ARTICLE

Physiological Responses during Moderate Exercise in Thermo-neutral and Hot Environment for Normal Weight

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Abstract
Background: Recent research has shown that climatic stress has the ability to cause changes in exercise performance. The purpose of this study was to investigate whether the current exercise prescription guidelines remain appropriate or should be modified, given rise of summer temperatures in the United Kingdom, and to what effect the prescription guidelines had on individuals with different body weights. **Subjects and Methods:** Twenty healthy normal weight adult males with a body mass index (BMI) 23±1.9, and waist to hip ratio (WHR) 0.89±0.04, age 24±1.4 year were randomly assigned to either cycling for 30 min in a climate chamber at either at 18ºC (thermo-neutral) or 30ºC (hot environment) (T18, T30), with 24-h between trials. The third trial was performed at 30ºC with an adjusted workload (T30a) to determine whether workload adjustment was necessary in order to reduce HR to approximately that of T18 levels 24-h after the second trial. Heart rate (HR), RPE, VO_2, CHO and fat utilization; energy expenditure in calorie KCAL ($kcal.min^{-1}$) and RER were determined**. Results**: HR at T30 was significantly higher than the HR at T18 and at T30a. Carbohydrate (CHO) and fat utilization; energy expenditure in calorie KCAL ($kcal.min^{-1}$) and Respiratory Exchange Ration (RER) HR at T30a dropped to a level close to the HR level of T18. No statistical differences were found for KCAL, VO_2, RER, CHO and fat between the three trials. **Conclusion**: Exercising moderately for 30min in a hot environment of 30ºC, compared to 18ºC, raises the HR and the RPE for normal weight men. Adjusting workload is not required to reduce HR whilst exercising moderately in 30ºC.

Keywords: Hot Temperature, Thermo-neutral, Moderate Intensity, Physical Activity, Energy Expenditure.

Introduction
Several professional recommendations suggest that healthy adults should undertake at least 30 minutes of moderate

exercise five times a week to improve and maintain good health (1,2). These recommendations are also valuable for weight management in the obese (3). Suggested exercise include moderate intensity aerobic physical activity (such as brisk walking) at a perceived exertion rate (RPE) of 11 to 14 on the Borg scale for any activity that burns 3.5 to 7 calories per minute (kcal/min) or vigorous intensity aerobic physical activity that burns more than7 kcal/min for a minimum of 20 min three days a week (4). At least five episodes per week of moderate activity lasting 30 min is recommended by the chief medical officer of England (5).

The weather and seasonal change influence the overall levels of fitness, activity and physiological responses to exercise. Plasqui et al. highlighted that the shorter days during the winter months, with significantly colder temperatures, should also be considered (6). This was noted to result in a decrease of physical fitness (7). Climate change and global warming has resulted in exposure to increased temperatures for many parts of the world. Climate change has already begun to have an impact in some European regions such as the UK in the form of heat waves over the summer months which are the most popular times for exercise (8).

This study investigated the physiological responses to exercising moderately for 30 minutes in a thermo-neutral summer temperature in Edinburgh for normal weight adult men. It was hypothesized that normal weight exercising at moderate intensity for 30min at 30ºC would significantly increase heart rates (HR) and body fuel utilization, expressed as energy expenditure in calorie KCAL (kcal. min^{-1}) and percentage of fat (%) to carbohydrate (CHO) used, when compared to exercising in the thermo-neutral environment.

Subjects and Methods

Participants

Twenty, healthy normal weight adult males with normal body mass index and waist-hip ratio were included (Table 1). Their mean (SD) age 24±1.4 years. They were regularly exercising but not undergoing any specific training program. None of the participants were acclimatized to heat. The participants were familiarized with the experimental procedures and associated risks by visiting the laboratory and the chamber room. The University of Edinburgh Ethics Committee approved the study. All volunteers gave informed written consent and completed a medical questionnaire prior to commencement of the study.

