Effect of Parathyroid Hormone and Body Mass Index on Overall Stability Index in Saudi Males with Vitamin D Deficiency

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Abstract: The purpose of this study is to determine the correlation between parathyroid hormone (PTH) and body mass index (BMI) on the overall stability index (OSI) in Saudi males with vitamin D deficiency. **Method:** A total of 669 adult Saudi males with mean age of 19.9 years suffering from vitamin D deficiency were participated in this study. The subjects were divided according to their PTH status into two groups; group 1 (n=619) having a normal PTH values; and group 2 (n=50) suffering from hyperparathyroidism. Participants were also categorized based on their BMI into; underweight (BMI≤17.9), normal (BMI=18-24.9), overweight (BMI 25-29.9), and obese (BMI≥30). The OSI protocol was used to compare vitamin D deficiency subjects' that having normal PTH values with those suffering from hyperparathyroidism for different BMI categories. The Biodex Balance System was used to measure the OSI values. **Results**: No significant differences were observed between normal and high PTH groups in age, weight, height, BMI, OSI, vitamin D, calcium, phosphorus, and alkaline phosphatase. A significant positive correlation between OSI and PTH (r=0.135, P=0.011) was perceived. The results also revealed that the BMI had a significant positive association with OSI (r=0.521, P<0.001). In addition, BMI had positive correlation with PTH (r=0.109, P=0.042). The highest average OSI value was observed in the subjects having both obesity and hyperparathyroidism. **Conclusion:** The PTH and BMI have a positive correlation with OSI, which means that hyperparathyroidism and obesity synergistically increase the risk of falling in Saudi males with vitamin D deficiency.

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Key words: Parathyroid Hormone; Body Mass Index; Overall Stability Index.

1. Introduction

The basic function of the parathyroid hormone (PTH) is to enhance the release of calcium from the large reservoir in the bones. It also, is in charge of stimulating the activity of 1-α-hydroxylase enzymes, which converts 25-hydroxycholecalciferol [25(OH)-D], the major circulating form of inactive vitamin D, to 1,25-dihydroxycholecalciferol, the active form of vitamin D, in the kidney (Poole and Reeve, 2005).

Normal bone destruction is carried out through indirect stimulation of PTH to osteoclasts activity, which is responsible for bone resorption. As the osteoclasts do not have a receptor for PTH, the PTH binds to osteoblasts, the cells responsible for creating bone, stimulating osteoblasts to increase their expression of RANKL and inhibits their expression of osteoprotegerin (Kamycheva, 2004).

Vitamin D is a significant nutritive for healthy bones and a deficiency of the vitamin resulting in many metabolic bone diseases as rickets in children or osteomalacia in adults (Trivedi et al., 2003). The regulation of vitamin D level is carried out through the interaction between various factors, including intestinal absorption, renal function, serum calcium level and PTH (Eastell et al., 2003).

Obesity defined as a medical condition with excess adiposity or when the body mass index (BMI) is above 30 kg/m^2, and the obese individuals demonstrate abnormal metabolic and endocrine functions (Seidell and Flegal, 1997; WHO, 2000).

Obesity is considered as a major public health problem that have a great regard in many countries. It has a great impact in development of vitamin D deficiency as many previous studies have reported an inverse relationship between circulating concentrations of 25(OH)-D, BMI and body fat mass (Parikh et al., 2004), even in earlier ages (Kensarah et al., 2015).

Both vitamin D and PTH have an essential role in bone metabolism and calcium homeostasis, and it has become increasingly clear that the vitamin D endocrine system is related to obesity in adults. Obesity has been found to be associated with lower levels of serum 25-OH vitamin D and higher levels of serum PTH. PTH has been postulated as an independent predictor of obesity, and low vitamin D intake was associated with increased BMI (Gunther, 2001).

Recently, the prevalence of obesity in the Arabian Gulf region has been increased, due to the discovery of oil and related increases in economic growth, access of food and a more convenience-oriented lifestyle (Al-Rethaiaa et al., 2010). The level of vitamin D among young adult Saudi obese is negatively associated with body mass index and classes of as well as PTH levels (Al-Sultan et al., 2011; Kensarah and Azzeh, 2012).

Balance is a process controlled by sensory input, central processing, and neuromuscular responses. The sensory components of this process include the vestibular, visual and proprioceptive systems. The central nervous system can adjust body sway and posture; by integrating this information and controlling skeletal muscles to generate joint torque and adjust joint angles (El Fiky and Helal, 2014).

An intact neuromuscular system and sufficient muscle strength are needed for an appropriate motor response that required returning the center of mass within the base of support when balance is disturbed. Impairment in any component of the postural control system can lead to disturbance of balance and falls (Filimban et al., 2015).

