 2.946 when p = 0.0060. However; USI was increased considerably in females than male subjects by t value = -6.235, when p = 000.

DISCUSSION

This research project studied the effect of BMI on the motor control of core stability in healthy subjects. Balance tests (static and dynamic) were assessed using prokin system. During eye open and eye close bilateral static balance test; MLSD, AFBS, AMLS, and PE parameters significantly increased in group III of high BMI (BMI>30 kg/m2) than other groups. Also; it was evident during the unilateral right foot static balance test; only COPX significant in group III. There wasn't any significant difference in other parameters. Regarding the dynamic balance test; it was no difference detected between the three groups of subjects. Male subjects had a significant increase in AFBS and EA more than female subjects, specifically in groups I, II during bilateral static tests. Also; it was observed that COPX increased significantly in males during the right foot balance test, and this was only for groups I, and II.

Statistical results of the dynamic balance test revealed that the upper stability index was significantly better in male subjects than the females in the three groups, and vice verse for under stability index. According to our results, no differences in Romberg test parameters were determined between female and male subjects in the three groups as it was equal to zero for all. The present study emphasized on the effects of BMI on motor control element of CS; where there are increased MLSD, AFBS, AMLS, and PE parameters during static balance test in group III of high body mass index which is a compensation for reduced endurance and strength of the core muscles and altered recruitment of these muscles.[8] Our results are in agreement with that found by Al Abdulwahab and Kachanathu, (2016), who have found a strong association between CS and BMI by testing the endurance of anterior core muscles for 39 nonathletic subjects with BMI ranged from 25 to 29.9 kg/m^2. The role of CS during functional and sports activities to transfer muscle energy and movement from the body torso to the peripheral extremities has been documented. [33] Therefore; if the core muscles are weak and the extremities are strong, it will lead to low force production and improper and limited movement patterns of extremities due to a decrease of muscular energy from the core. The body must incorporate motor-processing, sensory, and biomechanical principles coupled with past experiences and the ability to give anticipatory responses to maintain core stability (Comerford, 2001). Accordingly; the body must control the trunk in response to destabilizing internal or external forces that are generated by extremities and expected/unexpected challenges to stability (Borghuis, 208). Our study results are proportionate with previous studies showing that the endurance of core muscles is correlated with that of the low back (Fogelholm, 2006). Also; overweight has resulted in low endurance times and strength decrease in younger people (Cavuoto, 2014).

In this study, the differences between females and males during balance tests (static and dynamic) were supported by the results of Atılgan *et al.,* (2012), who have investigated static balance for boys and girls of 9-16 years old using prokin system, and observed that boys were better in their results than girls. The possible explanations for that boys or males have in general a more active life than the girls or female subjects. Earlier assessments of body compositions suggest that obese males experience increases in fat-free mass equivalently to increases in fat mass, while females gain mostly fat mass (Lafortuna, 2004; Lafortuna, 2005). Highest fatty infiltration was found more in rectus abdominal muscle, and with a low percentage in lateral abdominal muscle and paraspinal muscle in overweight and obesity subjects (Ryan, 2014). The fat intramuscular deposition is linked with diminished functional performance in healthy adults (Hicks, 2005). Our investigation of the dynamic balance clarified no difference among the groups. It may be correlated with increased inertia of the body in subjects with overweight against the acceleration. In our study, the measurement of CS was limited to the motor control element; other aspects of CS should be assessed, including endurance, strength, motor control, and flexibility.

Conclusion

The results of our study showed a positive influence of BMI on the motor control element of CS both in nonathletic healthy adults. It was evident in static balance; where the subjects in group III with high BMI >30 kg/m^2 had increased parameters of static balance test. Male subjects in groups I, II, had better balance results (static and dynamic) in comparison with female subjects. These findings could be referred to when one is interpreting CS in LBP and lower extremity disorders, especially in overweight individuals. Dynamic and static assessment of CS should be used as an indicator and predictor for core musculatures' strength and endurance to encourage the subjects to control their BMI and improve general health.

