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ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

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Obesity Associated Morphology Leads Lateral Balance Distortion and Increased Energy Consumption During Treadmill Walking

Obeziteye Bağlı Morfoloji Koşu Bandında Yürüme Sırasında Lateral Denge Bozukluğu ve Artmış Enerji Tüketimine Neden Olur

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This study was presented as a poster at FEPS 2017 (Federation of European Physiological Societies and the Austrian Physiological Society), 13-15 September 2017, Austria.

ABSTRACT Objective: Obese and overweight adults have low levels of adherence to the sports activities compared to their normal-weight counterparts. As obese individuals having greater body weight and change in walking biomechanics compared to normal gait pattern may lead increased walking energy expenditure. In this study, we have aimed to explain increased energy expenditure of obese subjects in terms of possible differences in gait variables comparing with normal-weights. **Material and Methods:** There were 2 groups as normal-weight and obese subjects, each including 14 healthy male participants. The energy expenditure of participants was measured via indirect calorimetry in resting and walking in 3 walking speeds conditions as preferred walking speed (PWS), <30% slower than PWS and >30% higher than PWS. The spatiotemporal variables and displacement of center of body mass (COM) were recorded simultaneously with walking energy expenditure measurement. **Results:** The resting oxygen consumption (VO_2) was significantly higher in obese subjects (p<0.001). The significance was disappeared when resting VO_2 normalized to fat-free mass of subjects (p=0.951). VO_2 was significantly different between 2 groups in all walking conditions (p=0.002, p=0.001, p=0.039, respectively). The step width of obese participants was significantly higher in all walking conditions (p=0.001, p<0.000, p=0.000, respectively). COM mediolateral displacement was significantly higher in obese subjects in all walking speeds (p<0.000, p<0.000, p<0.000, respectively). However, vertical displacement of COM did not change significantly between 2 groups (p=0.820, p=0.301, p=0.219, respectively). While mediolateral displacement of COM was decreased, vertical displacement was increased significantly with each speed increment. **Conclusion:** The lateral balance is affected more in obese individuals; they prefer to walk in wider step width to keep mediolateral movement of COM in lateral limits; in turn use more energy compared to normal-weights.

Keywords: COM; gait analysis; indirect calorimetry; spatiotemporal gait variables; obesity

ÖZET Amaç: Obez ve/veya fazla kilolu yetişkinler, normal kilodaki yaşıtlarına göre spor aktivitelerine düşük düzeyde bağlılığa sahiptirler. Obez bireylerin daha fazla vücut ağırlığına sahip olması ve yürüme biyomekaniklerinde normal yürüme modeline kıyasla olan değişimlere bağlı olarak artmış yürüme enerji tüketimine neden olabilir. Bu çalışmada, obez katılımcıların artmış enerji tüketimlerini, yürüme parametrelerinde normal kilodakilere oranla olabilecek değişiklikler karşılaştırılarak açıklamayı hedeflemekteyiz. **Gereç ve Yöntemler:** Normal-kilolu ve obez katılımcılar olmak üzere 2 grup vardı, her grupta 14 sağlıklı erkek katılımcı yer almaktaydı. Katılımcıların enerji tüketimi, dinlenme ve 3 yürüme hızı; Tercih Edilen Yürüme Hızı (TEYH), TEYH'den <%30 daha yavaş, TEYH'den >%30 daha hızlı koşullarında olmak üzere indirekt kalorimetre ile ölçüldü. Spasyal ve temporal parametreler ve vücut kütle merkezi (VKM)'nin yer değişimi, yürüme enerji tüketimi ölçümü ile eş zamanlı kaydedildi. **Bulgular:** Dinlenme sırasında oksijen tüketimi (VO_2) obez katılımcılarda fark edilir derecede yüksek bulundu (p<0,000). Bu fark, dinlenme sırasında tüketilen VO_2 katılımcıların yağsız vücut kütlesi ile normalize edildiğinde ortadan kalktı (p=0,951). Tüm yürüme koşullarında, VO_2 2 grup arasında belirgin derecede farklı bulundu (sırasıyla p=0,002, p=0,001, p=0,039). Obez katılımcıların adım genişliği, tüm yürüme koşullarında daha fazla bulundu (sırasıyla p=0,001, p<0,000, p=0,000). VKM'nin yatay düzlemde yer değişimi, obez katılımcılarda tüm yürüme koşullarında belirgin derecede daha yüksek bulundu (sırasıyla p<0,000, p<0,000, p<0,000). Ancak, VKM'nin düşey düzlemde yer değişimi 2 grup arasında fark edilir derecede değişmedi (sırasıyla p=0,820, p=0,301, p=0,219). Her yürüme hızı artışı ile birlikte, VKM'nin yatay düzlemde yer değişimi azalırken, düşey düzlemde yer değişimi belirgin derecede arttı. **Sonuç:** Obez bireylerde yatay düzlemde denge daha çok etkilenir, VKM'nin yatay düzlemdeki hareketini yatayda ulaşılabilecek maksimum sınırlar içerisinde tutmak için daha geniş adım genişliğinde yürümeyi tercih ederler, sonuç olarak da normal kilolulara göre daha çok enerji kullanırlar.

