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ชีวกลศาสตร์ทางการกีฬา (Sports Biomechnics)

KNEE BIOMECHANICS IN OBESE FEMALE DURING LOCOMOTION: A CROSS-SECTIONAL STUDY

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ABSTRACT

The purpose of this study was to compare knee biomechanics during walking such as gait tempero-spatial, kinematic, and kinetic (external knee adduction moment) between overweight obesity I, obesity II and normal healthy female subjects. Eighty Thai females aged between 18 to 40 years, participated in this study and categorized into 4 groups such as normal, overweight, obese I and obese II by BMI level (WPRO). A cross-sectional experimental study was designed to investigate each walking velocities such as self selected, and constant velocity (1.24 m/s) of all participants using 3-D Motion Analysis (N = 80). The significant difference was determined using 2-way ANOVA (p = 0.05). The results indicated that the overweight and obese groups had changed gait biomechanics and increased knee joint load during walking in all type of velocities when compared with normal groups. In conclusion, the knee adduction moment was higher in overweight, and obese participants that represent the higher knee joint load to be induced joint cartilage damage cause of osteoarthritis. For future study, using the orthosis for reduce biomechanical load that cause of joint cartilage may interest to investigate for prevention potential knee joint osteoarthritis in high BMI female person.

Keywords: Knee joint load / Gait / Obesity / Female

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ชีวกลศาสตร์ของข้อเข่าขณะเดินในหญิงอ้วน

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บทคัดย่อ

หญิงอ้วนเป็นกลุ่มที่มีความเสี่ยงสูงต่อภาวะข้อเข่าเสื่อม โดยดัชนีมวลกายที่สูงขึ้นมีผลต่อปัจจัยทางชีวิกลศาสตร์ขณะเดินที่ส่งผลต่อการเกิดภาวะข้อเข่าเสื่อม วัตถุประสงค์ของการศึกษาในครั้งนี้ ได้แก่ การเปรียบเทียบชีวกลศาสตร์ของข้อเข่าขณะเดินระหว่างกลุ่มผู้หญิงที่มีระดับดัชนีมวลกายต่างๆ กัน โดยแบ่งออกเป็น 4 ระดับได้แก่ ปกติ น้ำหนักเกิน อ้วนระดับที่ 1 และ อ้วนระดับที่ 2 โดยผู้เข้าร่วมงานวิจัยเป็นหญิงไทยที่มีระดับดัชนีมวลกายแบ่งออกเป็น 4 กลุ่ม จำนวนทั้งสิ้น 80 คน อายุระหว่าง 18 ถึง 40 ปี การศึกษาแบบทดลองโดยให้ผู้เข้าร่วมงานวิจัยเดินด้วยความเร็ว 3 ความเร็วได้แก่ ความเร็วปกติของตนเอง ความเร็วคงที่ 1.24 เมตรต่อวินาที และความเร็วที่คำนวณจากความยาวของขา โดยใช้ระบบการวิเคราะห์การเคลื่อไหว 3 มิติ เป็นเครื่องมือในการเก็บข้อมูล การเปรียบเทียบความแตกต่างระหว่างกลุ่มดัชนีมวลกาย ใช้สถิติ การวิเคราะห์ความแปรปรวนแบบ 2 ทาง ผลการศึกษาพบว่า ในกลุ่มอ้วนระดับที่ 2 มีค่า โมเมนต์การหุบเข่าจากภายนอกสูงสุด แตกต่างอย่างมีนัยสำคัญทางสถิติเมื่อเทียบกับกลุ่มอ้วนระดับที่ 1 น้ำหนักเกิน และ ปกติในทุกความเร็วของการเดิน จึงสรุปได้ว่า หญิงที่มีดัชนีมวลกายสูง จะเกิดการเปลี่ยนแปลงทางชีวกลศาสตร์ในขณะเดิน และ มีปัจจัยที่แสดงถึงการรับน้ำหนักของข้อเข่าที่สูงกว่ากลุ่มอื่นๆ ซึ่งมีความสัมพันธ์ต่อการเกิดภาวะข้อเข่าเสื่อมในอนาคต และเป็นที่น่าสนใจในการศึกษาถึงอุปกรณ์ที่ใช้ลดปัจจัยทางชีวกลศาสตร์เพื่อป้องกันการเกิดข้อเข่าเสื่อม

