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**Research Article / Araştırma Makalesi**

# Validity of SenseWear Armband in assessing the energy expenditure at different exercise intensities during menstrual cycle

## *Menstrual döngüde farklı düzeyde enerji harcamasının değerlendirilmesinde Sensewear Armband'ın geçerliliği*

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**ABSTRACT**

**Objective:** The purpose of this study was to determine the validity of the SenseWear Armband (SWA) in assessing the energy expenditure at different exercise intensities during midfollicular and luteal phases of the menstrual cycle.

**Material and Methods:** Twenty volunteer women athletes (age: 20.6±1.6 yrs, height: 168.3±7.3 cm; menstrual cycle: 28.8±2.1 days) with regular menstrual cycle participated in the study. Participants performed treadmill running exercise for 10 min at 35% and 75% of their $VO_{2max}$ in their midfollicular (days 7-9) and luteal phases (days 21-23). Phases of the menstrual cycle were confirmed by hormone analysis. Energy expenditure during the running exercise was assessed simultaneously by the indirect calorimetric method, and the SWA. Multi-way ANOVA was used for the effect of method (2) x phase (2) x intensity (2) on energy expenditure. In addition, the Pearson correlation coefficient was determined between the variables.

**Results:** Estradiol and progesterone levels measured in the midfollicular phase were significantly higher than in luteal phase (p<0.05). Energy expenditure at 75% intensity was significantly higher than energy expenditure at 35% intensity (p<0.05). No significant method (p>0.05) and phase (p>0.05) effect was found in energy expenditure. There was no significant method x phase, phase x intensity, and method x phase x intensity interaction (p>0.05), however method x intensity interaction was significant (p<0.05). At the midfollicular phase the correlations between energy levels from indirect calorimetric and SWA methods were not significant (for 35%, r=0.382; for 75%, r=0.147; p>0.05). In contrast, significant correlation was found between energy levels from the indirect calorimetric, and the SWA methods at the luteal phase (for 35%, r=0.495; for 75%, r=0.748; p<0.05).

**Conclusions:** The results of the present study indicated that energy expenditures at different menstrual phases were similar and that SWA was a valid method in assessing energy expenditure at different exercise intensities during the menstrual cycle.

**Keywords:** *Indirect calorimetry, oxygen consumption, midfollicular phase, luteal phase*

**ÖZ**

**Amaç:** Bu çalışmanın amacı, menstrual döngünün midfoliküler (MP) ve luteal fazında (LP), farklı şiddette egzersizlerde enerji harcamasının değerlendirilmesinde SenseWear Armband'ın (SWA) geçerliliğini belirlemektir.

**Gereç ve Yöntem:** Çalışmaya bireysel ya da takım sporlarında en az üç yıldır yarışmacı sporcu olan sağlıklı 20 kadın (yaş: 20.6±1.6 yıl; boy:168.3±7.3 cm; menstrual döngü gün sayısı:28.8±2.1 gün) katıldı. Katılımcılar menstrual döngünün MP (7-9. günler) ve LP fazlarında (21-23. günler) koşu bandında maksimal oksijen tüketiminin ($VO_{2maks}$) %35 ve %75'inde 10'ar dk koşu egzersizi yaptılar. Menstrual döngünün fazları hormon analizi ile teyit edildi. Koşu egzersizlerinde eşzamanlı olarak indirekt kalorimetrik yöntem (İKY) ve SWA ile enerji harcaması ölçüldü. Yöntem (2) x faz(2) x şiddet (2)'in enerji harcaması üzerine etkisini belirlemede çok yönlü ANOVA kullanıldı. Değişkenler arasındaki ilişkiler Pearson korrelasyon katsayısı (r) ile belirlendi.