Experimental trials

Each participant performed three experimental trials, over three different visits and each separated by 24 hours. They were randomly assigned to either 18ºC or 30ºC trials (T18, T30) while the third trial was performed at 30ºC with an adjusted workload (T30a). These three trials consisted of 30 minutes cycling at a constant workload at 60rpm. The T30a trial was conducted at 30ºC, with workload adjustment. The rationale of this trial T30a was to determine whether workload adjustment was necessary in order to reduce HR to approximately that of T18 levels. And, if so, how much of a reduction was necessary, with the adjustments being monitored from the first 2 minutes. If the HR increased by 6 bpm above its T30 level, the load was reduced by 0.1 kg in order to maintain T30 HR values at 2 min intervals throughout the 30 min trial. All trials were conducted at the same time of the day to control for circadian variation in physiological and metabolic factors. Participants wore only shorts, t-shirt, a pair of socks and running shoes; identical clothing was worn for each cycling trial. The participants were not allowed to consume fluid at any time during the trials.

Pre-testing

Participants were requested to refrain from moderate and/or vigorous/heavy physical activity, such cycling or going to the gym, for at least 24hr before each trial. They were also requested to refrain from consuming food any later than 12hr before commencement of the trials. Before the experimental trials started, all participants completed pre-test assessments to determine exercise intensity relative to 60% of maximum heart rate (MHR). HR_{max} is estimated by using the age-adjusted formula, in which the age-predicted HR_{max} equation is 220 – age (9). They cycled (Monark 814) for 15 mins, initially for 5 mins at 60 rpm, and after 5mins a load of 1kg was added, with a further increment at 10 min. The incremental power of cycling was determined in watt (W) as 60W, 120W and 180W. HR was monitored continuously throughout the 15 min pre-test and recorded three times at 5-minute intervals. HR behavior was modeled as a function of the workload by using linear regression to predict the required workload corresponding to 60% of MHR. Before recording their body mass, participants were asked to urinate if necessary. Dry nude body mass (kg) and height (cm), without shoes, was measured using a freestanding adjustable measuring device (Seca Stadiometer). BMI was calculated from measured height and weight [body mass (kg)/height (m^2)]. Waist circumference was measured midway between the lower rib margin and the iliac crest in the horizontal plane.

Table 1. The average and standard deviation of participants' age, height, body mass index (BMI) and Waist-to-hip ratio (WHR) in the two groups.

Variable	n=20
Age (year)	24 (1.4)
Height (cm)	168.0 (50.4)
Weight (kg)	80.0 (7.7)
BMI (kg/m^2)	23.0 (1.9)
WHR	0.89 (0.04)

Table 2. Significance levels for the repeated measures ANOVA tests

	Heart Rate	RPE	RER	KCAL	CHO	FAT	VO_2
Overall	0.000*	0.001*	0.738	0.190	0.772	0.772	0.297
18C/30C	0.002*	0.019*	1.000	0.278	1.000	1.000	0.631
18C/30Ca	1.000	0.366	0.708	0.381	1.000	1.000	0.169
30C/30Ca	0.003*	0.021*	1.000	1.000	1.000	1.000	1.000

* Differences significant at the level of 5%

Table 3. Multiple Comparison test showed the significance levels for the repeated measures ANOVA tests for the HR and RPE in G1.

	HR	RPE
T18/T30	0.000*	0.015*
T18/T30a	0.282	1.000
T30/T30a	0.002*	0.013*

*HR and RPE significant differences ($p< 0.05$) in the three trials.

Table 4. The mean, standard deviation ($\mu \pm \sigma$) and p-value for VO2, RER, CHO, FAT and KCAL.

