# EFFECTS OF EXERCISE ON HUMAN ENERGY METABOLISM IN HIGH TEMPERATURE AND HIGH HUMIDITY ENVIRONMENT

*EFEITOS DO EXERCÍCIO SOBRE O METABOLISMO ENERGÉTICO HUMANO EM AMBIENTES DE ALTA TEMPERATURA E UMIDADE*

*EFECTOS DEL EJERCICIO SOBRE EL METABOLISMO ENERGÉTICO HUMANO EN AMBIENTES DE ALTA TEMPERATURA Y HUMEDAD*

**Original Article**
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## ABSTRACT

Introduction: Many exercise enthusiasts have started participating in sports in the high-temperature environment in recent years due to the increasing popularity of these sports habits. However, their scientific studies still have a gap in their safety and effectiveness. Objective: Measure the energy supply characteristics of fat and sugar oxidation during exercise in different high-temperature and humidity environments. Methods: 20 healthy adult subjects were exposed to fixed-intensity exercise for 20 minutes at 30-33 °C, 20% relative humidity (RH), and 50% RH, respectively. Results: Under the silent exposure condition, compared with RH 20% and RH 50% under high temperature, sugar oxidation was significantly increased (P<0.01), while fat oxidation was significantly reduced (P<0.01), and total energy consumption was significantly increased (P<0.01). Under the condition of 65% VO2 max exercise, compared with RH 20% and RH 50% at high temperatures, the amount of sugar oxidation was significantly reduced (P<0.05), and the total energy consumption was significantly reduced (P<0.05). Conclusion: Under 65% exercise under VO2 max in the high temperature and humidity-controlled environment, the high temperature and medium humidity (RH 50%) environment consumes more energy, and there is a greater amount of sugar oxidation. ***Level of evidence II; Therapeutic studies - investigating treatment outcomes.***

**Keywords:** Hot Temperature; Energy Consumption; Exercise.

## *RESUMO*

*Introdução: Muitos entusiastas do exercício físico começaram a participar de esportes no ambiente de altas temperaturas nos últimos anos devido a crescente popularidade desses hábitos esportivos, embora seus estudos científicos ainda apresentem uma lacuna sobre sua segurança e efetividade. Objetivo: Comparar as características do fornecimento de energia de oxidação de gordura e açúcar durante o exercício em ambientes de alta temperatura e umidade diferentes. Métodos: Um total de 20 sujeitos adultos saudáveis foram expostos a exercícios de intensidade fixa durante 20 minutos a 30-33 °C, 20% de umidade relativa (RH) e 50% de RH, respectivamente. Resultados: Sob a condição de exposição silenciosa, comparado com RH 20% e RH 50% sob alta temperatura, a oxidação do açúcar foi significativamente aumentada (P<0,01), enquanto a oxidação da gordura foi significativamente reduzida (P<0,01), e o consumo total de energia foi significativamente incrementado (P<0,01). Sob a condição de 65% de exercício de VO2max, comparado com RH 20% e RH 50% a altas temperaturas, a quantidade de oxidação do açúcar foi significativamente reduzida (P<0,05), e o consumo total de energia foi significativamente reduzido (P<0,05). Conclusão: Sob a condição de 65% de exercício sob VO2max, no ambiente de alta temperatura e umidade controlados, o ambiente de alta temperatura e umidade média (RH 50%) consome mais energia, havendo uma maior quantidade de oxidação de açúcar.* ***Nível de evidência II; Estudos terapêuticos - investigação dos resultados do tratamento.***

***Descritores*:** *Alta Temperatura; Consumo de Energia; Exercício Físico.*

## *RESUMEN*

*Introducción: En los últimos años, muchos aficionados al ejercicio han comenzado a practicar deportes en el entorno de altas temperaturas debido a la creciente popularidad de estos hábitos deportivos, aunque sus estudios científicos aún presentan lagunas sobre su seguridad y eficacia. Objetivo: Comparar las características de suministro energético de la oxidación de grasas y azúcares durante el ejercicio en diferentes entornos de alta temperatura y humedad. Métodos: Un total de 20 sujetos adultos sanos fueron expuestos a ejercicio de intensidad fija durante 20 minutos a 30-33 °C, 20% de humedad relativa (HR) y 50% de HR, respectivamente. Resultados: Bajo la condición de exposición silenciosa, en comparación con RH 20% y RH 50% bajo alta temperatura, la oxidación de azúcar se incrementó significativamente (P<0.01), mientras que la oxidación de grasa se redujo significativamente (P<0.01), y el consumo total de energía se incrementó significativamente (P<0.01). Bajo la condición de ejercicio VO2max 65%, en comparación con RH 20% y RH 50% a alta temperatura, la cantidad de oxidación de azúcar se redujo significativamente*