**Bulgular:** Midfoliküler fazda ölçülen estradiol ve progesteron, luteal fazdan anlamlı derecede yüksekti (p<0.05). Enerji harcaması üzerine hem yöntem hem de faz etkisi anlamlı bulunmadı (p>0.05). Yüzde 75 şiddette enerji harcaması %35'dekinden anlamlı derecede yüksekti (p<0.05). Yöntem x faz, faz x şiddet ve yöntem x faz x şiddet etkileşim istatistikleri anlamlı değildi (p>0.05). Yöntem x şiddet etkileşimi istatistiksel olarak anlamlıydı (p<0.05). MP'de İKY ve SWA ile ölçülen enerji değerleri arasındaki ilişkiler (%35 $VO_{2maks}$ için r=0.382; %75 $VO_{2maks}$ için r=0.147) anlamlı değildi (p>0.05). Buna karşılık LP'de İKY ve SWA ile ölçülen enerji değerleri arasında anlamlı ilişki (%35 $VO_{2maks}$ için r=0.495; %75 $VO_{2maks}$ için r=0.748) saptandı (p<0.05).

**Sonuç:** Çalışmanın bulguları, menstrual döngünün farklı fazlarında enerji harcamasının benzer olduğunu, SWA'nın her iki fazda da enerji harcamasını geçerli bir şekilde ölçtüğünü ortaya koydu.

**Anahtar Sözcükler:** *Endirekt kalorimetri, oksijen tüketimi, midfoliküler faz, luteal faz*

## INTRODUCTION

Double labeled water (DLW) and indirect calorimetry (IC) are accepted as the gold standard methods to assess energy expenditure (1). DLW is often used to evaluate physical activity in daily life, and IC is commonly used for energy expenditure estimation in laboratory settings. The use of both methods is limited as they require high level of technical

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knowledge and skills, and are expensive and time consuming. At present, the SenseWear Pro3 Armband (BodyMedia Inc., Pittsburgh, PA) (SWA) estimates energy expenditure with the help of multiple sensors and a specific algorithm.

Validity studies that compare the SWA with gold standard methods have revealed that it can be used to estimate energy expenditure of sedentary individuals during daily physical activity (2,3), walking or jogging on a treadmill (4-7), and cycle (2) or arm ergometer exercises (8), and different training applications and competitions (9). However, studies on athletes determined that compared to the reference methods, the validity of SWA has shown variations depending on the intensity of treadmill (5) and rowing ergometer (10) exercises, strength and endurance training (11), and during competitions (9).

In women with regular menstrual cycles, fluctuations in blood concentrations of sex hormones have a potential to affect their exercise metabolism. The vast majority of studies in women have shown that menstrual cycle significantly alters substrate metabolism during submaximal exercise (12), and the respiratory exchange ratio (RER) is systematically lower in the luteal phase (LP) than in the mid follicular phase (MP) (12,13). It has been found that women with regular menstrual cycles used less glucose in the LP than in MP at 90% compared with 70% lactate threshold intensity during consecutive 25-min cycling exercises (14). In the same study, it was also found that blood lactate (LA) concentration and CHO oxidation were lower but total fat oxidation was higher during LP at 90% lactate threshold. Exercise intensity is also another important factor in substrate utilization during different phases of the menstrual cycle (13).

The effect of sex hormone fluctuations in menstrual cycle on substrate utilization during exercise is uncertain. Horton et al. (15) determined that in cycling ergometer exercise at exercise intensity corresponding to 50% $VO_{2max}$, CHO and fat oxidation were similar during early follicular phase, MP and LP of the menstrual cycle. In addition, other studies also reported similar substrate utilization (CHO and fat oxidation) during different phases of the menstrual cycle (16).

During the menstrual cycle, changes in RER measured in exercises of similar intensities can alter the caloric value of oxygen consumption (17), and this alteration in caloric expenditure as a result of a possible change in substrate utilization during different phases of the menstrual cycle was mostly determined by using IC. However, no study has been found that used the SWA for the estimation of energy expenditure during different phases of the menstrual cycle. Hence this study aimed to determine the validity of SWA in assessing energy expenditure at different exercise intensities during the menstrual cycle. We have two hypotheses in this study: a) Energy expenditure is different during the menstrual cycle due to increased fatty acid metabolism in the luteal phase compared with the mid-follicular phase; b) SWA is a valid method for assessing energy expenditure during the menstrual cycle.