คำสำคัญ: การรับน้ำหนักของข้อเข่า / การเดิน / ภาวะอ้วน / ผู้หญิง

INTRODUCTION

Obesity is a global issue of metabolic disease[1]. According to the World Health Organization (WHO) report, more than 1.6 billon adults are overweight[2]. Obesity is one of the most serious chronic global disorders being a strong risk factor for several diseases including knee osteoarthritis (OA)[3]. The prevalence of obesity in Thailand has been doubled in the past two decades. Data from three consecutive Nation Health examination surveys (NHES) have shown a secular trend, as the prevalence of obesity with body mass index = 25 kg/m^2 in adults increased from 13.0% in men and 23.2% in women in 1991 to 18.6% and 29.5% in 1997 and 22.4% and 34.3% in 2004, respectively[4].

The major of osteoarthritis risk factor in load-bearing joint such as knee, hip, and ankle and non load-bearing joint such as hand is strongly associated with obese women[1, 5-7]. Increased body mass index contribute to a substantially increased risk of knee osteoarthritis. Magnitude of the association was significantly stronger in woman than men with significant difference[2].

There are inconsistent reports of the tempero-spatial, kinematic, and kinetic parameters of walking in obese individuals but otherwise healthy subjects. Several studies report that obese adults or children have a shorter step length, a wider step width and a longer double support time[8-10]. In obese subjects, there were decrease in step length, cadence and walking speed but increase in step width, % double support and overall stance time during a gait cycle[8]. The obese group walked slower and had a shorter stride length. They also spent more time on stance phase and double support in walking[10]. However, a significant reduction in velocity for overweight adults was identified by each study[11-12]. A reduction in velocity has been shown to lead to changes in three dimensional kinematic and kinetic parameters. A reduction in velocity was associated with reduced stride length, cadence, sagittal joint range, ground reaction forces, and peak knee joint moment.

There are several studies to investigate the gait kinematic of obese. There were less knee flexion at early stance but the degree of hip extension and ankle plantar flexion were increased throughout the stance phase. Sagittal knee joint range have been found to be within normal limits for overweight adults[10]. Alterations in the components of the joint range have been noted for adults with excess mass. Reduced knee flexion and increased ankle dorsiflexion and eversion have been reported[10]. However, some study identified no differences in kinematics; alternatively, their results showed increased ground reaction forces leading to increased joint kinetics for obese adults[9]. The larger VGRF of the obese versus normal-weight subjects reflect the much greater body mass of the obese adults. Whereas the vertical GRF increased in nearly direct proportion to body mass were greater in the obese than would have been predicted according to body mass[9]. The obese individuals might adjust their gait characteristics in response to their heavy bodies to reduce the moment about the knee and the energy expenditure per unit time[10]. The peak knee joint moments have been noted as similar between overweight and healthy weight groups[10]. In contrast, a significantly increased peak knee adduction moment has been reported[12]. It is unclear whether the difference of the knee biomechanics parameters between differences BMI level in healthy subjects. There are few differences in sagittal or frontal knee joint biomechanics for an increase in body mass were seen[13].

There is growing interest in the role of the external knee adduction moment in the pathogenesis of knee pain and osteoarthritis. The external knee adduction moment tends to adduct the knee into a varus position and is significantly correlated with disease severity[14]. There is considerable evidence indicating that obesity plausibly represents one of the most important risk factors for particular peripheral joint sites, predominantly the knee site[2]. Intuitively, it seems likely that obesity can increase the biomechanical loads in knee joint load, and it is generally accepted that knee OA is driven by biomechanical loading[15]. Body mass index was significantly positive associated with osteoarthritis risk in knee site[2]. Biomechanical factors such as kinetic and kinematic conditions during walking should be carefully considered for the treatment of cartilage disease in weight bearing joints[16]. Increased mechanical loads related to obesity appear as a logical explanation to the increased risk of osteoarthritis in weight-bearing joints with destruction of the cartilage and ligaments. The prevalence of musculoskeletal problem is correlated with rising obesity population[1]. However, it is unclear whether the difference of the external knee adduction moment and other biomechanics parameters between obese and normal healthy subjects. For this study, we focused our investigation on the tempero-spatial, kinematic and kinetic especially the external knee adduction moment.