Verbal's	T18	T30	T30a	F-value	p-value
VO2 (l.min-1)	1.7 ± 0.5	1.6 ± 0.6	1.5± 0.4	230.2	0.060
RER (CO2/%O2)	0.9 ± 0.06	0.9 ± 0.07	0.9 ± 0.06	0.089	0.915
CHO (% kcal)	74.6 ± 19.7	72.8± 19.0	73.2 ± 22.2	0.093	0.962
FAT (% kcal)	25.4 ± 19.7	28.9 ± 20.2	26.8± 22.2	0.129	0.879
KCAL (kcal.min-1)	8.3 ± 2.3	7.6 ± 2.6	7.2 ± 2.3	245.2	0.093

While the participant was standing, hip circumference was measured at the point yielding the maximum circumference over the buttocks using a tape measure to measure to the nearest 0.1 cm. Waist to hip ratio (WHR) was calculated by dividing waist and hip (cm), with all measurements were taken by a researcher experienced in anthropometric measurement.

Exercise

Twenty-four hours after the pretesting time, participants cycled in constant workload at 60rpm on cycle ergometer for a 30min at a load reflecting 60% of predicted MHR. The HR was measured continuously and recorded at 5minute intervals during each session (PE 4000, Polar, Finland). Expired air was collected during the 10^{th}, 20^{th} and the 30^{th} min within the 30 min bout, and the Douglas bags were immediately analyzed to determine oxygen and carbon dioxide concentrations (Servomex Systech ZR89314, Systech Instruments, UK). All gas volumes were corrected based on standard temperature using a Harvard Dry Gas Meter (Cranlea, Birmingham). This measurement used to calculate the energy expenditure value, which includes oxygen consumption (VO_2), respiratory exchange ratio (RER), and the percentage of fat and carbohydrate used. The energy expenditure (KCAL) was used to determine the energy value for each trial expressed as kcal. min^{-1} (kcal. min^{-1}=l. min^{-1} × caloric equivalent per liter O_2 at the given respiratory quotient rate).

Statistical analysis

A multivariate repeated MANOVA was conducted with the three different measures as the within subjects factor. The multivariate tests of within-subjects effects were significant, Wilk's L = .199, F (12, 38) = 3.93, $p < .01$, $h^2 = .55$. Follow-up univariate tests, however, found that only the differences in RPE (F (2, 24) = 9.18, $p < .01$, $h^2 = .43$) and HR were significantly different for the three trials. For RPE, significant differences were found between 18C and 30ºC as well as between 18ºC and 30ºC (both $p < .05$). In terms of heart rate, significant differences were found between 18ºC and 30ºC and between 30ºC and 30ºC (both p < .05). There was no difference found between trials for kcal energy expenditure (both per minute and kcal/kg i.e. weight relative), CHO and fat utilization, and VO_2.

Results

The workload adjustment at the T30a trails was 0.1=6 W/kg and the body weight was only 0.36±0.19 kg below the pre-exercise weight between the three trials. After performing repeated measures ANOVA revealed significant differences between the average HR across the three trials (*F*-value: 227.78, *p*-value: 0.001) where the mean of HR at T30 is significantly higher than the mean of HR at T18 and at T30a. The HR increased rapidly from T18 to T30. It can be seen that from T30 to T30a, the HR dropped to the level in close proximity to the HR level of T18. Table 2 illustrates the significance level for the study variables.

A considerable increase variation in the RPE of mean (12%) was observed from T18 to the T30 compared to a smaller increase variation of mean (just 2%) from T18 to T30a. The observed mean differences in RPE were increased by ratio 1.2 and 0.3 for T18–T30 and T18-T30a respectively. The 95% confidence intervals obtained for the mean differences for T30-T18 and T30a-T18 were 0.89±0.28 and 0.16±0.19 respectively. As expected, the ANOVA test shows that there were significant differences between the means (*F*-value: 1445.63, *p*-value: 0.001) and Bonferoni test and shows the mean of RPE at T30 is significantly higher than at T18 and T30a in Table (3)

On the amount of KCAL (Table 3) this study observed a decrease of 1.1 and 1.3 kcal.m^{-1} from T18 to T30 and to T30a, with 14.0 % and 15.0 %, respectively. By using ANOVA, at the level of significance of 5%, this study concludes that there are no significant differences between all temperatures table (4). The RPE scales are consistent with the HR. However, for CHO and FAT, it was observed a small decrease of usage from T18 to T30 and to T30a. The mean differences for CHO were 1.3 and 5.8 %kcal with percentage decreases of 2 and 7% respectively and percentage decreases of FAT were 6 and 28%kcal. The lowest level of usage of CHO, and thus the highest of FAT, was observed at T30a. Although, the ANOVA analysis allow this study to conclude that these differences are not significant.