## MATERIAL and METHODS

### Participants

Twenty female athletes with at least three years of competition experience in different sport branches, with regular menstrual cycles for the past six months (menstrual cycle X=28.8±2.1 days), who did not use any hormones or other drugs, had no history of injury, and did not receive medical support for the past month (body height (BH): 168.3±7.3 cm, body weight (BW): 62.7±10.4 kg, body fat percent (BFP): 22.3±6.5%, fat free mass (FFM): 48.3±5.5 kg) participated in the the study voluntarily. The participants were given a detailed information about the study and signed informed consent. The study was approved by the Non-Interventional Clinical Research Ethics Board (Approval Number : GO 15/522-17) and the research was done under the guidelines of the Declaration of Helsinki.

### Procedures

Data were collected randomly by repeated measurements during MP (7-9$^{th}$ days) and LP (21-23$^{rd}$ days) of the menstrual cycle. Participants reported to the laboratory on three occasions, one for the maximal oxygen consumption test ($VO_{2max}$), and two for the energy expenditure test. $VO_{2max}$ test was performed randomly following blood sampling for estradiol (E2) and progesterone (PRO) hormone analysis during MP (7$^{th}$ day) or LP (21$^{st}$ day). Energy expenditure test for the phase in which $VO_{2max}$ was measured was applied 48 hours after the initial $VO_{2max}$ test. Energy expenditure was measured at two different exercise intensities at running speeds corresponding to 35% and 75% of participants' $VO_{2max}$ during both phases. Participants were asked not to consume alcoholic and caffeinated beverages in the evening before tests, and to avoid intense exercise within the last 24 hours. Energy expenditure tests were performed after an overnight fast, and all tests were performed at the same time of the day during both phases, with same sportswear and shoes.

### Anthropometric Measurements

Participants' BH was measured by a wall-mounted stadiometer with an accuracy of ±0.1 cm (Holtain Ltd, England), and BW was measured three times before all tests using an electronic scale with an accuracy of ±0.1 kg (Tanita SC330, Germany). Body composition as BFP and FFM was also determined with the same foot-to-foot bioelectrical impedance analyzer before the energy expenditure tests during MP and LP with standardized methods.

**Maximal Oxygen Consumption Measurement**

$VO_{2max}$ was determined in one of the menstrual phases on the first visit with at least two hours after the breakfast, on a motorized treadmill (ELG Woodway GmbH, Germany) with constant grade and increased speed running protocol by an automatic portable gas analyzer ($K4b^2$, Cosmed Srl, Rome, Italy). The gas analyzer was calibrated with a 4.10 % $CO_2$, 15.70 % $O_2$, balance $N_2$ gas mixture (The Linde Group, Turkey) before each session. The flow sensor was calibrated with a 3-liter syringe (Cosmed, Italy). After warm up on a motorized treadmill with 0% grade at 6.0 $km.h^{-1}$ speed for 5 min, participants performed the test with the speed increased by 1.0 $km.h^{-1}$ every 3 min and continued until volitional exhaustion. Heart rate (HR) was recorded at 5 s intervals by using a HR monitor (Polar, Finland) integrated in the oxygen analysis system.

The average $VO_2$ and HR measured in the last 30 s of each workload were accepted as the physiological response of that workload. The highest $VO_2$ value was accepted as $VO_{2max}$. The criteria used to confirm the achievement of $VO_{2max}$ in the treadmill test were (a) plateau of $VO_2$ despite increasing the running speed (change in $VO_2$ ≤150 $ml.min^{-1}$); (b) RER greater than 1.10; (c) reaching ± 10 beats of the age predicted maximum HR determined by the formula (220-age); and (d) blood lactate concentration higher than 8.0 $mmol.L^{-1}$ (18). The $VO_2$ values measured during the test were plotted as a function of the running speed to determine the running speed corresponding to 35% and 75% $VO_{2max}$ for each participant. For this, 1st or 2nd order polynomial curves were fitted to the discrete data in the running speed vs.-$VO_2$ graphs ($R^2 \geq 0.90$).

