

## Estimation of Energy Expenditure with Two Different Footwear's in Normal Healthy Females

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### ABSTRACT

**Background:** Footwear plays an important role while walking. Complaints of foot pain and disability are more common in women. The Physiologic Cost Index (PCI) derived by MacGregor is a tool to calculate the energy expenditure, as an alternative to Laboratory & Caloric Measurements.

**Objective:** To estimate energy expenditure for walking with two different footwears (flat flip flops and sports shoes) in normal healthy females.

**Method:** 100 Female subjects with Normal BMI aged between 20-30 Years were assessed to calculate the PCI, First with flat flip-flops and then with an ideal pair of sports shoes (control group), during walking at their chosen speeds over 15 consecutive lengths of a 40m oval track (total walking distance 600m). Resting and Walking heart rate was recorded. Speed was calculated using the standard mathematical equation (Speed = Distance/time). Two PCI values were calculated for each individual, using the McGregor's Equation.

**Result:** The Mean Walking Speed with flip-flops was  $54.03 \pm 4.90$  meters/minute. Mean walking speed with sports shoes was  $56.14 \pm 5.45$  meters/minute. There was a statistically significant difference in mean PCI for walking between flip flops ( $0.667 \pm 0.15$  beats/meter) and sports shoes ( $0.592 \pm 0.17$  beats/meter), showing that lesser energy expenditure is required for walking with Sports Shoes than with Flat Flip-Flops. (P Value < 0.05)

**Conclusion:** The study showed that Walking in Sports Shoes, requires significantly less energy expenditure as compared to the usual flip-flop footwear for the same distance. This concludes that Sports Shoes are energy cost effective when compared to the counterpart.

**Keywords:** Physiologic Cost Index (PCI), McGregor's Equation, Flat footwear, Ideal Footwear, Walking, sports shoes.

### INTRODUCTION

Human Beings are one of the few species who has mastered the ability of Bipedal Locomotion, and the Foot has been a base for such a peculiar gait. Footwear has a prominent role in protecting the foot from mechanical trauma during locomotion, as well as from the hazards of temperature and moisture. However, since the production and popularity of fashion footwear over a

decade, the functional aspect of footwear has been substituted by the need of fashion. In women of all ages, Shoe selection is primarily based on fashion considerations, many of which are antagonistic to the optimal function of the ankle-foot complex. [1]

Different footwear's, Orthosis, prosthesis or any kind of external device has shown to have an effect on energy

expenditure. Energy expenditure is the amount of energy (or calories) that a person needs to carry out their physical functions. The Total Daily Energy Expenditure (TDEE) is variable for each and every individual. [2]

Thong style flip-flop footwear has gained popularity, owing to their attributes of having a lightweight, breathable and easily available, their convenience and cheaper cost. This style of footwear is defined by having a strap across the dorsal fore-foot, attaching to the insole between the hallux and second toe to the thin, flexible outer sole. [3] Shroyeret.al showed that walking in flip-flops resulted in a shorter stride length, a shorter stance time, a smaller ground reaction force (GRF) impulse, and a larger ankle contact angle compared to running shoes, affecting the gait biomechanics. [3] Habitual use of unstable and incompatible footwear results in undue muscular activities over the ankle-foot complex during walking. Their simple design is responsible for causing injuries of the foot and lower leg. [4] It has been seen that unstable footwear compromises energy expenditure which in long term can have a deleterious effect on energy expenditure. [5, 6]

Again, Sports shoes are considered to be ideal footwear as they meet the standards required for ideal footwear. [7] Since very less data is available on the energy expenditure with the usage of sports shoes, there is need to identify its effect on energy expenditure considering it as a standard parameter.

Traditionally, Calculation of Energy Expenditure has relied on Laboratory & Caloric Measurements, as well as with various mechanical systems, which, many times is difficult to obtain and impractical in clinical set-ups [8]

The Physiologic Cost Index (PCI) as derived by MacGregor is a tool designed to calculate PCI, as an alternative to Lab-Based Caloric Analysis for Energy Expenditure. [8,9] The use of PCI as a unit of

energy expenditure using MacGregor's Index is considered valid and reliable. [7,10]

There is a Good Amount of evidence on PCI calculated in individuals with external devices such as Orthosis, Prosthesis and with different surface tracks and in different pathological conditions. But very less literature available on flip flops and sports shoes on energy expenditure. Hence there is a need to objectively quantify the effect of different footwear on energy expenditure, selectively Flip-Flops and Sports Shoes, using Physiological Cost Index (PCI).