Anahtar Kelimeler: VKM; yürüme analizi; indirekt kalorimetre; spasyal ve temporal yürüme değişkenleri; obezite

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Obesity is characterized as excess fat accumulation caused primarily by consuming more energy than expending energy. Although there is a widespread desire to reduce obesity among individuals, the prevalence of obesity still continues to increase around the world, since feeding on unhealthy foods and decreased physical activity that are intertwined by modern social life and environmental conditions.[1] However, there is a clear evidence that both participating in a regular sports activity and making some regulations in food choice behaviors can prevent excess weight gain and reduce body fat.[2] However, there is a clear evidence that obese and overweight adults have low levels of adherence to the sports activities compared to their normal-weight counterparts. Some studies have also claimed that not engage to a regular sports activity or spend less time in daily physical activities in addition to attendance to sedentary behavior may all be the key factors to lead obesity.[3-6] As claimed by Ekkekakis and colleagues, the perceived physical capability of obese adolescents may possibly create further barriers to their attendance in a regular sports activity program.[7]

While an initial caloric imbalance caused by increased energy intake and insufficient energy consumption gives rise to obesity, ones to obesity comes to exist, it becomes a substantial obstruction to attend a sports activity. Pietiläinen et al. have defined this relationship as vicious cycle, since insufficient physical activity leads obesity and obesity; in turn, causes the inactivity.[7,8]

Walking activity, among other physical activities, can be thought a valuable choice to increase physical activity level and is highly recommended to general population in order to increase the energy expenditure over an ordinary day.[9-11] A notable study with normal-weight and obese adolescents has shown that although both groups have similar energy expenditure levels during walking activity, obese participants were still found physically less active determined via accelerometers.[12] It is clear that comparative studies that using energy expenditure measurement and analyzing the movement pattern of body during a particular type of sports activity are desirable to further assess the relationship between physical activity level and the occurrence of obesity both in children and adults.[3,7,12]

Previous studies have indicated that individuals with obesity have higher energy expenditure levels during walking activity due to having greater body weight, in turn change in their walking biomechanics compared to normal walking pattern.[13,14] The walking characteristics of obese adults are differed in terms of spatiotemporal parameters of walking activity like, they prefer to walk in lower walking speeds and stride length, but increased step width, and also varied in terms of higher displacement of center of mass (COM) both in mediolateral and vertical directions with respect to normal-weight individuals.[15-17] In this study, we have aimed to explain the increased energy expenditure of obese subjects in terms of possible differences in walking activity variables like the displacement of COM in vertical and mediolateral directions, and also spatiotemporal variables comparing with normal-weight peers. The findings of this study may provide additional insights into differences in walking pattern of obese individuals, and in turn help to develop ideal exercise programs in terms of type and intensity of the appropriate sports activity, or any rehabilitation method to enhance the distorted side of their walking or any supporting equipment that may be used during their walking activity to reduce energy consumption and ensure longer periods of physical activity.