**Energy Expenditure Measurements**

Energy expenditure was determined by using both the SWA and IC ($VO_2$ and $VCO_2$) simultaneously at running speeds corresponding to 35% and 75% $VO_{2max}$ during both phases of the menstrual cycle.

***Indirect calorimetry:*** After 5-min warm-up at self selected tempo, 2-min stretching and 3-min passive rest, participants exercised for 10 min at speeds corresponding to 35% and 75% $VO_{2max}$, respectively. Between tests at different speeds, at least 2 min of rest or a break was given untill participant's HR dropped to half of the age predicted HR maximum. The $VO_2$ and $VCO_2$ values measured in the last 5 min of each speed were used to assess energy expenditure, which was calculated with the formula below (17):

$$\textit{Energy expenditure } (kcal.min^{-1}) = 3.941 * VO_2 + 1.106 * VCO_2$$

Whether $VO_2$ and $VCO_2$ reached steady state during both exercise intensities at different phases of the menstrual cycle was determined from the data recorded in the last 5 min. For this, consecutive one-minute average values of each participants' $VO_2$ and $VCO_2$ in the last 5 min were calculated separately for each phase and exercise intensity. Coefficients of variation (CV) were calculated by using the [(X/SD)x100] formula with the mean and standard deviation of one-minute $VO_2$ and $VCO_2$ average values. It was assumed that the energy expenditures of participants whose CV of consecutive $VO_2$ averages were less than 10% would have reached a steady state (19). Participants with CV higher than 10% for $VO_2$ and $VCO_2$ were excluded from the assessment. All participants' CV were less than 10% for $VO_2$ and $VCO_2$ at both exercise intensities and phases.

***SenseWear armband:*** As indicated before, the SenseWear Pro3 Armband (BodyMedia Inc., Pittsburgh, PA) was also used to estimate participants' energy expenditure. After participants' personal information including age, sex, BH, BW and smoking habit was transferred from a software program (v6.1) to the device, the SWA was placed on the middle of the right arm triceps muscle. Energy expenditure was recorded concurrently together with indirect calorimetry. Energy expenditure values in $kcal.min^{-1}$ in the last five minutes were taken into consideration.

**Statistical Analyses**

After descriptive statistics of all variables were obtained, differences between participants' body composition, resting HR, and hormone concentrations (PRO and E2) measured during MP and LP were determined using the dependent samples t-test. The 2 x 2 (phase x intensity) factorial repeated measures ANOVA was used to determine the effects of phase and exercise intensity on HR and RER measured during the exercises. Similarly, the 2 x 2 x 2 (phase x method x speed) factorial repeated measures ANOVA was used to determine the effects of phase, method and speed on energy expenditure. Partial eta-square (η2) was calculated for effect size in the variance analysis, where the eta-square (η2) was classified as ≤0.01 small, ≤0.06 medium, ≤0.14 large effect (20).

Pearson's r correlation coefficient was used to examine the relationship between energy expenditures measured by IC and those estimated by SWA. The Bland-Altman method was used to determine the ±95% limits of agreement (LoA) between energy expenditures measured by IC and those estimated by SWA during both phases (21). The association between the difference and the magnitude of the measurement (i.e. trend) was examined by regression analysis. All statistical analyzes were perfomed with the SPSS program (v22.0) using a p=0.05 error level.

## RESULTS

The mean $VO_{2max}$ and $HR_{max}$ of the participants were 42.3 ml.min$^{-1}$kg$^{-1}$ and 194.3 bpm, respectively. E2 (73.2±31.2 pg-.ml$^{-1}$ for MP and 151.7±61.6 pg.ml$^{-1}$ for LP) and PRO (0.52±0.30 ng.ml$^{-1}$ for MP and 8.79±6.85 ng.ml$^{-1}$) levels were significantly higher in LP than in MP ($p<0.05$). Although BW increased significantly ($p<0.05$) in LP (63.3±10.5 kg) compared to MP (62.7±10.4 kg), this increase was less than 1%. There was no significant effect of menstrual cycle on BFP (22.3±6.5% for MP and 22.8±6.4% for LP) and FFM (48.3±5.5 kg for MP and 48.4±5.4 kg for LP) ($p>0.05$).

