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Human Balance during Gait for Normal and Fasting Subjects: A Biomechanical Study

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ABSTRACT

Fasting is the act of consuming no foods and drinks in a period of time. This study investigated whether fasting can be the reason that leads to inability to sustain balance during gait. Kinetic and kinematic parameters were measured in i) walking assessment ii) spin and walk assessment at i) normal and ii) fasting conditions. The parameters include frontal body posture, vertical ground reaction forces (VGRF), hip bending angles, knee angles, ankle angles and vertical center of gravity (VCOG). Eight male and eight female subjects aged 22 to 25 years had involved in this study. Five Oqus camera integrated with Qualysis Track Manager Software had been used for data acquisition and analysis purpose. All the measurements were taken during loading response phase of gait cycle. Then all of the raw data except for frontal body posture were further analyzed using SPSS V17 to determine significance and correlation among the parameters. The results yields that there is no significant different between fasting and normal conditions for either i) walking or ii) spins and walk assessment. However, comparison between male and female shows that male subject have higher value of VGRF and VCOG compared to female subject. This is due to the height and weight difference between the genders. As a conclusion, fasting has given no significant effects on human balance during gait either for male or female.

Keywords: Biomechanics, Fasting, Gait, Human Balance, Motion Capture.

1. INTRODUCTION

The human balance system composed of a complex coordination of central and peripheral system to maintain body's centre of mass over its base of support [1]. The complex system is known as sensorimotor control system that consists of sensory input, integration of input and motor output subsystem. Fasting is the act of obligatory to obey fasting rules which restrict eating and drinking for a period of time. In Malaysia, it may take 10 to 14 hours of fasting duration depending on the geographical location as well as astronomical calculation of the solar (sun movements contribute to the time of year).

Constriction from eating foods and drinking may cause loss of body fluids, declining of energy and change in body composition. In previous research done among Muslim athletes during fasting, they reported an increase of subjective feelings of fatigue, malaise, lethargy and mood swings which can be the reasons that leads to inability to sustain physical efforts and balance [2, 3, 4]. Body posture can indicates any muscles imbalances as the imbalance lead to postural changes [5, 6, 7]. Posture alignment reflects how the body maintains balance. Sagittal and frontal analyses are the methods that can be used in order to observe body posture [7]. For frontal analysis, a good posture will have gravity line fallen symmetrically between two feet, through the umbilicus, through xiphoid process, through nose and chin and between the eyes [7]. When subject's balance perturb by disturbance forces, the body will apply balance recovery

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strategy to maintain the balance. Some of the balance strategies are ankle, hip and step strategies as shown in Figure 1.0 [8, 9]. Applying balance strategies will cause flexion or extension of hip bending, knee angles and ankle angles.

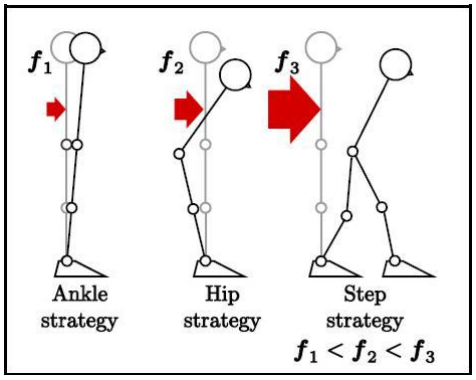

Figure 1. Some of the balance recovery strategies [8].

Vertical ground reaction force (VGRF) also can be used to assess balance during quiet standing as been suggested by Annica Onnel (2000). Changes in the value of VGRF may indicate balance condition of a person [10]. I-Han Tai *et al.* (2006) reported that a dual force plate which consisted of two plates and four load cells are used to record VGRF of each foot and COP. As a result, VGRF showed a trend that the ankle fracture patients (have high tendency to loss balance) moving the COP toward the affected side less especially the affected-forward direction. Centre of gravity is another one of important parameter for balance assessment. COG is a point at which all of the body mass (weight) is equally balance where the summation of all the forces and moments at this point is equal to zero. The location of COG depends on posture, proportion of body parts, age, deformity, distribution of fats and body mass and external forces [11, 12]. Normal COG for a normal person usually lies at a point of a midline, just anterior to the second sacral verterbra [11,12]. There are two types of COG that can be analyzed which is the vertical and horizontal.