MATERIAL AND METHODS

SUBJECTS

Participants aged between 19-31 years and who were obese [Body Mass Index (BMI)≥30 kg/m^2] and normal-weight (18.5≤ BMI≤ 24.9 kg/m^2) were recruited from the students of the Faculty of Medical Sciences. Volunteers were all healthy male matched by age and height. Fourteen participants in each group were recruited to the study if they were free of any orthopedic surgery, extremity injuries, neuromuscular disorders, cardiopulmonary insufficiency or serious respiratory problems, active infection, and drug usage that can affect energy expenditure or going on a diet. The body fat percentage of obese subjects was also attentively measured and ensured to be above 25%. All subjects were well informed about the protocols of study and the written informed consent was obtained. The Declaration of Helsinki was taken into consideration during the study, and the ethical approval of the study was taken from the Local Ethics Committee of Clinical Research by protocol number of 2016/10.

ENERGY EXPENDITURE MEASUREMENTS

Subjects were instructed to fast for at least 12 h, allowed to drink only water, and not to attend any sports activity for 24 h before test day. They were also advised to wear comfortable clothing and walking shoes while testing. The standing height of the participants was measured by a stadiometer and their body compositions were determined by bioelectrical impedance analysis method (Tanita BC-418 MA, Tanita Corporation, Japan).

The indirect calorimetry method (Vmax Spectra 29c. Yorba Linda, CA, USA) was used for evaluating energy expenditures of subjects during resting and walking activity. Subjects were asked to wear a special facial mask (Hans Rudolph, USA) to collect gas samples from inspired and expired air breath-by-breath during energy expenditure protocols. For the measurement of resting energy expenditure (REE), subjects have informed to stay quietly in supine position in an isolated room and they were waited for at least 5 min before the test to familiarize to mask. Then, 15 min REE measurement was performed.

Before walking energy expenditure measurements, the preferred walking speed (PWS) of each participant were determined as they were asked to walk 3 times along a 14-m walkway with their neutral walking speed. The duration of each tour was determined with infrared sensors which were placed 2nd and 12th meters, then the mean duration of 3 trials was calculated. Then, all participants performed a familiarization protocol to treadmill (Viasys Health Care, USA) for at least 10 min.[18] Subjects were allowed to rest at least 5 min until their heart rates reach ±5 of basal heart rate.[10] Then, they were instructed to walk for 7 min for each 3 walking speeds like; <30% slower than PWS, PWS, and >30% higher than PWS.

The first 10 min of REE measurement was accepted as habituation period and excluded from the analysis.[18] In terms of walking energy expenditure, the last 2 min of energy expenditure record was evaluated as the steady-state period and analyzed as averaging over 10s intervals.[19] The respiratory exchange ratio was also watched during measurements to evaluate the intensity of ongoing exercise.[18]

WALKING ANALYSIS PROTOCOL

The 3D walking analysis of participants was executed by high speed CCD cameras (BASLER Vision Technologies, Germany) during last 2 min of each walking protocols simultaneously with walking energy expenditure measurement. A single marker to COM (on skin), and 2 markers to mid-points of heels (on shoes) were attached to subjects for walking analysis protocol. The COM marker was attached to midpoint between two *posterior superior iliac spine* (PSIS) of individuals (Plug-in Gait). MaxPRO® (Innovision System, USA) software was used for 3D walking analysis recording and MaxMATE® (Innovision System, USA) was used for data analysis. The system was calibrated by using a L-frame and calibration wand before recording. Stride frequency and step width were evaluated as analyzing the mediolateral and vertical displacements of foot markers. The step width was determined as assuming the minimum level of vertical position of foot markers as heel-contact, then the difference between mediolateral positions of foot markers was calculated. The system sensitivity was 0.001 mm.