*(P<0,05), y el consumo total de energía se redujo significativamente (P<0,05). Conclusión: Bajo la condición de 65% de ejercicio bajo VO2max en el ambiente controlado de alta temperatura y humedad, el ambiente de alta temperatura y humedad media (RH50%) consume más energía y hay una mayor cantidad de oxidación de azúcar.* ***Nivel de evidencia II; Estudios terapéuticos - investigación de los resultados del tratamiento.***

***Descriptores:*** *Temperatura Alta; Consumo de Energía; Ejercicio Físico.*

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## INTRODUCTION

In extreme environments, human experience produces- -a series of physiological and biochemical reactions, especially in the process of movement, the body's metabolic process and energy supply will change greatly.[1] Humidity environment mainly affects the human body sweat, body heat distribution and human body water salt metabolism process, if the relative humidity is low, the body can reduce the heat dissipation by evaporation of the core temperature, and in the high humidity environment for a long time high intensity exercise, the body core temperature is difficult to reach a relatively stable platform, but continue to rise, this situation is very dangerous for athletes.[2] Walsh, et al. Reported that motility releases extracellular HSP 72.[3] Increase in extracellular HSP 72 The body's immune system may be a danger signal, and it can be associated with an antigen binding of the presenting cells to cause an immune response. Studies also show that at the high temperature ring Border movement made the plasma HSP 72 increase more pronounced.[4] And the same high temperature the influence of movement on the body under different relative humidity (RH) conditions. There have been relatively few studies studied.[5] And the relative humidity size is important to the body heat dissipation Action, 80% of the heat is lost through evaporation, and quiet when evaporation heat dissipation only accounts for 20% of the body heat loss, so relatively wet Degree size may influence body temperature changes after exercise. People as one of the components of nature, always interact with the surrounding environment, the surrounding environment temperature and humidity and other two natural phenomena always affect the people's life, work and survival, and with temperature and humidity of the human body's digestive and respiratory system, neuroendocrine system, cardiovascular system and exercise ability, and the body skin, fat content, tissue thickness and shape of the functional structure is relatively independent, but when the environment is bad and body homeostasis imbalance, the body will appear some symptoms.[6] Relevant studies have shown that appropriate exercise and fitness can improve the body's physical activity level, promote the body's health, improve the body's immunity, and reduce the probability of infection with various diseases. In high temperature environment, the risk of HRV infection increases; plasma at low temperature is immune to human liver cancer cells (Hep G2); and appropriate humidity reduces respiratory diseases (24%) and digestive diseases (51%).[7]

The study shows that compared with the normal temperature and normal wet environment, the core body temperature, blood lactic acid, heart rate and sweat ion concentration are significantly increased, and the duration of exercise is significantly reduced. The researchers have studied the physiological changes of the body in high temperature environment from different perspectives.[8] This study discusses the effects of quiet exposure and exercise on substrate metabolism and energy metabolism in high temperature and different humidity environment in the laboratory, aiming to provide reference for sports training, competitive competition and public fitness.

## Research object and research method

### Subjects of study

Ten healthy adult men from Beijing Sport University were recruited. Before the experiment, after medical history and physical examination, the subjects had no cardiovascular system, neuroendocrine system, respiratory system and other diseases, and the physical condition was good. The exercise habit was moderate intensity and regular exercise for more than 6 h per week, and no high temperature and high humidity exercise clothing.[9] Subjects filled in the informed consent form and voluntarily participated in this study. During the experiment, medication were not allowed for subjects to enhance exercise capacity, and subjects were not allowed to stay up late and strenuous exercise on the day before each experiment.

The study is Purely observational studies which no need to registry ID of ICMJE, and all the participants were reviewed and approved by Ethics Committee of Yunnan Minzu University, China (NO. 2021037)

### The experimental method

The VO2max is considered the most effective indicator of assessing cardiorespiratory fitness in exercise players, plus it is often used in exercise physiology laboratories to standardize the relative exercise load intensity in different subjects. The judgment criterion of VO2max is that the oxygen intake appears with the increased exercise load, or the breathing quotient reaches or exceeds 1.10, or the heart rate HR reaches or exceeds 220-age, and the subject's subjective feeling can not maintain the original exercise speed and continue to exercise, when the exercise load is VO2max. Each subject shall test VO2max at room temperature.[10] The specific test method is as follows: first, the subject shall prepare for 5min according to the previously set load to accommodate the load and runner speed; second, wear breathing mask and other related equipment; finally, increase load exercise test on the runner according to the previously set scheme. The starting load of the experiment was 8 km/h, 0% slope; followed by 1km / h every 1min. When the running speed increases to 17 km/h, the slope increases by 1% per 1min until the subject cannot move under the exercise load.