The purpose of this study was to compare knee biomechanics such as gait tempero-spatial, kinematic, and kinetic (external knee adduction moment) between obesity and normal healthy female subject during walking.

MATERAILS AND METHODS

Subjects

Eighty Thai females aged between 18 to 40 years, participated in this study. The International Obesity Task Force (IOTF) and the Steering Committee of the Regional office for the Western Pacific Region of WHO (WPRO) recommended that adult overweight could be specified in Asia when the BMI exceeded 23.0 kg/m^2 and that obesity should be specified when the BMI exceeded 25.0 kg/m^2. This Asian Classification was adopted in this study. Inclusion criteria included a BMI of 18.5 – 22.9 kg./m^2 (normal), 23 – 24.9 kg/m^2 (overweight), 25 – 29.9 kg/m^2 (obesity I) and > 30 kg/m^2, sedentary life style, free of lower extremity injuries affecting gait and has no knee pain, had never been previously diagnosed with knee osteoarthritis, experience, or sought medical treatment for knee osteoarthritis related symptoms, weight change < 2.5 kg net change during the previous 3 months, normal foot morphology, static knee alignment axis in frontal plane (valgus and varus) lesser than 10 degree, and no intra-articular ligament or meniscus pathology. All of participants were explained about objective, process of testing, the equipment components and safety features. Participants were informed about procedures and signed informed consent in accordance with the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University.

Experimental protocol

Subjects were asked to fill in a questionnaire form to answer about the general history, history of illness and exercise activity. The information was used to screen subjects before subsequent tests. All of practice and testing trials were performed in the Biomechanics Laboratory at Department of Physical Therapy, Faculty of Allied Health Sciences, Chulalongkorn University. The test procedure was read carefully to all subjects by researcher. Then subjects who were included criteria will know about the aim of study, experimental procedure and possible risks before signing the consent form.

Subject preparation

All subjects were requested to wear shorts, and tight fitting shirt. Each subject was determined anthropometry and reduced anxiety by explaining the detail of the test and the involved equipment. Height (cm), body weight (kg) and BMI (kg/m^2) of subject were measured by automatic standiometer. Body composition were measured by body composition analyzer that using bioelectrical impedance analysis (BIA) principle to show percent body fat, fat free mass, and lean body mass of each subjects. Leg length without shoes (the distance from the greater trochanter to the ground during quiet standing) and circumference were determined by measuring tape in centimeter[10]. The waist to hip ratio was using a measuring tape to measure the circumference of hips at the widest part of buttocks. Then, waist was measure at the smaller circumference of natural waist. To determine the waist/hip ratio, that divided waist measurement by hip measurement. All of anthropometry measurements were determined by researcher who had over 10 years' experience physical therapist. The data were corrected and used to compare for subjects.

Elastic stockinet was rolled over the thigh and leg sections of each lower limb to minimize the vibration of the muscles in walking[10]. To track the motions, spherical retro-reflective markers were placed on anatomical landmarks and segment that following the Helen Hayes marker set by researcher who had over 10 years' experience identifying anatomical landmarks[17].

3-D Motion Analysis Measurement

Temporo-spatial gait, 3-dimension kinetic and kinematic data were collected using an eight camera Motion Analysis System (Motion Analysis Corp., Santa Rosa, CA) that had flash rate of 120 Hz. The cameras were synchronized with the BERTEC force platform, which were set to have a sampling frequency of 1,200 Hz. Cortex version 2.5 was software created by the Motion Analysis corporation for use with their Motion Analysis motion capture system that combines 3 major functions into a single software package such as calibration of capture volume, tracking and identifying marker locations in calibrated 3D space and post processing tools for tracking, editing, and preparing the data for other packages. Then the data were processed with clinical gait evaluation module by OrthoTrak 6.6 Gait Analysis Software. Static and dynamic calibrations were performed before experimental trial.