STATISTICAL ANALYSIS

All data were analyzed via the STATISTICA Version 13.3 (TIBCO Software Inc., 2017). The descriptive statistics were given as means and standard deviations. The Shapiro Wilk test was used to control normality of data. In order to evaluate the difference between descriptive variables of two groups, Student-t test was used. In terms of evaluation of differences and interactions in mediolateral and vertical displacements of COM in 3 walking speeds and 2 participant groups, repeated measures of ANOVA were used. Sphericity assumption of data was controlled via Mauchley's test. Any data which sphericty was not ensured, Greenhouse–Geisser correction was applied. Post-Hoc Tukey Test was applied to determine pair-wise comparisons, and error-bar plots were drawn with GraphPad Prism 8 (free-trial version). The significance level was set to $p<0.05$.

RESULTS

Twenty-seven healthy male volunteers as fourteen normal-weight and thirteen obese subjects were included in the study. The demographic and anthropometric characteristics of participants are listed in Table 1. The subjects of both groups have quite similarity in age and height, although participants with obesity have significantly higher body mass, BMI, percent body fat, and FFM ($p<0.05$) (Table 1).

TABLE 1: Anthropometric characteristics of the participants.

	Normal-weight Group (n=14)	Obese Group (n=13)	p-value
Age (yr)	23.29 ± 3.63	23.38 ± 3.12	0.940
Height (cm)	176.24 ± 6.02	177.83 ± 4.53	0.447
BM (kg)	67.98 ± 8.64	107.99 ± 12.54	<0.000
BMI (kg/m2)	21.83 ± 2.14	34.08 ± 3.69	<0.000
Percent Body Fat (%)	13.57 ± 5.89	29.95 ± 3.38	<0.000
FFM (kg)	58.44 ± 5.47	75.36 ± 6.46	<0.000

The values are given as mean±SD.
BM: Body mass; BMI: Body mass index; FFM: Fat-free mass.
Significance of bold values p< 0.05 and p-values were obtained via Student-t test.

ENERGY EXPENDITURE MEASUREMENTS

The REE (kcal/day) values differed significantly between 2 groups ($p<0.000$). Another expression of energy expenditure, VO_2, which is the consumed O_2 per minutes, was found significantly higher in obese group during resting condition ($p<0.000$) (Figure 1A). However, the significant difference in energy expenditure between 2 groups disappeared when VO_2 is normalized to fat-free mass (kg) of participants ($p=0.951$) (Figure 1B, Table 2).

