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THERMOPHYSIOLOGIAL COMFORT PROPERTIES OF DIFFERENT CLOTHES AFTER AN ACTIVITY PERIOD

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Abstract: In this study five different knitted sport clothes were tested in a wear trial test with ten men subject. After the activity, subjects were included in a rest period of 20 minutes. In this period, microclimate temperature and relative humidity values were measured with a datalogger from four body regions (chest, abdomen, back and waist). The results showed that the lowest waist microclimate temperature value was seen in TS tencel single jersey fabric like the other three body regions. On the contrary to chest and back regions, the abdomen microclimate temperature values increase during the relaxing period. Also the lowest microclimate temperature values were seen in abdomen region. On the other hand the highest microclimate relative humidity values were seen in abdomen region (93-96 %).

Keywords: Clothing Comfort, Microclimate Temperature, Mikroclimate Relative Humidity, Maximum Oxygen Uptake, Heart Rate

Bir Aktivite Periyodu Sonrası Farklı Giysilerin Termofizyolojik Konfor Özellikleri

Öz: Bu çalışmada beş farklı spor giysi belirli bir antreman programında 10 erkek deneğe giydirilmiş ve aktivite sonrasındaki 20 dakikalık dinlenme periyodunda 4 farklı vücut bölümünün (göğüs, karın, sırt ve bel) mikroklima sıcaklık ve bağıl nem değerlerinin ortalamaları verilmiştir. Ayrıca dinlenme periyodu boyunca nabız ve maksimum oksijen tüketimi değerleri nabız ölçer polar saat ve kardiyo solunum fonksiyonları ölçüm cihazı kullanılarak ölçülmüştür. Sonuç olarak en düşük mikroklima sıcaklık değeri diğer üç bölgede olduğu gibi bel bölgesinde de TS kodlu tencel süprem kumaş numunesinde görülmüştür. Göğüs ve sırt bölgelerinden farklı olarak karın mikroklima sıcaklık değerlerinin dinlenme periyodu boyunca arttığı görülmüştür. Ayrıca en düşük mikroklima sıcaklık değerleri karın bölgesinde görülmüştür. Diğer yandan en yüksek mikroklima bağıl nem değerleri karın bölgesinde görülmüştür (%93-96).

Anahtar Kelimeler: Giysi Konforu, Mikroklima Sıcaklık, Mikroklima Bağıl Nem, Maksimum Oksijen Tüketimi, Nabız

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1. INTRODUCTION

Sport clothes effects the heat and moisture transfer during activity. So selection of appropriate sport clothes are very important. The heat and mass transfer ratios from the body especially depends on the construction of fabric, yarn type, knit type and porosity. Thermo-physiological comfort is associated with the thermal balance of the human body, which strives to maintain a constant body core temperature of about 37 °C and a rise or fall of ~ ±5 °C can be fatal (Saville, 1999). In the case of hard physical exercise or in tropical climates, the heat loss by evaporation is accompanied by sweating and the skin becomes covered with a film of water. For wearer comfort, this sweat should be transported away from the skin surface, in the form of liquid or vapour, so that the fabric touching the skin feels dry. The transport of both moisture vapour and liquid away from the body is called moisture management (Onofrei et al, 2011).

Different researchers investigated the effect of fibre, yarn and fabric properties on the thermal comfort performance of different fabrics.

Pac et al. (2001) worked about thermal comfort properties of fabrics and effects of fabric construction parameters, yarn properties and fibre morphology on thermal comfort. In this study, a new experimental device described which was used for measurements of heat absorption of textile materials in a transient state.

Ucar and Yilmaz (2004) studied about thermal resistance properties of cotton rib knitted fabrics. They found that a decrease in rib number of the order of 3×3, 2×2 or 1×1 leads to a decrease in heat loss due to an increase in the amount of air entrapped between the face and the back loop. The results also showed that reducing air permeability within the fabric heat exchange from the fabric to surrounding air will decrease because of tight structure of fabric.