Therefore, the accuracy of the VO2max test is quite important to determine the subject's ability and to give the appropriate exercise training intensity. Researchers usually use Bruce's test process to test subjects' treadmill VO2max. The experiment, the maximum duration of exercise at 90%VO2max and 95%VO2max with VO2max measured in the fourth minute, and the exercise time is significantly shorter. It is shown in the specific Figure 1.

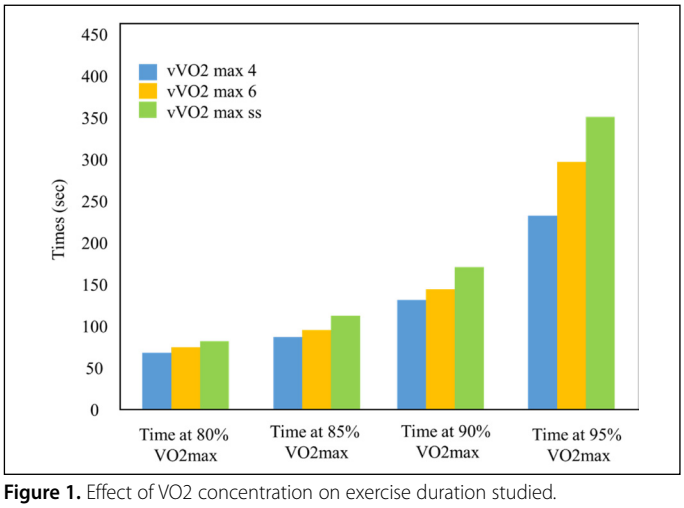


**Figure 1.** Effect of VO2 concentration on exercise duration studied.

The test scheme of this paper: the subjects first prepare for 5min on the platform movement with 8 km/h in the experimental environment, then wear the breathing mask and other related equipment, and conduct the incremental load exercise test on the platform platform according to the experimental design scheme. The starting load of the experiment was 8 km/h and the slope is 0; after increasing by 1 km / h every 1 min, the slope remains unchanged. When the running speed increases to 17 km/h, the slope increases by 1% every 1 min until the subject fails to keep the movement under the load and ends.

The instruments used in this study include the gas metabolism analyzer (Cortex MetaLyzer 3B, Germany, hardware version 2.7.0, software version Me-ta Soft 3.9), supporting running platform (VIASYS LE500CE, Germany), and electronic weight meter (OMRONHBF-356, Japan). The laboratory simulated high temperature and different humidity environment. In high temperature 33C, relative humidity, RH (R H), RH50%, RH80% three humidity environment, the exercise exposure at 65%VO-2mo for 20 min, while quiet exposure for 20 min As its own control. The changes of gas during the test were recorded by the gas analyzer, and the experimental data were analyzed statistically. The influence of different humidity in high temperature environment on human energy metabolism was observed.

Before the experiment, the subjects wore exercise shorts and weighed them barefoot, then dried the body sweat and weighed them barefoot. Test results were analyzed using SPSS20.0 statistical software using mean soil standard deviation, and paired t-test using pairwise experimental data for all 3 environments. A P <0.05 was considered as a statistically significant difference.

## Experimental result and analysis

### Body weight change before and after the experiment

As can be seen from Table 1, there was no significant difference in weight change values before and after the experiment in high temperature and humidity environment, but the most in high temperature RH80%, the second in high temperature dry environment, and the least in high temperature RH50%. Under the exercise conditions, the weight change in both RH50% and RH20% was significantly reduced (P <0.05), while the RH80% was the most, while the RH50% was the least. There was no significant difference in body weight change between high temperature RH50% and high temperature RH20% environment.

**Table 1.** Weight changes before and after the experiment (kg).

| Exercise intensity | Environment | n | Pre-experiment | After the experiment | Change value |
|---|---|---|---|---|---|
| Quiet | High temperature RH80% | 10 | 71.85±7.22 | 71.59±7.22 | 0.26±0.18 |
| | High temperature RH50% | 10 | 71.84±6.83 | 71.63±6.83 | 0.21±0.09 |
| | High temperature RH20% | 10 | 71.98±7.02 | 71.74±7.07 | 0.24±0.11 |
| $65\%VO_{2max}$ | High temperature RH80% | 10 | 71.55±6.81 | 70.71±6.95 | 0.74±0.18 |
| | High temperature RH50% | 10 | 71.57±7.06 | 71.07±7.03 | 0.50±0.11* |
| | High temperature RH20% | 10 | 72.17±7.24 | 71.66±7.12 | 0.51±0.13* |

### Effects of high temperature and different humidity environment on the energy supply of human fat metabolism

As seen from Table 2, high temperatures under 65%VO2mx exercise conditions. RH20% ambient fat oxidation, fat energy supply and fat energy supply ratio were the most significant, but there was no significant difference between high temperature and different humidity, only high temperature RH20% and high temperature RH50% (P <0.05). Under quiet conditions, the oxidation amount of RH20% and RH80%, fat energy supply and fat energy supply were significantly reduced (P. 01 (P <0.01), and increased in RH20% compared with RH80% (P <0.05). In addition, high temperature RH50% had the largest energy supply under quiet conditions, while high temperature RH50% was under 65%VO2me exercise.