The usage of the CHO increased from T18 to T30 and to T30a and represented by mean differences of increases 8.7 and 3.5%kcal respectively and percentage decreases of FAT were 6 and 28%kcal. The lowest level of usage of FAT, and thus the highest of CHO, was observed at T30a. Although, the ANOVA analysis allow us to conclude that these differences are not significant. The levels of RER remained stable from T18 to T30 and even from T18 to T30a. According to the ANOVA tests these differences between the means of RER for the different tests are not significant. On the amount of VO_2, no difference between the three trails was observed and the value decreased constantly by 0.2l.min^{-1} from T18 to T30 and to T30a. The VO_2 decreased from T18 to T30. In terms of the amount of VO_2, small reductions of 12% and 18% were observed, from T18 to T30 and from T18 to T30a. However, the VO_2 volume of oxygen was decrease from T18 to T30, but from T30 to T30a, the volume of oxygen is decreased (F-value: 1.791, p-value: 0.203).

Discussion

Exercise duration and intensity are the main components in any exercise or training program. Obese individuals should exercise at low to moderate intensity to oxidize high fat during the active period. This idea is based on two assumptions (1) that fat oxidation is higher with low-intensity activities than with high-intensity activities and (2) that a higher fat oxidation during exercise is, independent of total energy expended, associated with a higher fat mass loss (2, 10). Exercise at moderately intense levels 5/week, is equivalent to an energy expenditure of approximately 1500 kcal/week (11). The intensity and duration of physical activity differs between normal and over-weight adolescents, with no difference in estimated energy expenditure (12). They found that intensity, duration and total amount of PA in the obese group were significantly less than in the control group. On the other hand there was no difference in total energy expenditure and activity-related energy expenditure, these findings were supported by other researchers (13). Thermoregulatory mechanisms play important roles in maintaining physiological homeostasis during rest and physical activity. As exercising in hot and humid environments is a huge challenge to the body's ability to control its internal temperature, due to the high rates of metabolic heat production and heat gain through physical transfer from the environment (14-17). Furthermore, during exercise in the heat, the redistribution of blood from the body core to the skin decreases available muscular blood flow but may still be inadequate to control core temperature. When the core temperature rises, the basal metabolic rate can increase significantly and for every 0.6 ºC increase in core temperature there is a 10% elevation in the basal metabolic rate (18).

Environmental conditions may also have an effect on fat and carbohydrate use. High ambient temperatures could increase glycogen breakdown as a result of increased body core temperature and increase in the circulation of catecholamine. Low temperatures on the other hand, can increase carbohydrate metabolism, especially when shivering (10). It is noteworthy, that increasing the ambient temperature leads to an increase in carbohydrate oxidation during exercise and a concomitant decrease in fat oxidation, caused by increased muscle glycogen use with no change in glucose uptake by the muscle (19). In general fat ability for transfer heat is low, therefore people with more body fat are capable to conserve more heat in a cold environment (20). Thus it is important to consider prevailing levels of fitness and environmental conditions when determining exercise intensity and duration, as conditions like heatstroke, heat cramps/exhaustion are likely during moderate physical activity in hot weather. These ailments, associated with electrolyte imbalance, are more likely to occur for those in poorer physical health, as they tend to lose more sodium whilst exercising (7). Individuals can anticipate the heat stress and intensity they might reach, as there are signs of lowered power output and activation of muscles before reaching any critical core temperatures. This in turn allows for tactical adjustment of the output of power (17).