2. METHODS

2.1 Subjects

16 participants (eight males and eight females) age around 22 to 25 years old are selected to participate in this study. The subjects are healthy and free from any joint and muscular pathology. All participants were informed as to the procedures of the experiment and signed terms of informed consent. The means of subject's characteristic were tabulated in Table 1.

Table 1 Mean subject's characteristic

Parameter	Male (n=8)	Female (n=8)
Weight	65.15 kg	53.53 kg
Height	1.67m	1.55 m
BMI	23.29 (ideal)	22.53 (ideal)

2.2 Experimental Design and Procedures

Measurements were taken from 12pm to 4pm for both normal and fasting condition experiment. Thus, it means that for fasting subjects, they have at least not consumed any foods or fluids for six to ten hours. The assessments of the experiment were conducted at an identical

laboratory conditions and by the same examiners in each occasion. The average temperature of the laboratory is 28.5 degree Celsius. Each subject was asked to complete two set of assessment in two conditions which are normal condition and fasting condition. For the first task, subjects were asked to walk on 8.37 meters straight path walking platform in a well-lighted laboratory room. For the second task, subject also walks on 8.37 meters straight path walking platform but this time they had to spin three times first before trying their best to walk straight. 16 reflective markers of 19mm in diameters were placed over at the specific joint locations on the subject's lower extremities and upper extremities in order to analyze human balance during gait plus the posture. The position of the markers on the subject was shown in Figure 2 and the joint site of the markers location is listed in Table 2. The capture rate was set at 70 Hertz, and the duration of the capture was set to10 seconds and 20 seconds.

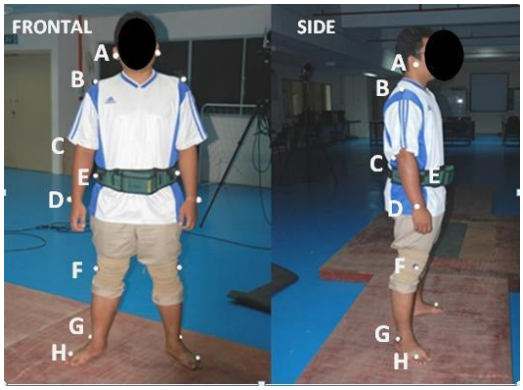

Figure 2. Frontal and side view of marker placement.

Table 2 Anatomical positions of markers

Marker	Anatomical Position on Joint
A	Ear
B	Shoulder
C	Elbow
D	Wrist
E	Hip
F	Knee
G	Ankle
H	5th Metatarsal

3. RESULTS AND DISCUSSION

3.1 Frontal Body Posture

Frontal body posture was examined based on reference guided by Dr.Winchell [13]. Dr. Winchell's graphical reference were chosen because the alignment of head, shoulders and hips suits the specification of walking posture from W. Bumgardner (2011) and M. Bush (2010) [14,15].

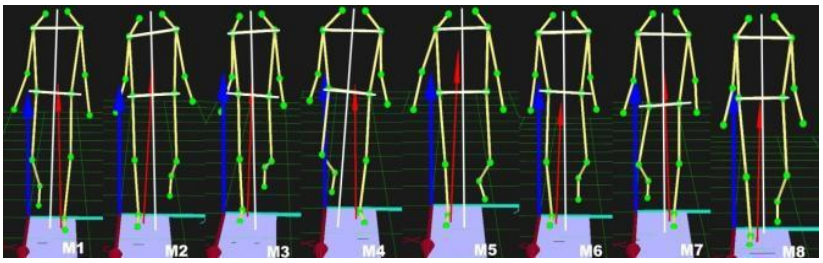

Figure 3. Frontal body posture for male subject during gait at normal condition.

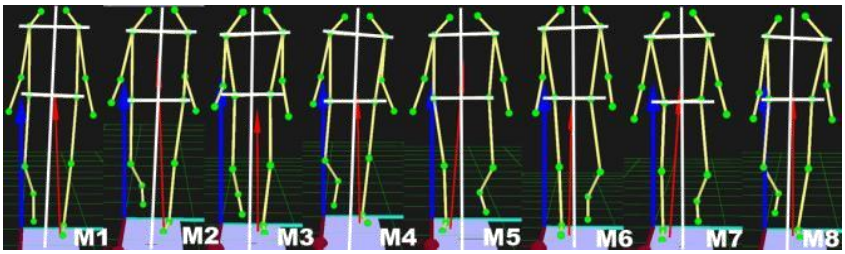

Figure 4. Frontal body posture for male subject during gait at fasting condition.