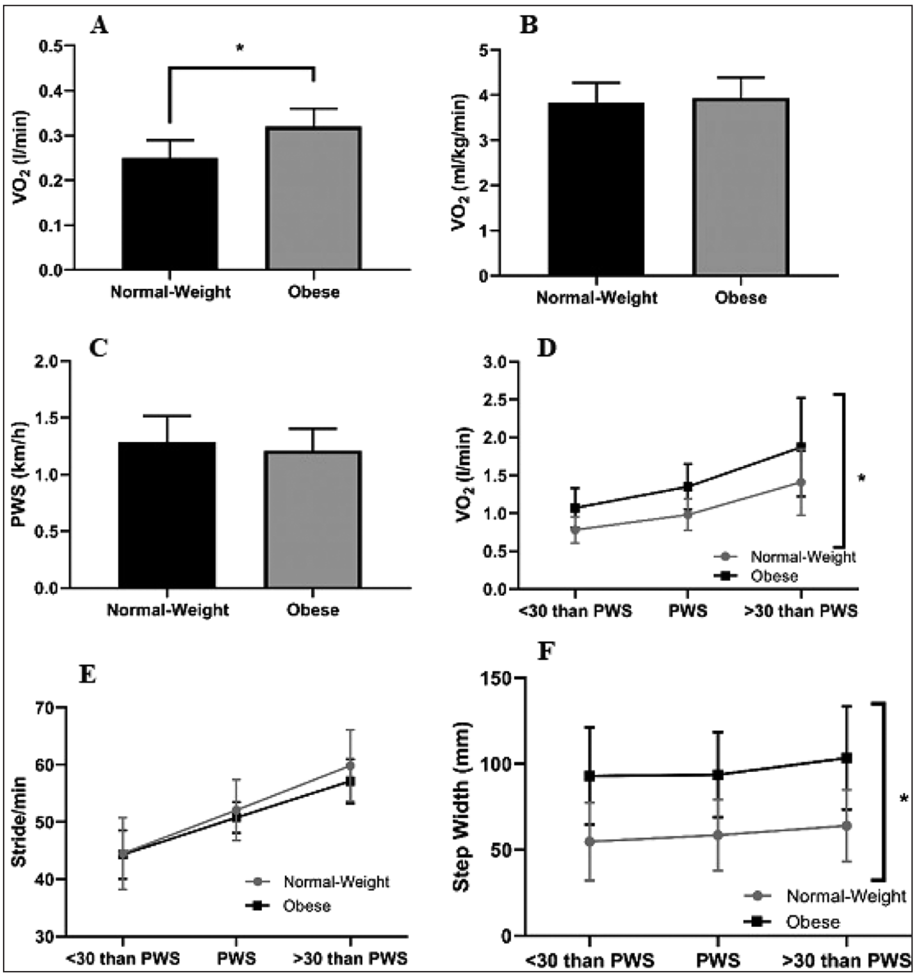

FIGURE 1: A) The comparison of the VO_2 (l/min) during resting condition, **B)** normalized VO_2 (ml/kg/min) to FFM during resting condition, **C)** PWS (km/h), **D)** VO_2 (l/min) with respect to the walking speeds, **E)** Stride with respect to walking speeds, and **F)** Step width (mm) with respect to walking speeds between normal-weight and obese groups. Significant differences between 2 groups at a given speed was *$p<0.05$.

TABLE 2: The comparison of REE (kcal/day), VO_2 (l/min) and VO_2/FFM (l/min/kg) during resting, and PWS (km/h) of participants.

	Normal-weight Group (n=14)	Obese Group (n=13)	p-value
REE (kcal/day)	1737.83 ± 247.70	2244.68 ± 280.55	<0.000
VO_2 (l/min) during resting	0.25 ± 0.04	0.32 ± 0.04	<0.000
VO_2/FFM (ml/kg/min) during resting	29.77 ± 3.40	29.85 ± 3.57	0.951
PWS (km/h)	1.28 ± 0.23	1.21 ± 0.20	0.377

The values are given as mean ± SD. BM, body mass; BMI, body mass index; FFM, fat-free mass. Significance of bold values p < 0.05 and p-values were obtained via Student-t test.

The means of PWS of both groups were found to be similar (p=0.377) (Figure 1C, Table 2). According to the VO_2 values between 2 groups during 3 walking conditions, obese subjects have significantly higher values than normal-weights (p=0.002 for walking <30 than PWS, p=0.001 for walking in PWS and p=0.039 for walking >30 than PWS) (Table 3). Also, according to within-group comparisons for VO_2 (l/min) during walking >30 than PWS was significantly higher compared to VO_2 (l/min) during walking <30 than PWS and walking in PWS (p=0.001 and p=0.003 respectively), although the difference between VO_2 (l/min) during walking <30 than PWS and walking in PWS was not significant (p=0.249) in normal-weight group. In obese group, VO_2 (l/min) increased significantly with each speed increment (p=0.048 between <30 than PWS and walking in PWS, p<0.001 PWS and >30 than PWS, and p<0.001 <30 than PWS and >30 than PWS, respectively) (Figure 1D).