According to the WHO (21), people in the Europe spend most of their time indoors, whether at home or at work, where the optimum indoor temperature is between 18 -24ºC. Temperatures between the range of 21-25ºC are considered low risk of thermal injury, whilst those in the range of 26ºC - 30ºC are considered to be of moderate risk of thermal injury (21). No evidence for heat dissipation in the body, under moderate environment conditions, until the elevated set point is achieved (22). Using only the generic guideline prescription to determine exercise activity is still not sufficient to maintain good health, as it does not consider the important concept of physiological body responses towards the environment (i.e. temperature change). The differences between summer and winter season in total energy expenditure and physical activity was investigated in healthy young adults (6). No significant seasonal effect on PAL, with higher PAL levels in summer and lower levels in winter. The average PAL was not different between sexes except the difference between seasons was significantly higher for men than for women. The more active the subjects were during the summer, the greater the reduction in activity was in winter (6).

Therefore, when planning interventions and health promotion efforts, designed to increase activity levels in the general population, environmental factors (i.e. ambient temperature) related to seasonal variation in physical activity behaviors, must be considered (6,7). If the maintenance of moderate levels of activity is important for health reasons, and if this activity is more likely to be self-selected in leisure time, then consideration of seasonal changes in the physiological responses to exercise and the general health become important (7). Finally, it seems reasonable that the human organism has two protective systems in place: an anticipatory one to prevent excessive heat build-up as much as possible and a safety feedback mechanism to terminate exercise before catastrophic collapse (23). In the current study, the most obvious differences between the three trials were found in the HR and RPE data. Results show a significant difference in HR and RPE when exercising moderately for 30min in a hot environment of 30ºC (both $p < 0.05$). The results support the findings of other studies, in that exercising moderately will increase the RPE and HR (24,25). Craig suggested a direct link between the RPE and the brain (25). It seems that humans create a cortical image of homeostatic afferent activity reflecting the physiological condition of the body. However, those studies used temperatures higher than 30ºC with longer exercise duration (45-min), which is conflicting with both the exercise guideline prescription and this research. Interestingly, Crewe et al. (26) suggested that the subconscious brain must be able to forecast the duration of exercise and then set the rate of increase in RPE at greater levels in hot conditions, and with higher intensities, so that fatigue occurs before the body temperature can rise excessively.

It is feasible that energy expenditure is not the most important factor modulated by the extent of elevation in body temperature during moderate physical activity (24). The increases in HR are most likely due to redistribution of central blood volume toward the skin, resulting in a decreased stroke volume. The increases in skin blood flow to facilitate heat dissipation during exercise in the heat are partly met by a reduction in intestinal blood flow (27). Minimal limitations is certainly made apparent during low intensity exercise, as continued exercise in the heat at low intensity shows neither compromised muscle blood flow, nor reduced blood pressure (19, 27). Interestingly, even though there was a significant difference in HR, RPE between trials at T18 & T30, there was no difference between the T30a & T18 trials. This shows that when repeating the same exercise for 30 mins at 30°C, after just 24 h, the body can adapt to this heat exposure. This may further explain the raise on HR and RPE when exercising for the first time at 30°C, as a result of a rapid physiological response to the high temperature.

In conclusion, exercising moderately for 30 minutes, in a hot environment, raises the HR and the RPE, of normal weight men. Evidence shows, that there is a significant increase in HR when individuals of normal weight, exercise in higher temperatures (30°C). In addition, exercising for 30mins, in higher temperatures (30°C) has no significant impact on CHO, fat utilization or total energy expenditure. We concur with the notion against taking extreme physical activity in abnormally high temperatures as this may lead to physical complications. The main practical implications from this study include 1) Exercising moderately for 30-min in a hot environment of 30ºC, compared to 18ºC, raises the HR and the RPE for normal weight males; 2) People can safely exercise moderately for 30-min in a hot environment (30ºC) and 3) The exercise prescription guidelines could be modified to include exercising for 30min even in environmental temperatures of 30°C. Further work is needed on implications of exercising moderately for 30 minutes to maintain good health for normal and overweight people. Current guidelines are quite generic and some modification may be needed.

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