Özçelik et al (2007) studied thermophysiological comfort properties of interlock knitted fabrics with air-jet textured, false-twist textured and non-textured filament PES yarns. They used Alambeta test device for the experiments. The results showed that non-textured filament yarn produced fabrics showed lower thermal resistance values than textured fabrics.

Cubric et al (2012) worked with different fabric parameters which effect heat transfer properties of porous textile structures. A group of single jersey knitted fabrics were used in the experimets and they all treated with same finishing operation. They found that thermal resistance of knitted fabric depends on thickness, weight, cover factor and porosity properties of fabric.

Afzal et al (2014) investigated thermal insulation properties of interlock knit fabrics. The results showed that fibre type is an important factor which effects thermal insulation properties of interlok fabrics. The other important factors effect the thermal insulation properties of fabrics; fabric stitch length, yarn specific heat and fabric density.

Özkan and Meriç (2015) studied about thermophysiologial comfort properties of knitted fabrics which is used for cycling clothes production. For this reason six different type of fabric were chosen from the market. Air permeability, Sweating hot plate and MMT test devices were used in the experimets. The results showed that warp knitted fabric were preferred for summer cyling clothes because of good air permeability, low thermal resistance, low water vapor resistance and good moisture management properties.

But there aren’t so much work about dynamic comfort measurements with human subjects. Some of the researhes were given in below:

Wong and Li (2004) studied about correlation coefficients of objective and subjective comfort measurement techniques. They found that for some body locations objective and subjective humidity and moisture sensation results are highly correlated. Also, time, garment, body location and their interactions influenced the physiological and psychological responses.

Purvis and Tunstall (2004) investigated effects of two different sock types on foot skin temperature of subjects. Sixteen subjects were chosen for experiments. They studied a running exercise which comprised from two session. A standard running sock were used in the first session and an ergonomic asymmetric fitted sock were used in the second session. They found that the ergonomic sock was perceived to be cooler than the standart running sock and it was preferred in the situations which subjective perceptions may be more important than objective measurements.

Brazaitis et al (2010) studied effects of different type of t- shirts on physiological and psychological thermal comfort of subjects during exercise and recovery periods. For these reason two types of t- shirt samples were produced. The first one cotton, the other one is PES knitted fabric. The results showed that PES fabric didn't improve any thermophysiological and subjective sensation response. But PES t-shirt sample change skin temperature to pre-exercise level fastly and enabled good thermal sensation. CT fabric evaporated sweat slowly than PES knitted t-shirt. They also declared that water transfer was more important than water absorption in maintaining comfortable microclimate in a garment.

Kaplan and Okur (2012) studied on thermal comfort properties of sports garments by using subjective wear trial tests. The tests were placed accordingly an activity protocol under controlled environmental conditions. They found that cheast microclimate temperature is significantly correlated with the coolness and dampness ratings. Additionally, at high activity period back microclimate relative humidity values higher than, the chest microclimate relative humidity values.

Atasagun et al. (2015) studied effects of Viloft yarn and its blends for sport clothes with subjective and objective wear trial tests. As a result, the mechanical properties of viloft yarn knitted fabrics isn't better than commercial fabrics. The thermal and water vapor resistane of Viloft/wool blended fabrics are very good but moisture management properties of these fabrics are poor. On the other hand, Viloft/Coolmax blended fabrics showed low water vapor resistance and good moisture transfer properties. In this paper, microclimate temperature and microclimate relative humidity values of five different types of knitted sport clothes were measured in dynamic conditions after an activity period. The relaxing period were seperated for four region and the results were taken per minute. As a result, performances of some selected sports garment fabrics were compared with physiological measurements during rest period of wear trial.