Running speeds corresponding to 35% and 75% $VO_{2max}$ were 5.0±0.9 km.h$^{-1}$ and 8.1±1.0 km.h$^{-1}$, respectively. The ratio of $VO_2$ measured at an average speed of 5.0 km.h$^{-1}$ in MP and LP corresponded to 34.9% and 34.7% $VO_{2max}$, respectively, and at an average speed of 8.1 km.h$^{-1}$ this ratio in MP and LP corresponded to 74.7% and 73.8% $VO_{2max}$, respectively. Physiological responses at intensities corresponding to 35% and 75% $VO_{2max}$ in both phases of the menstrual cycle are given in Figure 1. The effect of exercise intensity on HR was significant ($p<0.05$, partial $n^2=0.98$). HR values measured at 75% intensity were significantly higher than those at 35% intensity. However, the phase effect on HR, and phase x intensity interaction were not significant for HR ($p>0.05$) (Figure 1A). The effect of exercise intensity on RER was significant ($p<0.05$, partial $n^2=0.85$), whereas the phase effect was not ($p>0.05$). RER values measured at 35% exercise intensity were significantly lower than those measured at 75%. The phase x intensity interaction on RER was also non-significant ($p>0.05$) (Figure 1B).

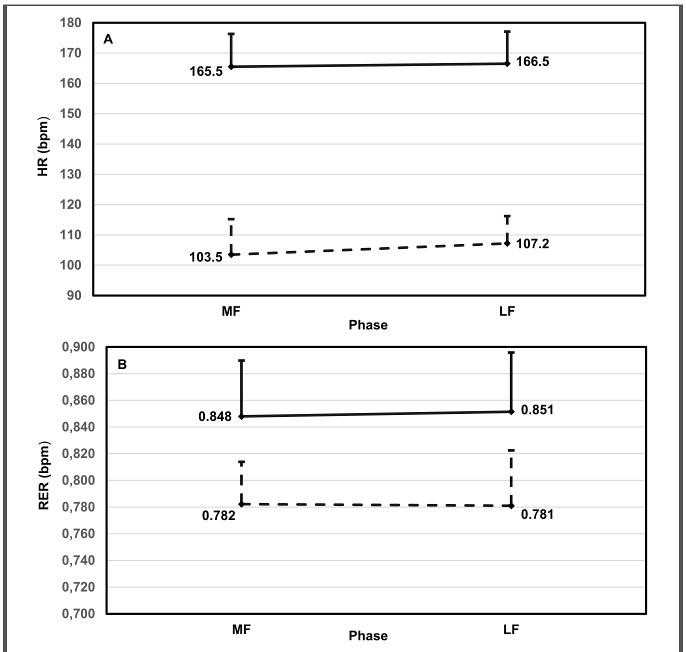


**Figure 1.** Physiological responses at 35% and 75% VO2max intensities during the menstrual cycle. A) HR, B) RER. Dashed line 35%, dark line 75% $VO_{2max}$

Table 1 presents the energy expenditure values obtained from IC and the SWA at intensities corresponding to 35% and 75% $VO_{2max}$ during menstrual cycle, and Table 2 gives the results of 2 x 2 x 2 (method x phase x intensity) Three-Factor Repeated Measures ANOVA. The effect of both methods and phases on energy expenditure was not significant (Table 2). However, the energy expenditures measured at 75% intensity were significantly higher than those measured at 35% intensity due to the increase in exercise intensity (Table 2). The interaction statistics of method x phase, phase x intensity, and method x phase x intensity were not significant, except for method x intensity that was found to be significant.