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Key points

- Assessment of motor control elements (static and dynamic balance) of core stability of the spine.
- Investigation of the effect body mass index on the motor control elements of core stability in both female and male subjects.
- Comparison the the motor control elements of core stability between female and male subjects.
- Using the findings of this study when one is interpreting CS in LBP and lower extremity disorders especially in overweight subjects.

REFERENCES

Aggarwal A., Kumar S., Madan R., Kumar R. 2011. Relationship among different tests of evaluating low back core stability. *Journal of Musculoskeletal Research.,* 14(2):1250004-1- 1250004-9.

Akuthota V, Nadler SF. Core strengthening. *Arch Phys Med Rehabil.* 2004; 85 (1): S86-92.

AlAbdulwahab SS., Kachanathu SJ.2016. Effects of body mass index on foot posture alignment and core stability in a healthy adult population. J*ournal of Exercise Rehabilitation.,* 12(3):182-187.

Atilgan OE. 2013. Effects of trampoline training on jump, leg strength, static and dynamic balance of boys. *Science of Gymnastics Journal,* 5(2):15-25.

Berrigan F., Simoneau M., Tremblay A., Hue O., Teasdale N. 2006. Influence of obesity on accurate and rapid arm movement performed from a standing posture. *Int J Obes (Lond)*. 30:1750-1757.

Borghuis J., Hof AL., Lemmink KA. 2008. The importance of sensory-motor control in providing core stability: implications for measurement and training. *Sports Med.,* 38:893-916.

Butowicz CM., Ebaugh DD., Noehren B., Silfies SP. 2016. Validation of two clinical measures of core stability. *Int J Sports Phys Ther.*, Feb; 11(1): 15–23.

Cavuoto L A., Nussbaum M A. 2014. Obesity-related differences in muscular capacity during sustained isometric exertions. *Journal of Occupational and Environmental Hygiene*. 11(9):583-590.

Comerford MJ., Mottram SL. 2001. Movement and stability dysfunction: contemporary developments. *Man Ther.* 6:15-26.

Cowley PM., Swensen TC. 2008. Development and reliability of two core stability field tests. *J Strength Cond Res*., Mar; 22(2):619-624.

De Oliveira Pinheiro AR., de Freitas SF., CorsoI AC. 2004. An epidemiological approach to obesity. *Rev Nutr.,* 17:523-533.

Faries MD., Greenwood G. 2007. Core training: Stabilizing the confusion. *Strength Cond J.,* 29:10-25.

Fogelholm M., Malmberg J., Suni J., Santtila M., Kyröläinen H., Mäntysaari M. 2006. Waist circumference and BMI are independently associated with the variation of cardio-respiratory and neuromuscular fitness in young adult men. *Int J Obes (Lond)* 30:962-969.

Fredericson M., Moore T. 2005. Muscular balance, core stability, and injury prevention for middle- and long-distance runners. *Phys Med Rehabil Clin N Am.* 16:669-689.

Gribble PA. 2003. The Star Excursion Balance Test as a measurement tool. *Athl Ther Today.* 8(2):46–47.

Hamlyn N1., Behm DG., Young WB. 2007. Trunk muscle activation during dynamic weight-training exercises and isometric instability activities.*J Strength Cond Res.*, Nov; 21(4):1108-12.

Hibbs AE., Thompson KG., French D., Wrigley A., Spears I. 2008. Optimizing performance by improving core stability and core strength. *Sports Med.* 38(12):995-1008.

Hicks GE., Simonsick EM., Harris TB., Newman AB., Weiner DK., Nevitt MA., Tylavsky FA. 2005. Cross-sectional associations between trunk muscle composition, back pain, and physical function in the health, aging and body composition study. J *Gerontol A Biol Sci Med Sci.*, 60(7):882-887.

Johanne MV., Cheryl L. 2000. Muscles activation in therapeutic exercise to improve trunk stability. *Arch Phys Med Rehabil*. 81(10): 1370-1379.