Subjects were asked for perform static trial to system detect the reflective markers. Then, four medial marker of knees and ankles were removed for prepare walking trial. Subjects were allowed to walk barefoot. The speed of walking were set in 2 velocities such as the self-selected speed, and constant speed of 1.24 m/s.[7,17]

Subjects were required to walk along 10 m. walkway. Subjects were given enough time to warm up and became familiar with each velocity. The sequence of walking velocity for each subject start with self-selected velocity. Five minute rest between five successful trials was performed for preventing muscle fatigue. Five successful trials of a velocity were collected for each subject[11]. Successful trials were defined as the trials which subject walk with complete contact with the force plate.

Main Outcome Measures

The data were corrected from right side of lower extremities. Cortex version 2.5 and OrthoTrak Gait Analysis version 6.6 software were used to define the interested data included spatio-temporal parameters: step width (cm),velocity (cm/sec), stride lenght (cm), cadence (step/min), support time (% gait cycle), non support time (% gait cycle), step length (cm), and double support time (% gait cycle); kinematics: peak knee flexion angle (^{o}) during stance phase and kinetics: vertical ground reaction force, peak external knee adduction moment (Nm/w and Nm) and knee adduction moment impulse (Nms/w and Nms).

Statistical Analysis

Statistical analysis was performed with the SPSS 17.5 for Window. The level of significance was set at p-value < 0.05. Subject demographic data were expressed as mean ± standard deviation (SD) value. Investigation data were expressed as mean ± standard error of mean (SEM) value by average from five complete trials. The normal distribution of data was tested by Kolmogorov-Smirnov test. The difference of mean between each BMI groups and walking velocity were test by 2-way ANOVA and Bofferoni Post Hoc test.

RESULTS

The eighty participant's demographic characteristics were shown in table 1. There were not significant difference between groups in age, height, and leg length. As expected, there were significant between group that the weight, body mass index, percent body fat, fat mass, and lean body weight were higher in overweight, obesity I and obesity II than normal group, respectively.

The spatiotemporal variables of each walking velocity were shown in table 2. When walking with self selected speed we found that there was significantly difference in the step width between normal (9.95 ± 0.70) and obesity II (12.28 ± 0.47) groups (p = 0.034). Moreover, the support time (normal = 59.37 ± 0.33; obesity II = 61.35 ± 0.30) and non-support time (normal = 40.63 ± 0.33; obesity II = 38.65 ± 0.30) were significantly difference between normal and obesity II groups (p = 0.000). In addition, the support time (overweight = 60.07 ± 0.38; obesity II = 61.35 ± 0.30) and non-support time (overweight = 39.93 ± 0.38; obesity II = 38.65 ± 0.30) were significantly difference between overweight and obesity II groups (p = 0.030). As the self selected speed, there were significantly difference between normal and obesity II in the support time (normal = 59.43 ± 0.45; obesity II = 61.16 ± 0.51) and non-support time (normal = 40.57 ± 0.45; obesity II = 38.84 ± 0.51) during walk with constant velocity (1.24 m/s) (p = 0.039).

The kinetics and kinematic variables were shown in table 3. We found that there were significant differences of the peak external knee adduction moment and the knee adduction moment impulse between difference BMI groups. When walk with self selected speed we found that there was significantly difference in the peak external knee adduction moment (Nm/w) between normal (0.334 ± 0.031) and obesity I (0.222 ± 0.022) groups (p = 0.021). In addition, there were significantly differences in the peak external knee adduction moment (Nm) when compare with obesity II (28.089 ± 2.905) to normal (15.645 ± 1.738; p = 0.027), overweight (19.501 ± 2.020; p = 0.006), and obesity I (22.886 ± 2.377; p = 0.002). There was significantly difference in the knee adduction angular impulse between normal (0.112 ± 0.015) and obesity I (0.083 ± 0.009) groups (p = 0.015). During walking with constant velocity (1.24 m/s), we found that that there was significantly difference in the peak external knee adduction moment (Nm/w) between normal (0.352 ± 0.033) and obesity I (0.214 ± 0.024) groups (p = 0.005). In addition, there were significantly differences in the peak external knee adduction moment (Nm) when compare with obesity II (21.821 ± 2.232) to normal (14.584 ± 1.329; p = 0.019), overweight (16.494 ± 1.076; p = 0.022), and obesity I (18.205 ± 1.541; p = 0.004). There was significantly difference in the knee adduction angular impulse between normal (0.120 ± 0.015) and obesity I (0.074 ± 0.010) group (p = 0.024). There was no significantly difference in the peak knee flexion angle, the peak vertical ground reaction force when walking with the three experimental speeds.