**Table 1.** Energy expenditure values obtained from IC and the SWA at 35% and 75% $VO_{2max}$ during the menstrual cycle phases

| Method | Phase | 35% $VO_{2max}$ (kcal.min$^{-1}$) | 75% $VO_{2max}$ (kcal.min$^{-1}$) |
|---|---|---|---|
| **SWA** (kcal.min$^{-1}$) | **MP** | 5.7 ± 1.2 | 8.8 ± 1.6 |
| | **LP** | 5.3 ± 1.2 | 8.8 ± 1.7 |
| **IC** (kcal.min$^{-1}$) | **MP** | 4.2 ± 1.1 | 9.5 ± 1.7 |
| | **LP** | 4.3 ± 1.0 | 9.6 ± 1.3 |

IC: indirect calorimetry, MP: mid-follicular phase, LP: luteal phase

**Table 2.** Repeated measures ANOVA in 2x2x2 (method x phase x intensity) for energy expenditure as from IC and SWA during MP and LP of the menstrual cycle

| Independent variables | F | p | Partial $\eta^2$ |
|---|---|---|---|
| **Method** | 0.96 | 0.341 | 0.06 |
| **Phase** | 0.15 | 0.706 | 0.01 |
| **Intensity** | 336.0 | **0.000** | **0.96** |
| **Method x phase** | 1.80 | 0.199 | 0.10 |
| **Method x intensity** | 40.7 | **0.000** | **0.72** |
| **Phase x intensity** | 0.93 | 0.350 | 0.06 |
| **Method x phase x intensity** | 1.75 | 0.204 | 1.10 |

There was no significant correlation between energy expenditure measured by IC and that estimated by the SWA at both intensities during MP (r=0.38 for 35% $VO_{2max}$,, r=0.15 for 75% $VO_{2max}$, p>0.05). However, the correlation between energy expenditures measured by IC and that estimated by the SWA during LP was moderate at 35% intensity (r=0.50, p<0.05) and strong at 75% intensity (r=0.75, p<0.05).

The upper and lower LoA in the mean of the differences were calculated as 1.17 and -3.93 $kcal.min^{-1}$ at 35% intensity during MP, respectively. The upper LoA for the mean of differences was 3.15 $kcal.min^{-1}$, and lower LoA was calculated as -1.65 $kcal.min^{-1}$ at 75% intensity at the same phase. During LP, the upper and lower LoA for the mean of differences at 35% intensity were calculated as 1.21 and -3.25 kcal.-$min^{-1}$, respectively. At the same phase, the upper and lower LoA for the mean of differences at 75% intensity were calculated as 2.88 and -1.31 $kcal.min^{-1}$, respectively. No significant correlation was found between the mean energy expenditure values of both methods and the differences in these methods during the menstrual cycle (r=-0.089, p=0.709 for MP, 35%; r=-0.113, p=0.635 for MP, 75%; r=-0.239, p=0.310 for LP, 35%; r=-0.352, p=0.128 for LP, 75%).

## DISCUSSION

The study examined the validity of the SWA in assessing energy expenditure at two different exercise intensities during different phases of the menstrual cycle. The main finding of this study suggests that the SWA is a valid method in estimating energy expenditure at two different exercise intensities during MP and LP. In addition study results also revealed that the phase effect of menstrual cycle on energy expenditure during low and high exercise intensities was not significant.

No statistically significant differences were found between the participants' body composition measured in both phases of the menstrual cycle, which was similar to those of previous studies. The study also revealed no significant differences between the participants' resting HR measured in both phases of the menstrual cycle, which is also consistent with the results of previous studies (15,22).

Although HR, RER and energy expenditure measured during both phases were similar, the increases in these parameters were significant as a result of increased exercise intensity, but the interaction of phase x intensity was not significant. These results suggest that exercise metabolism and energy expenditure did not change in different phases of the menstrual cycle, and that the increases in HR, RER and energy expenditure were similar in both phases due to the increase in exercise intensity. In addition, non-significant phase x intensity interaction for RER indicates that the increase in the utilization of CHO in energy metabolism due to the increase in speed is independent from the phases of the menstrual cycle.