Kazuto W., Kei M. 2004. Use of ultrasonography to evaluate thickness of erector spinae muscle in maximum flexion and extension of lumbar spine. *Spine.* 29(13): 1472-1477.

Keys A., Fidanza F., Karvonen MJ., Kimura N., Taylor HL. 2014. Indices of relative weight and obesity. *Int J Epidemiol.,* 43(3):655-665.

Khaivan, Hides JA., Richardson CA. 2006. Use of real time ultrasonography imaging for biofeedback of lumbar multifidus muscle contraction of healthy subjects. J *Orthop Sports Phys Ther.*, 36(12): 920-925.

Kibler WB., Press J., Sciascia A. 2006. The role of core stability in athletic function. *Sports Med.*, 36(3):189-198.

Lafortuna C., Agostin F., Marinone P., Marazzi N., Sartorio A. 2004. The relationship between body composition and muscle power output in men and women with obesity. *J Endocrinol Invest.,* 27:854 - 861.

Lafortuna CL., Maffiuletti NA., Agosti F., Sartorio A. 2005. Gender variations of body composition, muscle strength and power output in morbid obesity. *Int. J. Obes.,* 29: 833-841.

Lehman GJ. 2006. Resistance training for performance and injury prevention in golf. *JCCA J Can Chiropr Assoc.,* 50 (1):27-42.

Marshall PWM., Desai I., Robbins DW. 2011. Core stability exercises in individuals with and without chronic nonspecific low back pain. *J Strength Condi Res*. 25(12):3404-3411.

McGill SM. Low back stability: From formal description to issues for performance and rehabilitation. *Exerc Sport Sci Rev.* 2001; 29(1):26-31.

McGill SM., Childs A., Liebenson C. 1999. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal datatbase. A*rch Phys Med Rehabil*., 80(8):941-944.

Panjabi MM. 2003. Clinical spinal instability and low back pain. *J Electromyogr Kinesiol.* 13(4):371-9.

Pasco JA., Holloway KL., Dobbins AG., Kotowicz MA., Williams LJ., Brennan SL. 2014. Body mass index and measures of body fat for defining obesity and underweight: a cross-sectional, population-based study.*BMC Obesity.*1:9.

Peate WF., Bates G., Lunda K., Francis S., Bellamy K. 2007. Core strength: A new model for injury prediction and prevention. *J Occup Med Tox.*, 2(3):1-9.

Ryan AS., Harduarsingh-Permaul AS. 2014. Effects of weight loss and exercise on trunk muscle composition in older women. *Clin Interv Aging.,* 9:395-402.

Salavati M., Moghadam M., Ismaeil Ebrahimi I., Arab AM. 2007. Changes in postural stability with fatigue of lower extremity frontal and sagittal plane movers. *Gait Posture.* 26(2):214–8.

Silfies SP., Ebaugh D., Pontillo M. *et al.,* 2015. Critical Review of the Impact of "Core Stability" on Upper Extremity Athletic Injury and Performance. *Braz J Phys Ther*., 19(5):360-368.

Stanton R., Reaburn PR., Humphries B. 2004. The effect of short-term Swiss ball training on core stability and running economy. *J Strength Condi Res.,* 18(3):522-528.

Tse MA., McManus AM., Masters RS. 2005. Development and validation of a core endurance intervention program: implications for performance in college-age rowers. *J Strength Cond Res.,* 19(3):547-552.

Waldhelm A., Li Li. 2012. Endurance tests are the most reliable core stability related measurements. *Journal of Sport and Health Science.* 1(2):121-128.

Willson JD., Dougherty, CP., Ireland, ML., Davis IM. 2005. Core stability and its relationship to lower extremity function and injury. *J Am Acad Orthop Surg.,*13(5): 316-325.

Zazulak BT., Hewett TE., Reeves NP., Goldberg B., Cholewicki J. 2007. Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study. *Am J Sports Med*., 35(7):1123-1130.

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