2. MATERIAL METHOD

2.1. Garment Properties

The properties of fabrics measured by standart methods are given in Table 1. Five kinds of short sleeve T-shirts were tailored to use in the experiments from these fabrics. All the fabrics were knitted with the same design and size. The design of t-shirts are shown in Figure 1. The weight of fabrics were measured with accured scales, average of five measurements were taken acording to TS251. The thickness measurements of the fabrics were measured according to ASTM D1777 using a James H. Heal R&B cloth thickness tester. The porosity values of fabrics were calculated according to

$$\varepsilon = 1 - \left(\frac{\pi d^2 l C W}{2t}\right)$$

where t is sample thickness (cm), l is loop length (cm), d is yarn diameter (cm), C is the number of courses per cm and W is the number of wales per cm (Yanılmaz and Kalaoğlu, 2012).

Table 1. The properties of fabrics used in the experiment

Fabric Code	Composition(%) and Yarn Count	Knit Type	Weight (g/m^2)	Thickness (mm)	Porosity (%)
CS	100% Cotton 30/1 Ne	Single Jersey	150	0.61	92.3
CPS	50-50% Cotton/Polyester 30/1 Ne	Single Jersey	148	0.57	92.7
POS	91% Textured Polyester 9% Spandex 100/108 Denier Textured Polyester, 20 Denier Spandex	Single Jersey	135	0.48	91.4
PM	98% Textured Polyester %2 Polyester Trilobal 220/360 Denier textured polyester, 20 Denier Polyester Trilobal	Mesh	146	0.62	93
TS	100% Tencel 30/1 Ne	Single Jersey	145	0.52	92.8

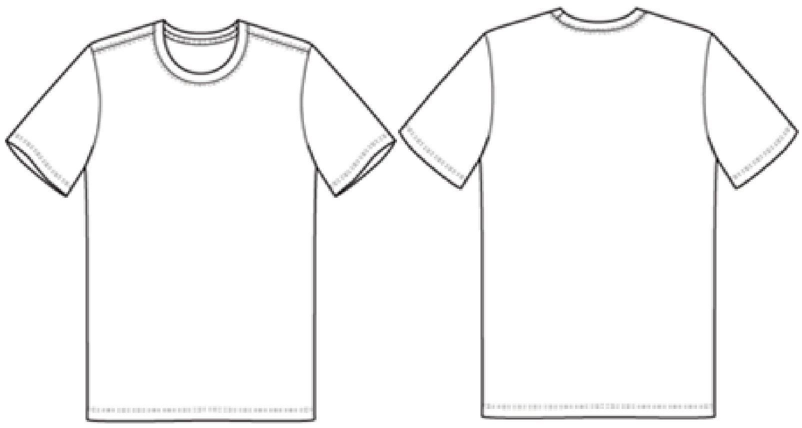

Figure 1:
The design of T-shirts

2.2. Subjects

Ten healthy athletes (Age: 21±3 yrs, Height: 180,3±5cm, Body weight: 70±5 kg) from Uludag University Sports Science Faculty were chosen to perform the wear trials. All subjects were healthy and nonsmoking, with no history of cardiopulmonary disease. Each subject read and signed a written informed consent of Declaration of Helsinki prior to participation in the wear trials. Uludag University Ethics Committee approved this study.

2.3. Activity Protocol

Each subject performed this submaximal exercise 5 times in total with 4-7 days intervals with 4 different test clothes and a control garment at 27 C° temperature and 45% relative humidiy atmosphere conditions. CS coded t-shirt made from cotton single jersey fabric was chosen as a control garment. At the beginning of the test, the subjects put the T-shirts and rested 10 minutes in laboratory conditions to adapt themselves to the experimental environment and during this period subjective termal sensation, garment wetness sensation and subjective comfort sensation were recorded. And than the subjects performed a wear trial protocol which comprised of 50 min exercise and then 20 min relaxation period. A datalogger (Almemo, Germany) used in the experiments to measure microclimate temperature and relative humidity from four different body locations (chest, back, abdomen and waist) during all exercise protocol. After 50 min exercise program, the speed decreased to 5 km/ h and after running 5 km/h for 5 minutes relaxation period started for 15 minutes. During the relaxation period, all the measurements were recorded continuously while the subject sitted on the chair.