The repeated measures ANOVA results revealed that the method effect on energy expenditure during different phases of the menstrual cycle was not significant. In addition, the non-significant statistics of method x phase interaction suggests that the change in energy expenditure due to menstrual phases was similar between the methods; whereas significant method x intensity interaction displays that the change in energy expenditure due to the increase in exercise intensity was different among methods. Drenowatz and Eisenmann (5) have reported that when exercise intensity reached 10 METs, SWA revealed a plateau in measuring energy expenditure, and at exercise intensities above 10 METs, it estimated the energy expenditure lower than 10 METs. In the present study, energy expenditure in both phases was lower than 9.0 METs, which was lower than the plateau value for SWA. The fact that compared to IC, the SWA correctly estimated energy consumption around an intensity of 10 METs (65% $VO_{2max}$), but underestimated at intensities exceeding 10 METs suggests that SWA can be used to measure energy expenditure at low-to-medium exercise intensities, but significantly underestimates the expenditure at higher intensities (5).

Likewise, in another study in both genders, it was determined that compared with IC, SWA significantly underestimated energy expenditure at an increasing exercise intensity on cycle ergometer (23). In contrast to this study, another study conducted with obese individuals reported that compared to IC, SWA significantly overestimated participants' energy expenditures during 5-minute cycling exercise (3).

When the results of studies conducted with many different populations on the validity of the SWA are compared with those of the studies using criterion methods (DLW or IC), SWA was observed to overestimate energy expenditures at low exercise intensities, and underestimate at high exercise intensities (4,6) during both endurance (6,8) and strength exercises (11). In the present study, although statistical significance was not reached, energy expenditure estimated by SWA at 35% $VO_{2max}$ in both phases were higher than those measured by IC, whereas the energy expenditure estimated by SWA at 75% $VO_{2max}$ were lower than IC (Table 1).

Although energy expenditure values estimated by SWA were within the LoA (± 2 SD), the range of the upper and lower LoA in low exercise intensity in both phases was higher than in high intensity exercise. Considering energy expenditure individually, this result suggested a high agreement between IC and SWA at high exercise intensities. However, the non-significant relationship between the differences of energy expenditures as measured by IC and those estimated by SWA at both intensities in both phases, and the mean energy expenditure values of two methods suggested that the mean bias of energy expenditure values estimated by SWA in both phases was constant, so did not depend on the magnitude of the measured value (i.e. no heteroscedasticity). In the present study, the mean of differences between methods regarding energy expenditure measured at both intensities in both phases, and the ranges of lower and upper LoA were smaller than the values obtained in a previous similar study (4), and higher than those obtained in studies on rowing ergometer exercise performed by overweight and obese men and women at 50% and 70% $VO_{2max}$ (10).

The correlation coefficients obtained in menstrual phases were different in the two methods. In contrast to the MP, there was a significant moderate positive correlation between the two methods in the LP. The relationships between energy expenditure values measured by IC and by SWA at different exercise modalities such as treadmill, cycle and arm/rowing ergometers varied widely in previous studies. Papazoglou et al. (3) found non-significant correlation between the energy expenditure of obese individuals measured by IC and those estimated by SWA during treadmill walking, cycling ergometer exercise, and stepping workout. However, several studies revealed moderate and high positive correlations (r=0.39 and r=0.90) between the energy expenditure values of men and women measured by the methods in different exercise modalities (2,4,5,7,8,10,23).

## CONCLUSION

Energy expenditures estimated by SWA at both high and low exercise intensities during the menstrual cycle were found to be similar with IC. However, as shown in previous studies, the energy expenditure estimated by SWA was higher at low exercise intensities and lower at higher intensities. In addition, the fact that the mean bias (i.e. the differences between IC and SWA) measured at both intensities during both phases was very low, and that the bias did not change depending on the magnitude of the measurement (i.e. no heteroscedasticity) suggested that SWA is a valid tool for estimating energy expenditure during the menstrual cycle.

***Ethics Committee Approval / Etik Komite Onayı***

The study was approved by the Non-Interventional Clinical Research of Hacettepe University Ethics Board (Approval Number : GO 15/522-17)

***Conflict of Interest / Çıkar Çatışması***

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

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***Author Contributions / Yazar Katkıları***

Concept – TH, AKİ; Design - TH, FY, AKİ; Supervison – AKİ, TH; Materials – TH, FY, MGK; Data Collecton and/or Processing – FY, MGK; Analysis and Interpretation – TH, FY; Literature Review – TH, FY ; Writing Manuscript - TH, FY; Critcal Reviews - AKİ, MGK

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