Table 1: Demographic and anthropometric characteristics of eighty female participants.

Parameter	Normal (n = 20)		Overweight (n = 20)		Obese I (n = 20)		Obese II (n = 20)		*P* value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Age (Years)	24.5	3.43	26.6	5.71	29.25	6.13	26.85	6.23	0.065
Weight (kg.)	51.1	2.89	59.94	4.1	69.33	6.37	86.99	9.88	0.000*
Height (cm.)	159.59	4.29	157.93	5.07	157.43	5.75	160.7	6.13	0.199
BMI ($kg.m^{-2}$)	20.12	1.21	23.96	0.66	27.87	1.35	33.68	3.81	0.000*
Right leg length (cm.)	81.4	3.62	79.3	4.24	78.58	4.09	80.91	2.88	0.064
Waist circumference (cm.)	69.93	4.67	78.08	4.33	85.58	4.74	97.04	8.76	0.000*
Hip circumference (cm.)	90.05	3.8	98.2	3.88	103.18	4.83	114.73	6.79	0.000*
Waist Hip ratio	0.78	0.04	0.8	0.06	0.83	0.05	0.85	0.07	0.000*
Right knee joint circumference (cm.)	33.69	1.39	36.93	1.7	37.75	2.39	41.93	2.88	0.000*
Right Q angle (degrees)	10.35	1.09	11.3	1.78	11.55	1.96	12.45	1.9	0.003*
Percent body fat (%)	28.05	3.86	30.95	3.29	34.83	3.91	37.81	4.83	0.000*
Lean body weight (kg.)	36.71	2.03	41.35	3.01	45.08	3.74	53.87	5.13	0.000*
Visceral fat (kg.)	2.73	0.99	4.98	0.9	8.5	1.38	14.73	4.99	0.000*

* significantly different between BMI groups ($p < 0.05$)

Table 2: Spatiotemporal parameters in the four groups during walking at self-selected speed (SS) and constant velocity (CV) with corresponding statistical findings (Bold indicates significance).