## MATERIALS AND METHODS

The study was a cross-sectional observational study. 100 Normal Healthy asymptomatic Females were selected using systematic sampling. Inclusion Criteria- Healthy Females between 20-30 Years of age, Females with Normal BMI. Exclusion Criteria: Any Musculo-Skeletal Pathologies, Neurologic Disorders or Cardio-Vascular Ailments, Psychological Illnesses, Subjects who have undergone recent surgical intervention or currently undergoing any rehabilitation program. The study was approved by the Institutional Review Board. All the subjects were informed about the aim and need of the study. Informed consent was taken from all the participants. Materials used were Weighing Machine, Inch Tape, Sphygmomanometer, Pulse Oximeter, Spot Marking Cones, Thong style Flat Flip-Flops/Sandals with No Rear Lock & Stability Straps and no raised heel, an ideal Pair of sport Shoes, and a stopwatch.



Figure 1: Ideal Sports Shoe



Figure 2: Thong Style Flat Flip-Flop

**Procedure:** The Assessment was a 2 Day Protocol; the First day with Flip flops, Second day with Sports shoes. The assessment gap was a minimum of 24 Hours. Resting Vitals were assessed on Day 1 which included Resting Pulse, Resting Blood Pressure, Resting Oxygen Saturation and Resting Respiratory Rate.

On Day 1, Subjects walked a 600m Track (40m Oval Track X 15 Rounds) using Flat Flip-Flops, and the time taken to complete the distance was noted. Walking Heart Rate was noted for every 3<sup>rd</sup> Completed Lap, using the Pulse Oximeter secured. Detailed Post-Exercise Vitals were recorded. Subjects were advised not to do any strenuous workout or any Heavy Work till the 2<sup>nd</sup> Day Protocol ends. On Day 2, Resting Vitals were assessed as done on Day 1 and Subjects again walked a 600m Track using Sports Shoes; in a similar fashion as done on Day1.

Walking Speed was calculated using the mathematical equation; Speed=Distance/Time. Physiologic Cost Index (PCI) was calculated using MacGregor's Equation:

$$PCI = \frac{\text{Walking Heart Rate} - \text{Resting Heart Rate}}{\text{Walking Speed}}$$

Unit: Beats/Meter

### STATISTICAL ANALYSIS

The Mean Walking Speed was calculated for both footwears. The Mean Physiologic Cost Index (PCI) was calculated for 2 footwears for each individual using the MacGregor's Equation. Comparison for energy expenditure for flat flip-flops and sports shoes was statistically

analyzed using the Student's unpaired t-test. Microsoft Excel 2016 and Graph Pad Prism 8.0.1 (244) software's were used for Data Analysis.

### RESULT

The result of Unpaired t-test showed that there was a statistically significant difference between the Mean Indices of energy expenditure for walking with flat flip-flops and shoes (P<0.05).

Table 1 shows the Mean + SD Walking Speed for flat flip flops and sports shoes. Table 2 shows Mean PCI for walking with Flat Flip-Flops, Sports Shoes and their comparison. It was seen that Mean + SD PCI for flip flops was 0.66 + 0.15 beats/meter and that for shoes was 0.59 + 0.17beats/ meter.

Table 1: Mean Walking Speed with Flat Flip-Flops and Sports shoes

Group	Mean Walking Speed (meters/minute)	Standard Deviation	P value
Flip- Flops	54.03	4.90	0.004*
Sports Shoes	56.14	5.45	

\*Statistical Significance = P Value <0.05

Table 2: Comparison of Physiological Cost Indices (PCI) for walking with Flat Flip-Flops and Sports Shoes.

Group	Mean PCI (Beats/Meter)	Standard Deviation	Difference	P Value
Flat Flip-Flops	0.667	0.158	0.075 ± 0.012	0.0014*
Sport Shoes	0.592	0.170		

\*Statistical Significance = P Value <0.05

The Clinical Significance of the data was assessed by Effect Size Calculation using the Glass's Delta Equation. Effect Size was found to be 0.475 i.e. Moderate clinical significance.

### DISCUSSION

The Study revolved around 100 Subjects, walking over a 600 m track (40 m X 15 Rounds) at their own pace, using flat flip-flops and then an ideal pair of sports shoes. Walking Speed was calculated using the Standard Mathematical Equation and all the variables measured during the performance (Resting Heart Rate, Walking Heart Rate, and Walking Speed) were added into the MacGregor's Equation and the

Physiologic Cost Index (PCI) was calculated for baseline comparison.