Vitamin D deficiency has been reported to affect mostly the weight-bearing antigravity muscles of the lower limb, which are necessary for postural balance, and a significant correlation between serum 25(OH)-D_3 concentration and the occurrence of falls in elderly people has been declared (Bischoff-Ferrari et al., 2004).

Postural stability can be defined statically as the ability to maintain a base of support with minimal movement, and dynamically as the ability to perform a task while maintaining a stable position. Postural stability is considered to be an important indicator of musculoskeletal health and therefore could be of importance in view of clinical issues (Kejonen et al., 2003).

Once a person action does not function accordingly, the ability to maintain balance becomes compromised and consequently, equilibrium becomes altered. A variety of sequel can occur due to poor balance therefore, clinicians need to address each component in order to prevent injury, reinjury or further trauma (Schmitz et al., 1998).

The purpose of this study is to determine the correlation between PTH and BMI on the overall stability index (OSI) of adult males with vitamin D deficiency.

2. Subjects and Methods

A total of 669 adult Saudi males with mean age of 19.9±1.6 years suffering from vitamin D deficiency were enrolled in this study. Subjects with evidence of cardiovascular disease (systolic blood pressure >120 mm Hg and diastolic blood pressure < 60 mm Hg), with associated hepatic or renal diseases, diabetes, hypercortisolism, malignancy and users of lower limb orthotics were excluded. Subjects with disturbance in proprioceptive sensation or vestibular system, and using drugs or medicine that might interfere with balance (alcohol, sedative and tranquilizers) were also excluded.

Weight and height scale were used to measure the BMI value. The Biodex Balance System (BBS, Biodex Corporation, Shirley, NY) was used to measure OSI. The tested biochemical indicators were vitamin D, PTH, calcium, phosphorus and alkaline phosphatase.

The normal values of the tested parameters are OSI (0.8 - 2.3), vitamin D (≥30 ng\ml), PTH (14 - 65 pg\ml), calcium (8.8 - 10.8 mg\dl), phosphorus (4.5 - 5.5 mg\dl) and alkaline phosphatase (60 -170 u\L).

Hence, hypovitaminosis D is one of the main factors associated with increasing serum PTH levels (Al-Sultan et al., 2011), participants with vitamin D deficiency were chosen in this study to find-out the role of high and normal PTH levels on OSI after controlling vitamin D, which is considered as a confounding factor.

Subjects were divided according to their PTH status into two groups; group 1 (N=619): having a normal PTH values (37.67 pg\ml ±12.56), and group 2 (N=50): suffering from hyperparathyroidism, with average PTH was 81.87pg\ml ± 22.72. Participants were also categorized based on their BMI into; underweight (BMI≤17.9), normal (BMI=18-24.9), overweight (BMI 25-29.9), and obese (BMI≥30).

The OSI protocol was achieved to compare vitamin D deficiency subjects' that having normal PTH values with those suffering from hyperparathyroidism, as well as determining if there was a correlation between the BMI and OSI in adults with vitamin D deficiency. BBS device was used to measure balance and postural stability under dynamic stress.

The BBS uses a circular platform that is free to move in the anterior–posterior and medial-lateral axes simultaneously. The BBS allows up to 20° of foot platform tilt, which permits the ankle joint mechanoreceptors to be stimulated maximally. The BBS measures, in degrees, the tilt about each axis during dynamic conditions and calculates an OSI.

A high score in the OSI indicates poor balance. The OSI score is believed to be the best indicator of the overall ability of the subject to balance the platform. The stability of the platform can be varied by adjusting the level of resistance given by the springs under the platform. The platform stability ranges from 1–12, with 1 representing the greatest instability. The lower the resistance level the less stable the platform (Cachupe, 2001).

Testing parameters were calibrated as; 20 seconds test duration, level 8 of stability, bilateral stance type, eyes open, three trial repetitions, and 30-second rest period between sets. Three test trials were performed to avoid excessive balance deviations. The participant's performance is noted as a stability index. Test results are compared to age dependent normative data.

Statistical Analysis

SPSS software version 20 was used for statistical analysis. A P-value less than 0.05 were considered significant. To determine significance between two variables, T-test was performed, while analysis of variance (ANOVA) followed by a least significant difference (LSD) test was done to measure the significances for more than two variables.

3. Results

Table (1) shows the baseline characteristics of the participants according to their PTH status. The average age of the whole sample was 20 years old, and the average BMI was 25.7 kg/m^2. No significant differences between the two groups in age, weight, height, BMI, OSI, vitamin D, calcium, phosphorus and alkaline phosphatase were observed. The significant (P<0.05) differences were exerted in PTH and vitamin D levels. The mean OSI value for hyperparathyroidism participants (1.01±0.41) was higher (P>0.05) than those of normal PTH (0.9±0.42). However, a significant (P<0.05) positive correlation between OSI and PTH (r=0.135, P=0.011) was perceived.