SPATIOTEMPORAL ANALYSIS

The stride frequency was not significantly different between 2 groups (p=0.927 for walking <30 than PWS, p=0.426 for walking in PWS, p=0.187 for walking >30 than PWS, respectively) (Table 3, Figure 1E). However, participants with obesity were found to have significantly higher step width values than normal-

TABLE 3: The comparison of VO_2 (l/min), stride frequency (stride/min), step width (mm), mediolateral and vertical displacement of COM (mm) of the participants.

	<30 than PWS	PWS	>30 than PWS
	VO_2 (l/min)	**VO_2 (l/min)**	**VO_2 (l/min)**
Normal-weight Group (n=14)	0.78 ± 0.17	0.98 ± 0.21	1.41 ± 0.44
Obese Group (n=13)	1.07 ± 0.27	1.35 ± 0.30	1.87 ± 0.65
p	**0.002**	**0.001**	**0.039**
	Stride Frequency (stride/min)	**Stride Frequency (stride/min)**	**Stride Frequency (stride/min)**
Normal-weight Group	44.50 ± 6.27	52.07 ± 5.21	59.86 ± 6.24
Obese Group	44.31 ± 4.23	50.77 ± 2.68	57.15 ± 3.87
p	0.927	0.426	0.187
	Step Width (mm)	**Step Width (mm)**	**Step Width (mm)**
Normal-weight Group	54.82 ± 22.62	58.62 ± 20.68	64.07 ± 20.93
Obese Group	92.89 ± 28.32	93.65 ± 24.76	103.41 ± 30.04
p	0.001	<0.000	0.001
	Mediolateral Displacement of COM (mm)	**Mediolateral Displacement of COM (mm)**	**Mediolateral Displacement of COM (mm)**
Normal-weight Group	58.43 ± 16.19	44.61 ± 9.01	39.84 ± 8.08
Obese Group	83.93 ± 14.77	63.07 ± 12.04	50.90 ± 10.49
p	<0,000	<0,000	<0,000
	Vertical Displacement of COM (mm)	**Vertical Displacement of COM (mm)**	**Vertical Displacement of COM (mm)**
Normal-weight Group	25.24 ± 6.51	37.98 ± 10.71	48.04 ± 11.36
Obese Group	25.83 ± 6.81	45.19 ± 23.06	54.60 ± 15.52
p	0.820	0.301	0.219

The values are given as mean ± SD. PWS, preferred walking speed; COM, center of mass. Significance of bold values p < 0.05 and p-values were obtained via Student-t test.

weight group (p=0.001 for walking <30 than PWS, p<0.001 for walking in PWS, p=0.001 for walking >30 than PWS), respectively) (Table 3, Figure 1F).

COM DISPLACEMENT

The mediolateral displacement of COM has differed significantly between normal-weight and obese groups (p<0.000 for walking <30 than PWS, p<0.000 for walking in PWS, p<0.000 for walking >30 than PWS, respectively) (Table 3). In addition, according to within group comparisons, mediolateral displacement of COM was significantly higher during walking in <30 than PWS compared to walking in PWS and walking in >30 than PWS (p=0.006 and p=0.001, respectively); however, it did not differ significantly between walking in PWS and walking in >30 than PWS (p=0.626) in normal-weight group. In obese group, mediolateral displacement of COM differed significantly with each speed increment (p<0.000 between walking <30 than PWS and PWS, p<0.0001 between walking <30 than PWS and walking >30 than PWS, p=0.004 between walking <30 than PWS and walking >30 than PWS, respectively (Figure 2A). However, the means of vertical displacement of COM were not changed significantly between 2 groups (p=0.820 for during walking in <30 than PWS, p=0.301 for during walking in PWS and p=0.219 for during walking >30 than PWS, respectively) (Table 3). In terms of within group comparisons, the vertical displacement of COM differed significantly with each speed increment in normal-weight group (p=0.002 between walking in <30 than PWS and walking in PWS, p<0.000 between walking in <30 than PWS and in >30 than PWS, p=0.025 between walking in PWS and >30 than PWS). In obese group, it has increased significantly between <30 than PWS and walking in PWS (p<0.000), and also between walking in <30 than PWS and walking in >30 than PWS (p<0.000); although the difference between walking in PWS and walking in >30 than PWS was not significant (p=0.056) (Figure 2B).