Table 1 shows Mean Walking Speed of 54.03 Meters/Minute for Flat Flip-Flops and Mean walking speed of 56.14 Meters/Minute for sports shoes. In a study done by Keiji Koyama et al. in 2012, where effects of Unstable Shoes on Energy Cost were analysed during treadmill walking at various speeds [5] It was concluded that Unstable Shoes can significantly increase Lower Limb Muscle Activation and a resultant increase in Energy Expenditure (Oxygen Cost). EMG studies done during the same study revealed increased Gastrocnemius & Soleus muscle activation as well as increased Heart Rate and  $VO_2$ .

Also, Increased Muscular co-contraction while walking with Flat Flip-Flops could be considered as a mechanism to restrict excessive foot movements and regulate the Knee & Ankle joints as compensation for the unstable interface of flip-flop footwear [11]

Our Analysis showed a statistically significant difference between the Mean Walking Speeds with Flip Flops and Sports Shoes (P Value <0.05). On regular basis, it is not habitual for the wearer to maintain the same speed level when walking in different footwear's. Instead of adducing excessive muscle co-contraction, reducing speed is seemingly a more natural approach for the wearer. [11] This can be linked to a decrease in walking speed with flip flops in our study. A Resultant increase in foot stability provided by sports shoes as compared to open toe footwear can also be linked to an increase in walking speed with sports shoes in our study.

Table 2 shows a comparison of Mean PCI Values while walking with flat flip-flops and sports shoes. There was a statistically significant difference between the PCI values showing that flip flops consumed more energy than sports shoes. In a study done by Xuili Zhang et al. in 2013 where Gait Biomechanics were compared while walking with flip-flops, sandals, shoes and barefoot walking [12] the author

concluded that walking with Flat Flip-Flops and sandals had different gait parameters as compared to shoes. In our study, sports shoes might have produced Smaller Loading Rate and a Peak Propulsive GRF while walking as compared to flat flip flops. This resultant but advantageous change in Gait Parameter can be attributed to an increase shoe width, stability as well as thicker sole and heel cushioning available in shoes which is absent in flip flops. The Low Sole Thickness, Rigid Heel and lack of cushioning in flip flops do not provide much force dampening during walking. [12] These factors together contributed in attenuation of forces while walking by supporting the foot and preventing injuries; the stability provided by shoes resulted in reduced muscle activation, which further reduced energy expenditure when compared to flip-flops. This also could be due to the fact that Flat Footwear's are relatively unstable as compared to Shoes.

Again, walking with flip-Flops is associated with an increase in Heart Rate and  $VO_2$ , reduced cadence as well as slower walking speed as compared to that with shoes. [5] This further increased energy expenditure for walking with flip-flops.

To obtain the Clinical Significance of the data, Effect Size was calculated using Glass's Delta Equation. [13] The Glass's Delta Equation was chosen as it allows measuring the effect size when two groups have different standard deviations. The Value obtained was 0.475 which showed Moderate Clinical Significance. This shows that the data obtained is statistically as well as clinically significant.

A highly significant interpretation obtained by statistical analysis, as well as with due consideration to the available literature, Our Study indicates that walking with Sports Shoes is a better alternative to walking with flat footwear when Energy Expenditure and Gait Biomechanics is concerned.

### Limitations

Small Sample Size, Outdoor Walking Environment; Temperature & Humidity were not controlled.

### Clinical Implications and Suggestions

This study is an attempt to highlight the ill-effects of Unstable Footwear in terms of energy expenditure, which contributes to muscle imbalance resulting in musculoskeletal dysfunction. Literature has shown the effects of prolonged use of unstable footwear which directly contributes to foot pathologies <sup>[14]</sup>

Footwear plays an important role in Human Gait and hence, Emphasis should be placed on the use of Ideal Footwear for walking. This could play an essential role in the prevention of the majority of musculoskeletal dysfunctions right from their foundation.

Further studies should be done, which takes into consideration, a Larger Sample Size as well as samples from different population groups, so that the clinical significance can be emphasized on a larger scale. Studies should also be carried on Indoor Treadmill walking as an alternative to walking on an outdoor track, which could rule out limitations of the walking environment which were experienced in this study.

### CONCLUSION

Our Study concluded that energy expenditure is less when walking with Sports Shoes as compared to walking with Flat Flip-Flops.

### List of Abbreviations

PCI; Physiologic Cost Index, HR; Heart Rate

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