The characteristics of the contributors based on their BMI status were seen in Table (2). About 20.9% of the selected samples were obese. There were significant differences (P<0.05) between groups regarding their OSI, vitamin D, and BMI, but not in PTH. Obesity increased the OSI values significantly (P<0.05) but decreased the vitamin D contents significantly (P<0.05). Correlation test resulted that BMI had a significant positive association with OSI (r=0.521, P<0.001), while a significant negative association with vitamin D (r = - 0.208, P <0.001). In addition, BMI had a positive correlation with PTH (r=0.109, P=0.042).

Table (3) presents the OSI and other variables depending on different BMI categories and between normal and high PTH groups. Numerically, the highest average OSI value was detected in obese and hyperparathyroidism group, then in obese and normal PTH participants. On the other hand, underweight and normal PTH group showed the lowest OSI value.

Table 1. Characteristics of participants (N = 669) according to their PTH status

Variables	PTH status		Total	P-value
	Normal (N=619)	Hyperparathyroidism (N=50)	(N=669)	
Age (year)	19.9±1.6	20.8±1.9	20±1.7	0.66
Wt (kg)	74.6±19.9	81.5±18.6	75.1±19.9	0.086
Ht (cm)	170.7±6	172.3±5.1	170.8±5.9	0.188
BMI (Kg/m^2)	25.51±6.34	27.46±5.97	25.65±6.33	0.131
OSI	0.9±0.42	1.01±0.41	0.91±0.42	0.222
VD (ng\ml)	11.13^a±3.57	9.12^b±3.08	10.98±3.57	0.006
PTH (pg\ml)	37.67^b±12.56	81.87^a±22.72	40.94±17.81	<0.001
Ca (mg\dl)	9.1±0.6	9±0.8	9.1±0.6	0.473
P (mg\dl)	3.8±1.8	3.9±1.9	3.8±1.8	0.78
ALP (u\L)	101.8±42.5	109.1±33	102.4±41.9	0.397

- Results are considered as Mean ± SD
- P-value was determined by T-test
- Abbreviations; BMI: Body Mass Index, OSI: Overall Stability Index, VD: Vitamin D as 25-(OH)-D_3, PTH: Parathyroid Hormone, Ca: Calcium, P: Phosphorus, ALP: Alkaline Phosphatase.

Table 2. Characteristics of participants (N = 669) according to their BMI status

Variables	BMI categories				Total (N = 669)	*P*-value
	Underweight (N=55)	Normal (N = 303)	Overweight (N =171)	Obese (N =140)		
OSI	$0.7^{c}\pm0.32$	$0.78^{c}\pm0.33$	$0.9^{b}\pm0.3$	$1.26^{a}\pm0.55$	0.91±0.42	<0.001
VD	$12.08^{a}\pm3.64$	$11.21^{a}\pm3.67$	$11.05^{a}\pm3.82$	$9.94^{b}\pm2.76$	10.98±3.57	0.022
PTH	36.99±12.13	39.17±14.97	44.29±20.64	42.24±20.92	40.94±17.81	0.087
BMI	$16.92^{d}\pm0.83$	$21.9^{c}\pm1.89$	$27.2^{b}\pm1.42$	$35.39^{a}\pm4.82$	25.65±6.33	<0.001

- Results are considered as Mean ± SD
- Means with different superscripts in the same row are significantly different ($P<0.05$) according to ANOVA and LSD analysis
- Abbreviations; BMI: Body Mass Index, OSI: Overall Stability Index, VD: Vitamin D as 25-(OH)-D_3, PTH: Parathyroid Hormone

Table 3. Characteristics of participants (N = 669) according to their PTH status and BMI categories