From Figure 3 and 4, the results of male (M) subject's body posture during walking are summarized in percentage as in Figure 5.

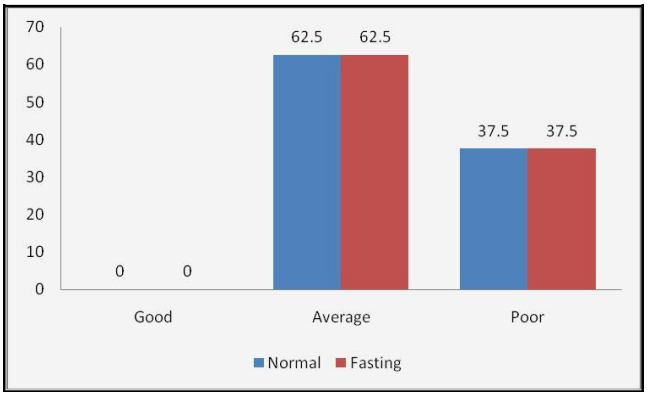

Figure 5. Percentage of frontal body posture level for male.

62.5 percent of male subjects have average level posture at normal and fasting condition. Meanwhile, 37.5 percent male subjects possessed poor body posture as shown in Figure 5.

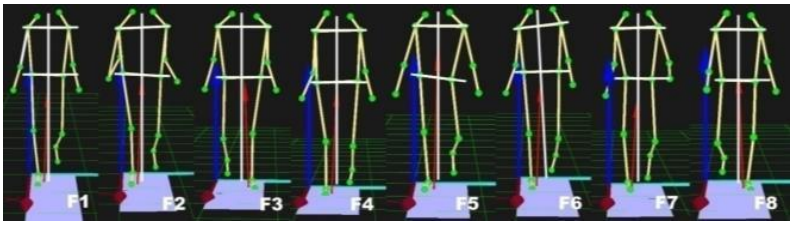

Figure 6. Frontal body posture for female subject during gait at normal condition.

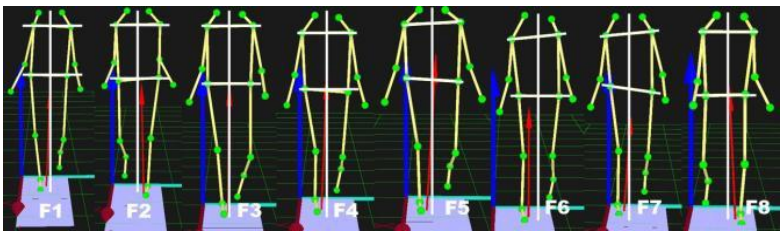

Figure 7. Frontal body posture for female subject during gait at fasting condition.

Figure 6 and Figure 7 are the graphical representation of female (F) subject's body posture during walking at normal and fasting condition results correspondingly. On the other hand, Figure 8 summarized the percentage of posture level for the female subject during walking at the two different conditions.

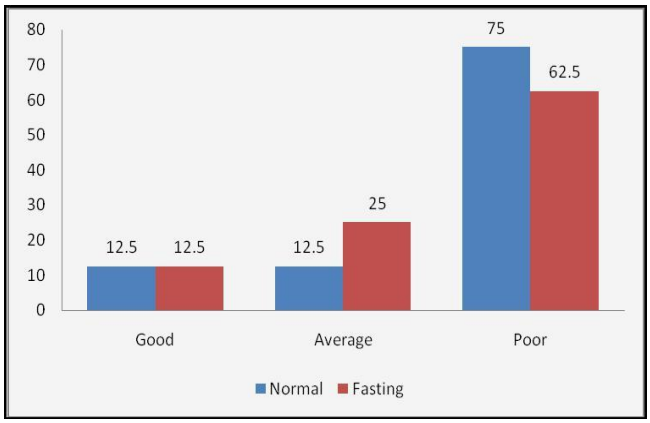

Figure 8. Percentage of frontal body posture level for female.

For female subjects as shown in Figure 8, 12.5 percent have good posture, another 12.5 percent shows average level and 75 percent shows poor frontal body posture level for spins and walk during normal condition. For spins and walk at fasting condition, 12.5 percent shows good body posture, 25 percent possess average level of body posture while 62.5 percent with poor body posture level. Thus, it can be said that there are no significant difference between fasting and normal condition but female subjects possess better posture compared to male subjects.