DISCUSSION

This study provides additional body of knowledge on differences between obese adults and normal-weight peers in terms of both the energy expended during resting and walking activity, and walking variables like spatiotemporal parameters and the displacement of COM. Previous studies have claimed that since individuals with obesity have lower metabolic rate than normal-weight individuals, they can gain weight more easily; however, a growing number of studies over the last 30 years show the opposite.[20-22] In fact, we have found that the mean of energy expenditure during resting (REE) was nearly 77% higher in obese participants than the normal-weight group. The increased FFM like bone, skeletal muscle, brain, heart, liver, and kidneys etc. to support the needs of excess body mass is the primary cause of increased REE in subjects with obesity.[22,23] The disappearance of significance in terms of energy expenditure levels differences between obese and normal-weight groups, when REE is normalized to FFM is also compatible with this idea.[21,22,24] In addition, our result regarding

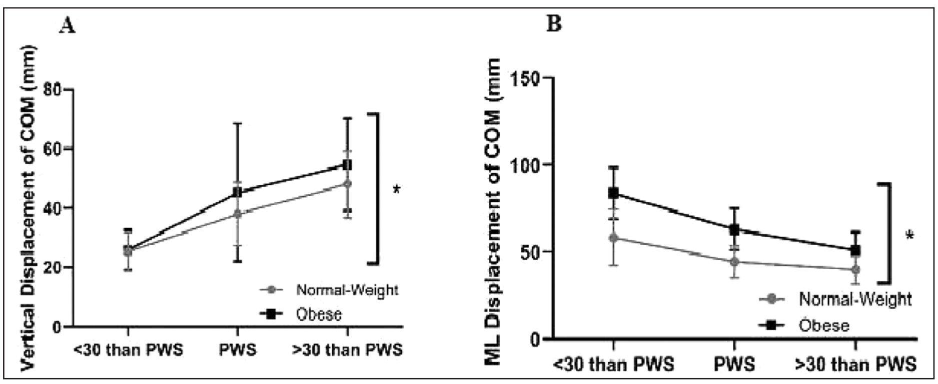

FIGURE 2: The comparison of mean ± SD values of mediolateral **A)** and vertical displacement **B)** of COM marker as a function of walking speed for normal-weight and obese groups. Significant differences between 2 groups at a given speed was *p<0.05.

to no significant difference in VO_2 levels between the normal-weight and obese groups after appropriate adjustments was done according to fat-free mass is also compatible with previous observations.

In our study, obese subjects have preferred to walk in similar walking speeds as normal-weight participants. In a study included lean and obese adults, the physical activity levels of participants were recorded via accelerometers, and they have found that PWS did not differ significantly between 2 groups as is in our case, although obese subjects preferred to walk one-third less distance than lean peers.[25] Browning et al. have claimed that if an obese individual was not in the morbid obese class (BMI≥40 kg/m^2), the relationship between walking speed and expended energy per walking distance may not differ significantly than normal-weight counterparts. Since the mean of BMI of our obese participants was not very high and they were also younger than the obese groups of previous studies may lead them to walk in similar speeds with normal-weight group. Although they have preferred to walk in similar speeds, obese subjects have still consumed significantly more energy than normal-weights during all 3 different walking speeds. It can be concluded that the excess body weight, especially heavier lower limbs, biomechanical factors like having difficulty in ensuring balance during walking, and wider step width, generally less active musculoskeletal system due to low level of physical activity and deconditioning in cardiopulmonary system are all thought to be responsible for the increased walking energy expenditure of individuals with obesity.[26]