PTH Status	BMI Categories	OSI	VD	PTH	BMI
Normal (N=619)	Underweight (N=55)	$0.7^{c}\pm0.32$	$12.08^{a}\pm3.64$	36.99±12.13	$16.92^{d}\pm0.83$
	Normal (n=284)	$0.78^{c}\pm0.32$	$11.25^{a}\pm3.72$	36.89±12.23	$21.88^{c}\pm1.9$
	Overweight (n=154)	$0.9^{b}\pm0.3$	$11.39^{a}\pm3.73$	39.77±13.53	$27.21^{b}\pm1.44$
	Obese (n=126)	$1.21^{a}\pm0.56$	$10.11^{b}\pm2.78$	37.13±12.21	$35.37^{a}\pm4.9$
	Total	0.9±0.42	11.13±3.57	37.67±12.56	25.51±6.34
	P-value	<0.001	0.025	0.386	<0.001
High (N=50)	Normal (n=19)	$0.91^{b}\pm0.36$	$10.61^{a}\pm3.06$	73.14±10.14	$22.17^{c}\pm1.83$
	Overweight (n=17)	$0.94^{b}\pm0.31$	$8.38^{b}\pm2.13$	84.97±29.04	$27.05^{b}\pm1.29$
	Obese (n=14)	$1.27^{a}\pm0.55$	$8.04^{b}\pm3.35$	90.36±25.43	$35.53^{a}\pm4.29$
	Total (n=50)	1.01±0.41	9.12±3.08	81.87±22.72	27.46±5.97
	P-value	0.018	0.045	0.28	<0.001

- Results are considered as Mean ± SD
- Means with different superscripts in the same column are significantly different ($P<0.05$) according to ANOVA and LSD analysis
- Abbreviations; BMI: Body Mass Index, OSI: Overall Stability Index, VD: Vitamin D as 25-(OH)-D_3, PTH: Parathyroid Hormone.

4. Discussion

This is the first study that analyzing the correlations between PTH, BMI and OSI in Saudi males with vitamin D deficiency. We found that the PTH and BMI have a positive correlation with stability index, which means that hyperparathyroidism and obesity increase the risk of falling in Saudi males with vitamin D deficiency.

As revealed from our study, obese subjects showed higher risk for balance instability, which is in accordance with most studies in adults. This effect might be attributed to the ankle torque generated depending on the distance between center of mass (COM) and the ankle joint. The higher this distance, the greater ankle torque produced to overcome the gravitational torque and maintaining the upright dynamic balance (Alexy et al., 2006; Del Porto et al., 2012). Obese subjects with excessive fat accumulation and larger COM expected to have higher distance and more corrective ankle torque than normal weight subjects to stabilize the natural stance (Teasdale, 2007).

Our findings are in line with other researches that found in controlling weight as a protective factor for balance stability. Teasdale et al., (2013) concluded that a positive and significant correlation was obtained between reducing weight and balance stability as measured by center of foot pressure speed. After weight loss program, all balance variables were also improved significantly (center of foot pressure speed, as well as anterior/posterior and medial/lateral ranges).

In addition, our findings were in consistence with Steinberg et al., (2013) who postulated that weight management program for childhood obesity improved stability, reduced potential estibular stress/disturbances, and decreased falling probability of the participants. Our results are consistent with Sun et al., (2016) who stated that their results may provide evidence to support the beneficial effects of a weight loss management program on postural stability and neuromuscular control, potential vestibular stress or disturbances, and a falling probability of obese children.

The results discussed above clearly indicated that the highest OSI value was detected in obese and hyperparathyroidism group. This confirms that hyperthyroidism, not only BMI, had a solid correlation with OSI. As a high score in the OSI indicates poor balance, a high level of PTH was associated with increased risk of balance disturbance.

The possible explanation could be related to that thyroid hormones have significant metabolic effects, and muscle wasting and weakness are prominent clinical features of chronic hyperthyroidism (Anne et al., 2005). Increased energy expenditure with increased oxidation of protein, glucose, and lipids (Rilis et al., 2002) characterize hyperthyroidism.

Furthermore, loss of muscle mass and subsequent sarcopenia all are prominent clinical features of hyperthyroidism (Ramsay, 1996). Strength deficits are a primary cause of movement abnormalities in both central and peripheral nervous system disorders. In addition, weakness may be the results of force modulation deficits or disuse. Loss of strength has a direct impact on balance. Adequate strength (to control body weight and any additional loads) through normal postural sway ranges is needed to permit dynamic balance activities such as reaching, learning, and lifting (Allison and Fuller, 2006).

The results of our results is in consistent with Anne et al., (2005) who found that hyperthyroidism is characterized by elevated basal whole body protein breakdown and synthesis, which could affect muscle strength and stability. Additionally, our finding is in consistent with Gerome et al., (2004) who showed that early thyroid stimulating hormone normalization is necessary to allow normal development of both the neurosensorial afferent pathways (vestibular, proprioceptive) and central integration (cerebellum, vestibular nuclei).

Previous study by Martin et al., (1991) provided conclusive evidence that exercise tolerance is impaired in short duration hyperthyroidism because of decreased skeletal muscle mass and oxidative capacity related to accelerated protein catabolism.

5. Conclusion

The PTH and BMI have a positive correlation with OSI index. The risk of falling in Saudi males with vitamin D deficiency was synergistically incremented by hyperparathyroidism and obesity.

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