3. RESULTS & DISCUSSION

3.1. Microclimate Temperature and Relative Humidity

The formation of moisture in the microclimate region between the skin and the garment gives a sense of moisture and stickiness (Ciesielska and Masajtis, 2008). The sports activities cause sweating which irritates the person during the rest period following the sports activities. The wear trial protocol includes a 50-minute training program followed by 5 min slow walk at a 5 min / h speed and 15 minutes sitting on a chair. The rest period is divided into 4 equal time sections and named as 5km/h slow running section and P1, P2 and P3 sitting on a chair.

During relaxing period microclimate temperature values change and relative humidity values change measurements for four body region were made with a datagogger. In Figure 2, chest microclimate temperature and relative humidity values were given.

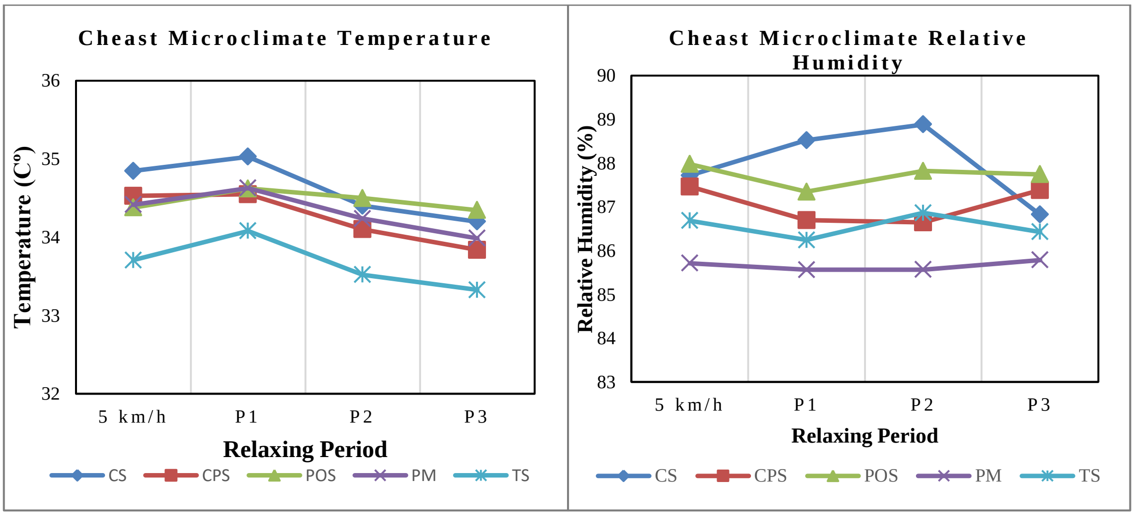

Figure 2:
Temperature and relative humidity change in cheast region after an activity period

The chest microclimate temperature values changes between 33-35 °C degree. The lowest cheast microclimate temperature was seen in the lowest thikness value TS tencel single jersey knitted fabric between 33-34 °C degree region. The CS coded cotton single jersey fabric was showed the highest microclimate temperature values during the relaxing period (34,5-35 °C).

This supports previous studies, sorption heat of cotton fabric causes sensible temperature increase affecting both skin surface and microclimate temperatures (Ha et al., 1999; Kaplan and Okur 2012). Also, while the temperature values rise in the P1 test period, the relative humidity values in the same range decrease. Sullivan ve Mecjavik (1992) declared that the moisture accumulated in the fabric increases the temperature of the garment before it evaporates. An increase in relative humidity was observed in the P2 time period when the temperatures decreased.

The chest microclimate relative humidity values changes between %85-89. The lowest cheast microclimate relative humidity value was seen in PM coded polyester mesh knitted fabric. Because of knit structure and porosity value of this fabric, air circulation into the microclimate is higher than the other fabrics which causes lower microclimate relative humidty values. On the other hand, the highest chest relative humidity values was seen in the highest weight value CS coded cotton single jersey fabric in P1 and P2 periods. Although the lowest thickness and weight values, POS polyester single jersey fabric were showed the highest temperature and relative humidity values in P3 period due to yarn type.