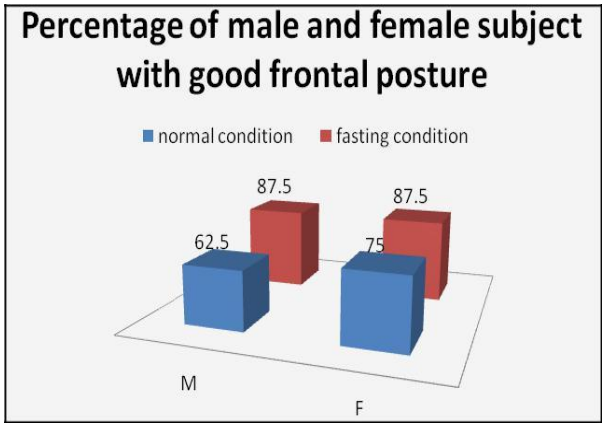

Figure 9. Percentage of subjects with good frontal posture for both genders during walking assessment.

Based on Figure 9, during gait at normal condition, female subjects have better results with 75 percent (six out of eight subjects) possess good frontal posture while the male subject with 62.6

percent (five out of eight subjects). Nevertheless, during gait at fasting condition 87.5 percent (seven out of eight subjects) for both male and female have good level of frontal posture. Thus, it shows some improvement on frontal body posture during fasting condition.

3.2 Vertical Ground Reaction Force (VGRF)

VGRF in this project were measured on both leg, the dominant and opposite leg. The dominant leg VGRF is labeled as VGRF1 while the opposite is VGRF2. Comparison between VGRF1 and VGRF2 for male, female and between the genders was made. As in Table 3, for male, the means value of VGRF1 is 667.12 N and VGRF2 is 681.18 N for walking at normal condition while for walking at fasting condition, value of VGRF1 is 659.88 N and VGRF2 is 679.9 N. Yet, the value of VGRF1 and VGRF2 increased during spins and walk for both normal and fasting condition.

For female, the means value of VGRF1 as shown in Table 4 is 565.12 N and VGRF2 is 555.85 N for walking at normal condition while for walking at fasting condition, value of VGRF1 is 561.18 N and VGRF2 is 561.82 N. Also, the value increased during spins and walk for both normal and fasting condition. The value of VGRF1 is nearly equal to VGRF2 therefore the subject can be said still in a balanced condition. Making comparisons between genders, VGRF1 and VGRF2 for male subjects are higher than female subjects due to weight of male subjects are higher.

Table 3 Mean and standard deviation of VGRFs value for male subjects at different condition and assessment

Assessment	Normal Condition		Fasting Condition	
	VGRF1 ± SD	VGRF2 ± SD	VGRF1 ± SD	VGRF2 ± SD
Walking	667.12 ± 84.26	681.18 ± 100.36	659.88 ± 92.25	679.90 ± 105.10
Spin and Walk	705.38 ± 121.49	735.20 ± 115.50	693.79 ± 90.51	704.09 ± 82.43

Table 4 Mean and standard deviation of VGRFs value for female subjects at different condition and assessment

Assessment	Normal Condition		Fasting Condition	
	VGRF1 ± SD	VGRF2 ± SD	VGRF1 ± SD	VGRF2 ± SD
Walking	565.12 ± 73.32	555.85 ± 58.58	561.18 ± 75.32	561.22 ± 83.40
Spin and Walk	653.89 ± 94.96	631.68 ± 95.04	612.46 ± 107.05	602.81 ± 112.33

3.3 Trunk Bending Angle

The hip bending, knee joint and ankle joint angles were analyzed to determine whether subjects applied balance control to prevent them from falling by flexion or extension movement of the joints stated. Discussing on the hip bending first, male subjects had angle of 166.17 degree during walking at normal condition and angle of 167.22 during walking at fasting condition. Based on T-test, it shows insignificant difference between the two conditions. However, bending angles become lower in spins and walk assessment for both normal and fasting condition indicating balance control is applied. For female subject, the bending angle is at 158.39 degree and 161.98 degree for walking at normal and fasting condition respectively showing insignificance ($P>0.05$) between the two values. Nevertheless, angles become larger in spins and walk assessment for normal and fasting condition. The changes indicate that subjects applied balance control. There is no significance between male and female for bending value.