Since stride frequency and stride length variables are mostly affected by walking speed and, as the means of PWS of both of our groups were not significantly different, may lead 2 groups to walk in similar stride frequencies. However, obese participants have preferred to walk in significantly greater step width than normal-weight group in all 3 walking speeds. Similarly, Browning et al. have found that obese subjects have preferred to walk in 30% wider step width than normal-weight group.[9] Since obese individuals have heavier lower extremities and wider thigh diameters, they have increased leg swing circumduction and prefer to walk in wider step width.[8,11] Previous studies have suggested that the regulation of all walking variables like walking speed, stride frequency and stride width in a highly controlled functional relationship gives a way to minimize the energy expended during walking.[27,28] For example, Donelan et al. have reported that if subjects were forced to walk in wider step width than their preferred step width, their walking energy expenditure was increased up to 50%.[11]

The step width also determines the lateral border of movement trajectory of COM to ensure balance during walking activity.[11] Our data is consistent with the idea that the mediolateral displacement of COM increases in parallel with the increase in step width of obese subjects. Similarly, Peyrot et al. have claimed that the mediolateral displacement of COM was higher in participants with obesity as they prefer to walk in wider step width than normal-weight counterparts.[29] In another study, the mediolateral displacement of COM was found nearly 50% higher in obese than normal-weight group while subjects walk in their PWS. They have also concluded as the higher walking energy expenditure of obese subjects was highly related with wider step width and in turn having larger mediolateral displacement of COM.[30] In addition, we have found that the mediolateral displacement of COM was significantly reduced in both groups by increment in walking speed. In consistent with our data, Orendurff et al. have indicated that the mediolateral displacement of COM was decreased by increment in walking speed.[31] They have even claimed that the restraining of mediolateral displacement of COM may be one of the factors for an energetically effective walking, and increase in mediolateral displacement of COM as in the case of obese individuals may increase the balance demands.

The measurement of vertical displacement of COM is a rather valuable method in terms of evaluation of walking activity effectiveness. Saunders et al. have claimed that the walking efficiency depends on 6 major factors in which 5 of them have evolved to reduce the vertical displacement of COM and to decrease the walking energy expenditure.[32] Indeed, we have found obese subjects have larger vertical displacement of COM parallel to increased walking energy expenditure for all 3 different walking speeds. Similarly, Orendurff et al. have found that vertical displacement of COM was increased, although the mediolateral displacement of COM was decreased by each walking speed increment.[31] In another point of view, Gard et al. have claimed that the increased step length with increased walking speed may be the primary reason of rise in vertical displacement of COM.[33]

CONCLUSION

The increased walking energy expenditure of our obese group can be explained in terms of variables that differ significantly between 2 groups as step width and mediolateral displacement of COM. It can be concluded as the lateral balance is affected more in obese people and they prefer to walk in wider step width to keep mediolateral movement of COM in its lateral limits; in turn use more energy during walking compared to normal-weight individuals. Both the increment in energy expenditure and demands in lateral balance of obese individuals in response to the increase in walking speed should be taken into consideration while advising a particular type of sports activity and duration, also protecting from any potential sport or home accidents.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

***Idea/Concept:** Dilan Deniz Koyuncu, Uğur Dal; **Design:** Dilan Deniz Koyuncu, Uğur Dal; **Control/Supervision:** Dilan Deniz Koyuncu, Uğur Dal, Zeynep Altınkaya; **Data Collection and/or Processing:** Dilan Deniz Koyuncu, Uğur Dal, Zeynep Altınkaya; **Analysis and/or Interpretation:** Dilan Deniz Koyuncu, Uğur Dal, Zeynep Altınkaya; **Literature Review:** Dilan Deniz Koyuncu, Uğur Dal; **Writing the Article:** Dilan Deniz Koyuncu; **Critical Review:** Uğur Dal; **References and Fundings:** Uğur Dal; **Materials:** Dilan Deniz Koyuncu, Uğur Dal, Zeynep Altınkaya.*

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