Velocity	Parameter	Normal		Overweight		Obesity I		Obesity II		*P* value in group comparisons and trend							
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Nor vs OW	Nor vs OB I	Nor vs OB II	OW vs OB I	OW vs OB II	OB I vs OB II	F	Trend
SS	Step Width (cm)	9.95	0.70	11.12	0.67	11.49	0.42	12.28	0.47	0.961	0.388	**0.034***	1.000	0.948	1.000	2.799	**0.046****
	Velocity (cm/sec)	116.34	2.21	115.29	1.80	115.96	1.62	113.10	1.80	1.000	1.000	1.000	1.000	1.000	1.000	0.602	0.616
	Stride Lenght (cm)	127.60	0.91	124.80	1.04	126.63	1.01	124.83	1.27	0.403	1.000	0.425	1.000	1.000	1.000	1.684	0.178
	Cadence (step/min)	110.63	2.26	110.98	1.39	111.38	1.75	109.70	1.50	1.000	1.000	1.000	1.000	1.000	1.000	0.167	0.918
	Support Time (% gait cycle)	59.37	0.33	60.07	0.38	60.42	0.22	61.35	0.30	0.723	0.120	**0.000***	1.000	**0.030***	0.241	6.900	**0.000****
	Non support time (% gait cycle)	40.63	0.33	39.93	0.38	39.58	0.22	38.65	0.30	0.723	0.120	**0.000***	1.000	**0.030***	0.241	6.900	**0.000****
	Step Length (cm)	62.74	0.52	62.00	0.60	63.42	0.70	62.58	0.92	1.000	1.000	1.000	0.943	1.000	1.000	0.692	0.560
	Double support time (% gait cycle)	9.68	0.27	10.21	0.39	11.00	0.32	10.82	0.27	1.000	**0.026***	0.079	0.482	1.000	1.000	3.611	**0.017****
CV	Step Width (cm)	10.04	0.53	11.18	0.61	10.73	0.51	11.93	0.53	0.864	1.000	0.101	1.000	1.000	0.747	2.105	0.107
	Velocity (cm/sec)	119.93	2.41	119.68	1.35	119.45	1.98	118.51	2.43	1.000	1.000	1.000	1.000	1.000	1.000	0.088	0.966
	Stride Lenght (cm)	127.73	1.51	125.80	0.99	127.45	1.36	125.91	1.64	1.000	1.000	1.000	1.000	1.000	1.000	0.522	0.668
	Cadence (step/min)	113.89	1.89	114.92	1.17	113.54	1.33	112.43	1.49	1.000	1.000	1.000	1.000	1.000	1.000	0.472	0.703
	Support Time (% gait cycle)	59.43	0.45	59.68	0.42	60.14	0.33	61.16	0.51	1.000	1.000	**0.039***	1.000	0.112	0.607	3.069	**0.033****
	Non support time (% gait cycle)	40.57	0.45	40.32	0.42	39.86	0.33	38.84	0.51	1.000	1.000	**0.039***	1.000	0.112	0.607	3.069	**0.033****
	Step Length (cm)	63.07	0.63	62.23	0.63	64.28	0.83	62.64	1.24	1.000	1.000	1.000	0.601	1.000	1.000	1.035	0.382
	Double support time (% gait cycle)	10.75	1.85	12.26	2.05	10.63	0.29	10.65	0.35	1.000	1.000	1.000	1.000	1.000	1.000	0.324	0.808

* significantly different between BMI group Bonferroni ** significantly different between BMI group ANOVA

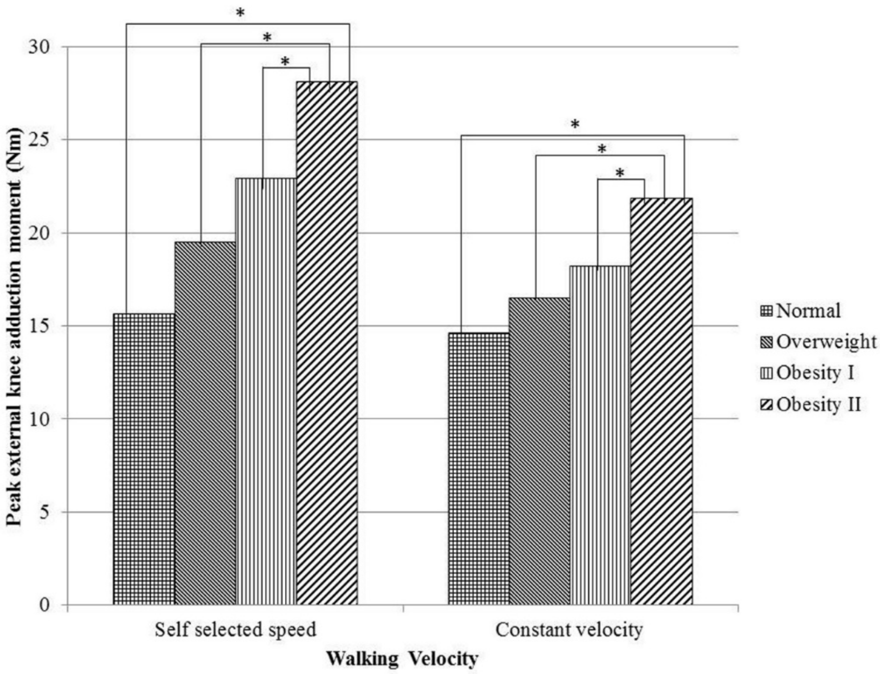
Table 3 Kinematic and kinetic parameters in the four groups during walking at self-selected speed (SS) and constant velocity (CV) with corresponding statistical findings (Bold indicates significance).