3.4 Knee Joint Angle

Knee joint angles shows value of 163.05 degree and 162.08 degree for male, and 161.18 degree and 157.08 degree for female during walking at normal and fasting condition correspondingly. Knee flexion occurs in both male and female during spins and walk assessment at normal and fasting condition showing the sign on balance control. There are no significant different (P>0.05) were found based on the T-test done for genders and condition applied during each assessment. The results for paired t-test were tabulated in Table 5 and Table 6.

Table 5 Paired samples T-test for knee joint angle between normal and fasting condition for male subjects

Assessment			
	t	**df**	**Sig. (2-tailed)**
Walking	0.528	7	0.614
Spins and walk	0.480	7	0.646

Table 6 Paired samples T-test for knee joint angle between normal and fasting condition for female subjects

Assessment			
	t	**df**	**Sig. (2-tailed)**
Walking	-1.572	7	0.160
Spins and walk	-2.185	7	0.065

3.5 Ankle Joint Angle

Next is the ankle joint angle with value of 94.5 degree and 93.67 degree for male subject during walking at normal and fasting condition respectively. While female shows value of 100.38 degree and 96.82 degree during walking at normal and fasting condition respectively. Plantar flexion (increase in angle) occur in male subject during spins and walks assessment at both condition. Conversely, dorsiflexion (decrease in angle) occurs in female during spins and walk assessment for both conditions. Insignificant value (P>0.05) was obtained from the T-test between genders and between fasting and normal condition for male and female as in Table 7 and Table 8.

Table 7 Paired samples T-test for ankle joint angle between normal and fasting condition for male subjects

Assessment			
	t	**df**	**Sig. (2-tailed)**
Walking	0.254	7	0.807
Spins and walk	-0.104	7	0.920

Table 8 Paired samples T-test for ankle joint angle between normal and fasting condition for female subjects

Assessment			
	t	**df**	**Sig. (2-tailed)**
Walking	2.226	7	0.061
Spins and walk	1.278	7	0.242

3.6 Vertical Centre of Gravity (VCOG)

Vertical centre of gravity (VCOG) of person depends on the height and activity done by that person. From this project, the results of VCOG which were measured by the position of hip marker in Z direction (in millimeters unit). Based on Figure 10, it clearly shows insignificant different between normal and fasting condition during walking assessment. The same results can be found in normal and fasting conditions during spins and walk. However, male subjects have higher VCOG than female because of their height are much higher that female.

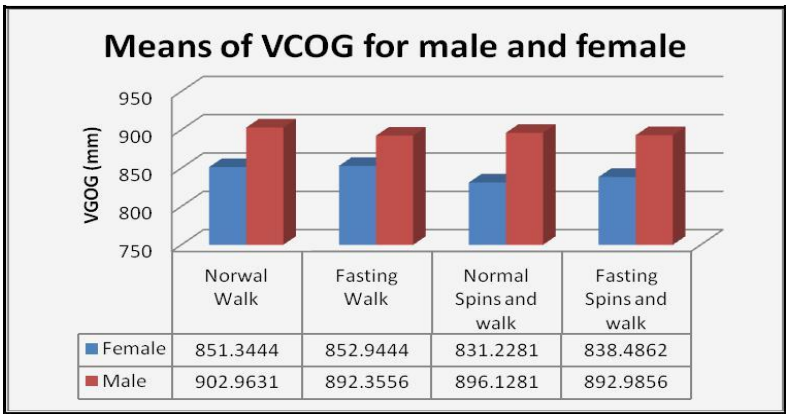

Figure 10. The means value of VCOG for male and female subjects.

4. CONCLUSION

As a conclusion, this study aim is to determine any differences between normal and fasting subjects during gait. The parameters related to human balance which is frontal body posture, vertical ground reaction forces (VGRF), hip bending angles, knee angles, ankle angles and vertical centre of gravity (VCOG) were studied and analyzed. The measurements were taken during loading response phase of gait between eight male and eight female subjects. The assessments done for data acquisition are for walking and spin assessment. The walking assessments were done at two different conditions which are normal and fasting condition. Data for each condition were taken on a separate day. Overall, there is no significant difference between fasting conditions with normal condition for either male or female subjects as been tested using paired samples T-test in SPSS. All the significant value for the parameters studied shows greater value than 0.05 ($P>0.05$) indicating insignificant condition. Nonetheless, if comparison were made between genders there is some significance. For example, based on the results obtained in this project, VGRF and VCOG for male subjects have greater value from female subjects due to weight and height. In other words, factors such as weight and height will effect on human balance. However, in this project, fasting will not caused any unwanted problems that might perturb human balance efficiency.

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