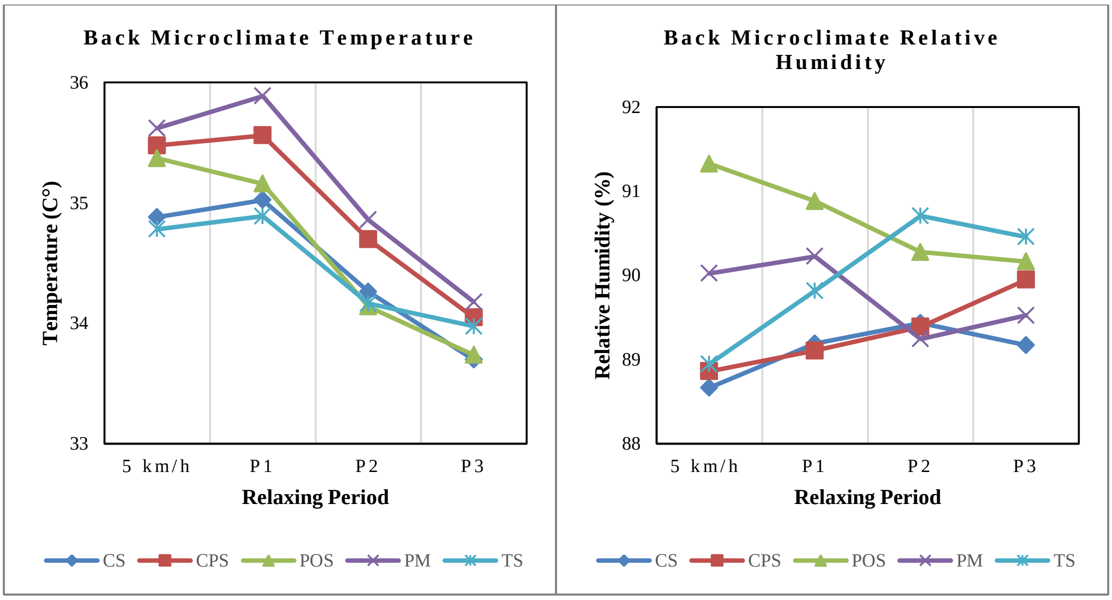

Figure 3:

Temperature and relative humidity change in back region after an activity period

Back microclimate temperature and relative humidity values were given in Figure 3. Back microclimate temperatures were measured higher than the chest microclimate temperature values (34-36 °C). As an expected, chest temperature values sharply decreased after P1 relaxing period. The lowest temperature values were measured in CS cotton and TS tencel knitted fabrics in the slow walking period (5 km / h speed). The lowest temperature values were seen in CS and POS coded fabrics at the end of the rest period (P3). Although PM coded fabric has mesh structure, it was measured higher than other garments in back region. This is most probably due to thickness of fabric. The relative humidity values of back region have changed in a narrow range (89- 91%).