Velocity	Parameter	Normal		Overweight		Obesity 1		Obesity 2		*P* value in group comparisons and trend							
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Nor vs OW	Nor vs OB I	Nor vs OB II	OW vs OB I	OW vs OB II	OB I vs OB II	F	Trend
SS	Peak knee flexion angle (°)	8.549	0.865	12.386	1.031	11.180	1.240	9.424	0.950	0.062	0.450	1.000	1.000	0.274	1.000	2.801	0.050
	Peak VGRF	1.180	0.034	1.135	0.022	1.105	0.027	1.117	0.007	0.599	0.659	1.000	1.000	1.000	1.000	1.215	0.310
	Peak external knee adduction moment (Nm/ w)	0.334	0.031	0.265	0.019	0.222	0.022	0.261	0.021	0.453	**0.021***	0.765	1.000	1.000	0.880	3.056	**0.033****
	Knee adduction angular impulse (Nms/w)	0.112	0.015	0.097	0.009	0.083	0.009	0.087	0.007	0.607	**0.015***	0.084	0.881	1.000	1.000	3.681	**0.016****
	Peak external knee adduction moment (Nm)	15.645	1.738	19.501	2.020	22.886	2.377	28.089	2.905	1.000	1.000	**0.027***	1.000	**0.006***	**0.002***	5.922	**0.001****
	Knee adduction angular impulse (Nms)	5.743	0.800	5.235	0.516	5.444	0.600	6.434	0.517	1.000	0.854	1.000	1.000	1.000	0.156	1.835	0.148
CV	Peak knee flexion angle (°)	8.965	1.044	11.944	0.948	11.358	1.056	10.599	0.906	0.220	0.550	1.000	1.000	1.000	1.000	1.698	0.175
	Peak VGRF	1.180	0.035	1.532	0.023	1.120	0.027	1.139	0.009	1.000	1.000	1.000	0.956	0.971	1.000	0.994	0.400
	Peak external knee adduction moment (Nm/ w)	0.352	0.033	0.271	0.024	0.214	0.024	0.255	0.024	0.238	**0.005***	0.317	1.000	1.000	0.806	4.098	**0.009****
	Knee adduction angular impulse (Nms/w)	0.120	0.015	0.086	0.010	0.074	0.010	0.077	0.008	0.685	**0.024***	0.111	1.000	1.000	1.000	3.345	**0.023****
	Peak external knee adduction moment (Nm)	14.584	1.329	16.494	1.076	18.205	1.541	21.821	2.232	1.000	0.987	**0.019***	1.000	**0.022***	**0.004***	4.916	**0.004****
	Knee adduction angular impulse (Nms)	5.733	0.823	5.104	0.557	5.342	0.658	6.288	0.608	1.000	0.873	1.000	1.000	1.000	0.258	1.567	0.204

* significantly different between BMI group Bonferroni ** significantly different between BMI group ANOVA

FIGURE LEGEND

Figure 1: Peak external knee adduction moment (Nm) in the four groups during walking at self-selected speed and constant velocity.



* significantly different between BMI groups ($p < 0.05$)

DISCUSSION

The result of our study showed that the different BMI level in woman had effect to gait patterns during each walking speed. The present study was used motion analysis to measure spatiotemporal, kinetic, and kinematic parameters over a wide range of BMI for Asia Pacific region population. Our findings were consistent with previous studies that higher BMI level tend to have wider step width, longer stance time and lesser non-support time while walking compared with normal group that indicated to change the gait pattern for dynamic posture stabilization[8, 10,16]

The knee flexion was meant to improve the absorption of additional impact imposed by heavier weight.[16] Furthermore, peak knee flexion angles during the stance phase have been reported as being lower and a smaller range of knee motion in obese people has been reported.[18,19] However, from our study we found that there was no significant in the peak knee flexion angle during stance phase due to all groups and walking velocities. It might be reflected that the joint load absorption effect from knee flexion mechanics during stance phase of walking was no difference in difference BMI level female. The higher knee joint load such as peak knee adduction moment person would be prone to induce articular cartilage injury that cause of the knee joint osteoarthritis. The previous studies found that obesity individuals walk with similar sagittal plan motion of knee and hip, but altered frontal plane of hip such as pelvic drop kinematics compared to non obese individuals at walking speed 1.25 m/s, which is close to the reported preferred walking speed for obese adults 1.29 m/s 18. At fast walking speed (1.5 m/s), obese individuals walk with both sagittal and frontal plane kinematic alterations that more extended knee during loading response phase and greater pelvic obliquity during single support phase.[20] The hip and ankle joint motion should be investigated in the further study.