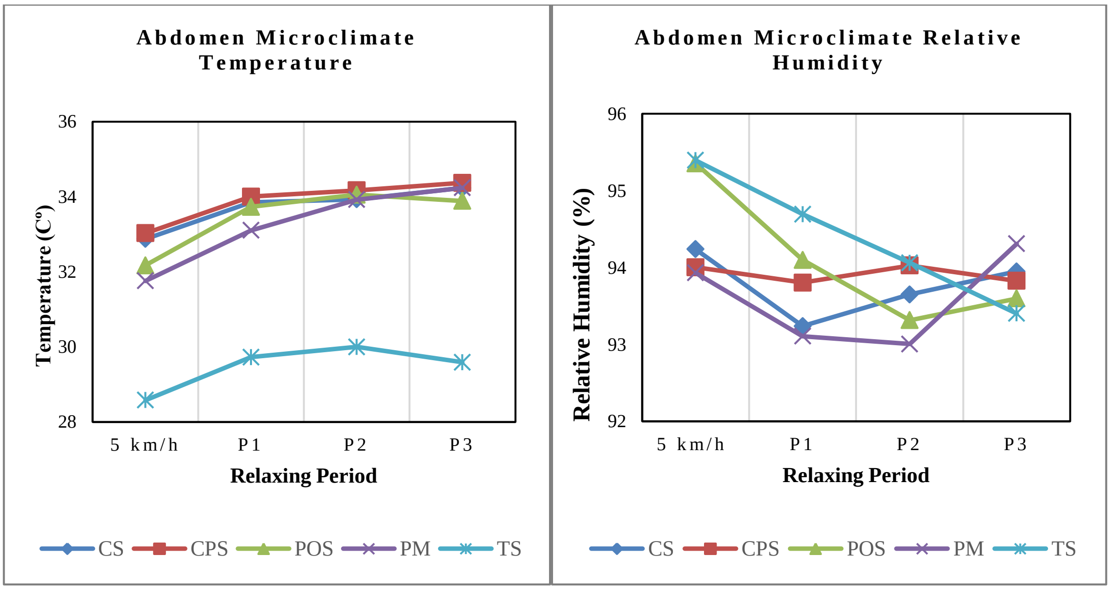

Figure 4:
Temperature and relative humidity change in abdomen region after an activity period

Abdomen microclimate temperature and relative humidity values were given in Figure 4. The lowest abdomen microclimate temperature was seen in TS tencel single jersey fabric because of yarn type and thickness of this fabric. The other test clothes were measured 32-34 °C temperature values during the relaxing period. On the contrary to cheast and back regions, the abdomen microclimate temperature values increase during the relaxing period. Also the lowest microclimate temperature values were seen in abdomen region. On the other hand, the highest microclimate relative humidity values were seen in abdomen region (93-96 %).

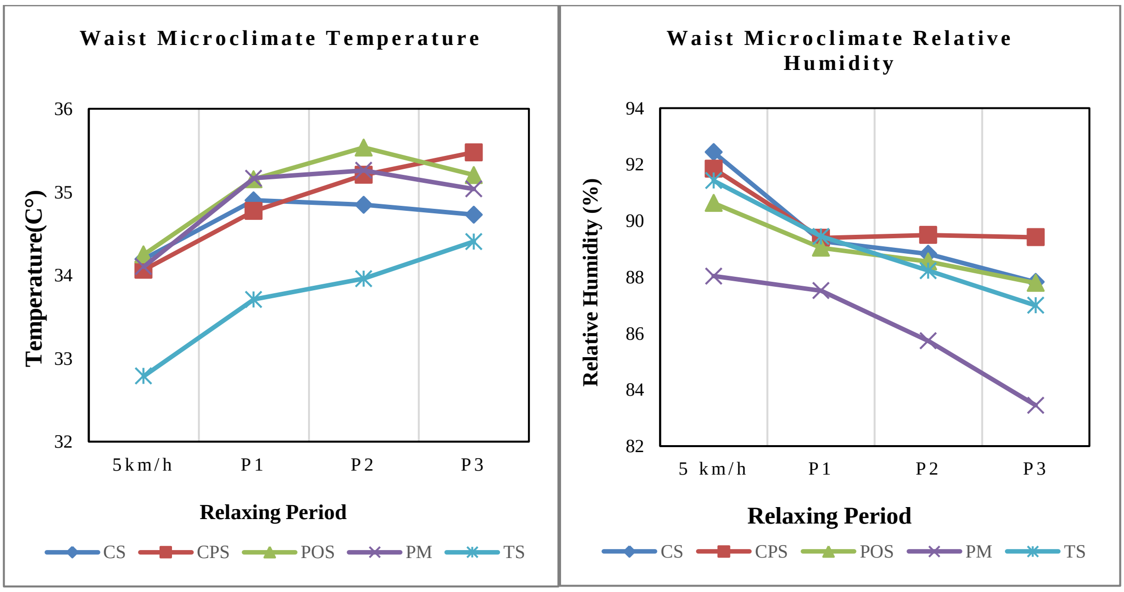

Figure 5:
Temperature and relative humidity change in waist region after an activity period

Waist microclimate temperature and relative humidity values were given in Figure 5. Like abdomen region, the waist microclimate temperature values increased during the relaxing period. Waist microclimate temperature were changed between 34-36 °C except TS coded single jersey fabric. The lowest waist microclimate temperature value was seen in TS tencel single jersey fabric like the other three body region. Because of thickness and yarn type of this fabric. On the other hand, the lowest waist relative humidity values were seen in PM coded polyester mesh knitted fabric. This is most probably due to highest porosity value of this fabric.

3.2. Maximum Oxygen Uptake and Heart Rate

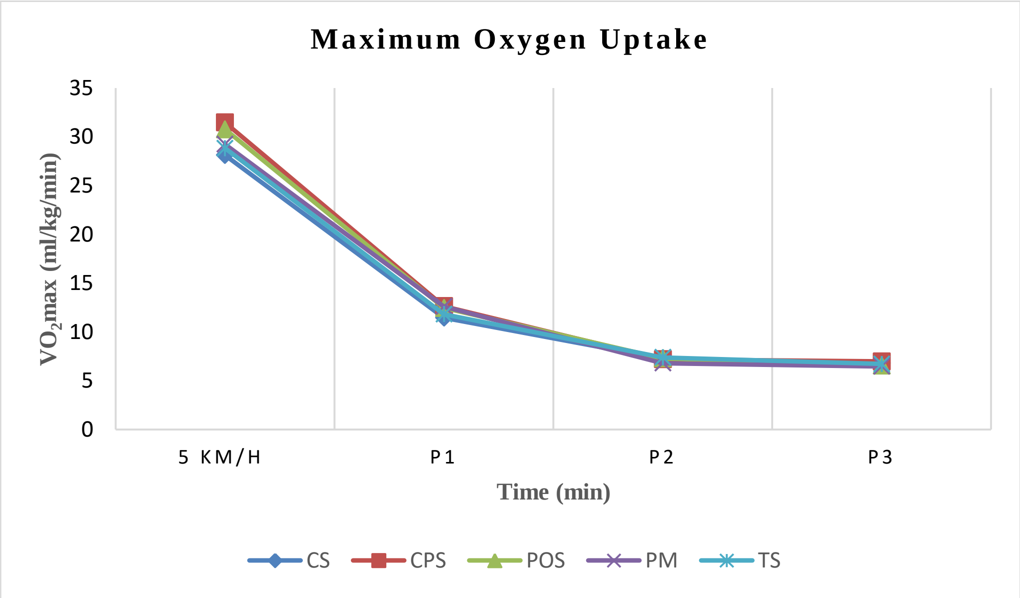

Figure 6:
Comparison of VO_2max values of subjects with speed after activity period

The maximum oxygen uptake (VO_2max) is defined as the amount of oxygen that a person can use per unit of time which means that the higher this value, the higher the aerobic capacity of the person. Maximum oxygen uptake change of five different type of test garments were given in Figure 6. At the beginning of relaxing period maximum oxygen uptake values of fabrics between 28-32 ml/kg/min. Maximum oxygen uptake values of garments decreased sharply between 5 km/h slow walking and P1 periods. On the other hand, the maximum oxygen consumption curve remained constant between P2 and P3 periods.