The peak VGRF was the cause of external load to act on lower extremity joint especially knee joint during walking. The increased forced passing across the articular surfaces may be prone to musculoskeletal pathology that induced cartilage damage cause of osteoarthritis.[13,21] From our study found that there was no significantly difference in the peak VGRF during walking all velocities that cause of normalizing with body weight. However, the articular architecture of all groups may be same in female participant groups. The raw vertical ground reaction force may better represent the risk of joint injury than normalized peak vertical ground reaction force.[13]

The knee adduction moment reflects the dynamic joint load on the medial compartment, and is a predictor for the risk of progression for the medial compartment osteoarthritis.[22-24]. The medial and lateral cartilage thickness variations in the knee are influenced by the peak knee adduction moment during normal walking.[16] The joint surfaces of obese are exposed to increase loading. Therefore, for adults who are obese the articular surfaces of the knee are subjected to greater absolute forces, and as a result may be prone to musculoskeletal pathology.[21] Investigations of joint loading in the knee typically normalize the knee adduction moment to global measures of body size such as body weight and height to allow comparison between individuals. However, such measurements may not reflect the knee architecture that affects the force acting upon the articular surface. The recent studies found that normalized peak external knee adduction moment were not sensitive to osteoarthritis severity; however, the non-normalization technique was superior at distinguishing between osteoarthritis severities.[25-27] In the present study, we present the results both of normalized and non-normalized PEKAMs. Our study found that the peak external knee adduction moment (Nm/w) was least in obesity I group for all walking velocities. However, the peak external knee adduction moment (Nm) was highest in obesity II groups comparing with the others in figure 1. As previous studies, that shown increased peak knee adduction have also been reported for adults with excess body mass. [10,12, 21] From the previous studies, the body mass index (BMI) significantly correlates with the incident risk of radiological and symptomatic knee osteoarthritis that was shown in each BMI increase by 1 kg/m^2 above 27 is associated with a 15% increased risk which cause a reduction of fatigue durability of articular cartilage.[5,6,28] A 5-unit increase in body mass index was associated with an 35% increased risk of knee osteoarthritis.[2] Mechanical stress resulting from a high body mass index (BMI) is known to be a risk factor for the development of knee osteoarthritis and better understanding of the positive effect of obesity on osteoarthritis development.[2] The result of our study that might confirmed the higher BMI level in female to be risk of articular cartilage damage caused of knee osteoarthritis.

The knee adduction angular impulse is the product of the average of briefly applied force, times the radius of a rigid body, times the brief time period, that is the time integral of the knee adduction moment over the stance phase. The knee adduction angular impulse provides a quantitative, albeit surrogate, measure of how the medial compartment is loaded during the entire stance phase of gait.[29] From our study we found that the normalize knee adduction moment impulse was least in obesity I group that should be not reflect the knee joint load. However, the non-normalized knee adduction angular impulse was investigated and there was no significantly difference in all groups during walking with all velocities.

The limitation of this study were the EMG and the direction of the center of pressure in the foot during stance phase measurement was not investigated since it is out of the scope of this study. The strength of this study was finding that the overweight and obese had changed gait pattern and knee biomechanics such as the knee adduction moment during walking. Further study should be investigate the effects of lateral wedge insoles to reduce knee joint load and their clinical effects.

CONCLUSION

In conclusion, the healthy overweight and obese participants had changed gait pattern and knee biomechanics during walking in all type of velocities. The knee adduction moment was higher in obese participants that represent the higher knee joint load to be induced joint cartilage damage cause of osteoarthritis. For future study, using the orthosis for reduce biomechanical load that cause of joint cartilage may interest to investigate for prevention potential knee joint osteoarthritis in high BMI female person.

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