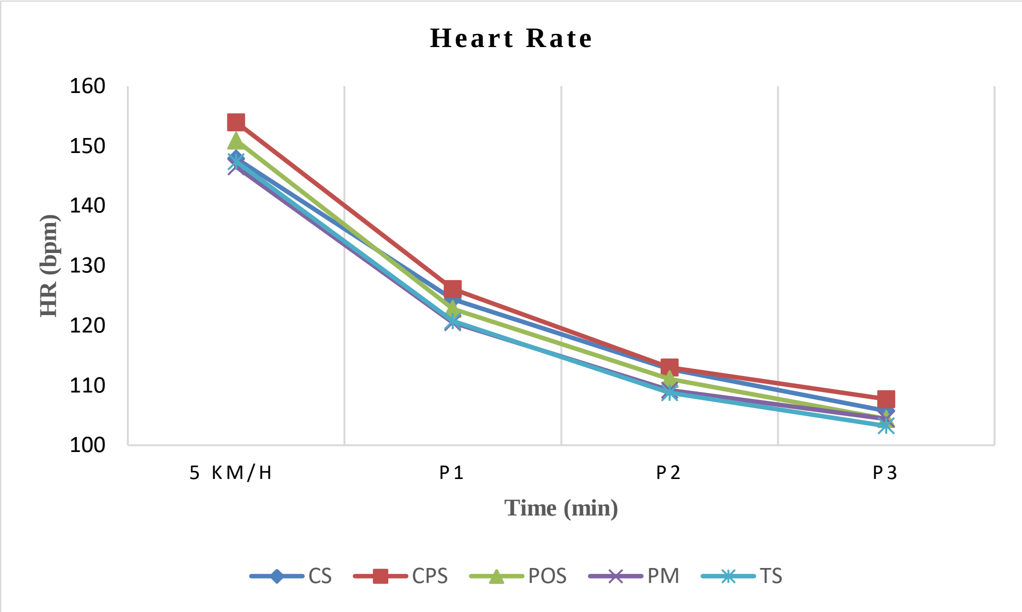

Figure 7:
Comparison of heart rates of subjects with speed after activity period

Heart rate change of five different type of test garments were given in Figure 7. The heart rate values of garments were measured similar to each other. Heart rate of garments were changed between the 100-150 bpm during the relaxing period. Heart rate values of garments dereased sharply between 5 km/h slow walking and P1 periods and continue to decrease the other relaxing periods(P2 and P3).

4. CONCLUSIONS

In this paper, microclimate temperature and microclimate relative humidity values of five different type of sport clothes were measured in dynamic conditions after an activity period. In the beginning of resting period (5 km/h and P1 region) the back microclimate temperature values higher than chest microclimate temperature values. This supports previous studies, back microclimate temperatures are higher than the chest microclimate temperatures throughout the activity (Nielsen and Endrusick,1990). On the contrary to chest and back regions, the abdomen microclimate temperature values increase during the relaxing period. Also the lowest microclimate temperature values were seen in abdomen region. On the other hand the highest microlimate relative humidity values were seen in abdomen region (93-96 %).

Brazaitis et all. (2010) investigated investigated the effect of two kinds of t-shirts (cotton and polyester) on physiological and psychological thermal response during exercise and recovery periods. They found that PES t-shirt enabled a faster return of skin temperature to pre-exercise level. In this work, Tencel knitted fabric were showed the lowest microclimate temperature values almost all body regions in resting period.

The lowest chest microclimate temperature was seen in TS tencel single jersey knitted fabric between 33-34 °C degree region. The remarkable point here is that while the temperatures rise in the P1 test period, the relative humidity in the same range decreases. The chest microclimate relative humidity values changes between %85-89. The lowest chest microclimate relative humidity value were seen in PM coded polyester mesh knitted fabric. This is most probably due to mesh structure and porosity value of this fabric. The lowest abdomen microclimate temperature was seen in TS tencel single jersey fabric between 28-30 °C degree region. The lowest waist microclimate temperature value was seen in TS tencel single jersey fabric like the other three body region. On the other hand, the lowest waist relative humidity values were seen in PM coded polyester mesh knitted fabric.

As a result, TS coded tencel single jersey knitted fabric were measured the lowest microclimate temperature values almost all body loations because of thickness and yarn type of this fabric. PM coded polyester mesh knitted fabric were measured the lowest relative humidity values (except back region) because of mesh structure and porosity value of this fabric. Also, the heart rate values of garments were measured similar to each other.

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