Under quiet conditions, high temperature RH20% sugar supply is the most, significantly higher than RH50%, 50% environment (P <0.01); high temperature RH80% is significantly more than R H (P <0.01); high temperature RH20% and RH80% are 36%, indicating drying and high wet environment, while RH50% environment is dominated by fat oxidation amount. The energy needed by the body in a quiet state of high temperature environment is mainly fat oxidation, and the fat energy supply ratio is up to 64% ~ 82%, indicating that fat is the main body of the body in high temperature and high humidity environment, and should provide energy substances.

The research of others shows that under the high temperature and different humidity environment, the aerobic capacity of the organisms in the high temperature and high humidity environment cannot be fully played. In this study, the body had the most total energy expenditure in a high-temperature RH50% environment under 65%VO2mp exercise conditions. Under the 65%VO2m ax exercise conditions, the oxidation amount of fat was not significantly different from the different humidity environments. High temperature RH20% The sugar was significantly less oxidized as compared to high temperature RH50% (P <0.05). The energy supply ratio of sugar and fat under high temperature RH20%, high temperature RH50%, 80% and 80% is 67%: 33%, 71%: 29% and 70%: 30% respectively, indicating that sugar oxidation is more than fat oxidation under moderate intensity exercise conditions. There are studies showing that heat stress has no adverse effects on sprint exercise within 15s, but has negative effects on 60s and 300s of intense exercise. The study showed that heat stress can significantly change the metabolic changes of absorbed sugar, fat and other proteins through the interaction between body tissues. This study used a moderate intensity aerobic exercise lasting 20 minutes, which specific physiological changes occur in the body, and whether the exercise ability has decreased significantly, we need further research.

**Table 2.** Changes of energy supply of superficial fat metabolism.

| Exercise intensity | Environment | n | Fat oxidation (mg/min/kg) | Fat for energy (cal/min/kg) | Fat energy supply ratio(%) | Total energy consumption (cal/min/kg) |
|---|---|---|---|---|---|---|
| Quiet | High temperature RH80% | 10 | 1.73±0.13 | 16.09±1.32 | 0.64±0.03 | 24.94±1.32 |
| | High temperature RH50% | 10 | 2.24±0.17** | 20.83±1.34** | 0.82±0.03** | 25.63±1.35 |
| | High temperature RH20% | 10 | 1.82±0.21*&& | 16.93±2.05*&& | 0.64±0.07&& | 26.29±2.0*&& |
| 65%VO2max | High temperature RH80% | 10 | 7.15±0.63 | 66.50±3.91 | 0.30±0.03 | 220.95±9.91 |
| | High temperature RH50% | 10 | 7.15±0.66 | 66.50±4.24 | 0.29±0.04 | 227.26±9.22 |
| | High temperature RH20% | 10 | 7.75±0.71 | 72.10±5.27 | 0.33±0.02& | 220.73±9.51& |

*p<0.05,**p<0.01, Comparison with high temperature RH80%;&p<0.05,&&p<0.01, Comparison.

## CONCLUSIONS

In this study, quiet exposure and exercise for 20 min under high temperature and different humidity were performed, respectively. We can see from the experimental data that the influence of different humidity environment on body weight under quiet conditions was not significant. Under exercise conditions, high temperature RH80% weight change values are significantly different compared with high temperature RH50% and high temperature RH20%, which may be related to the body produces more heat than the heat lost in high temperature and high humidity environment. In general, exposed to quiet conditions, high temperature and different humidity environment, high temperature dry environment (RH20%) consumes the most energy, while high temperature and medium humidity environment (RH50%) is the most fat oxidation, the largest energy supply ratio. Under 65%VO-2mu exercise conditions, high temperature and different humidity environment, high temperature and medium humidity environment (RH50%) consume the most energy, the most sugar oxidation, and the largest energy supply ratio.

All authors declare no potential conflict of interest related to this article

**AUTHORS' CONTRIBUTIONS:** The author made significant contributions to this manuscript. Jinrui Zhang: writing and performing surgeries; Han Liu: data analysis and performing surgeries; Weinan Dai: article review and intellectual concept of the article.

## REFERENCES

1. Gao H, Deaton AS, Fang X, Watson K, DenHartog E, Barker R. Effects of environmental temperature and humidity on evaporative heat loss through firefighter suit materials made with semi-permeable and microporous moisture barriers. Text Res J. 2022;92(1-2):219-31.
2. Maule AL, Heaton KJ, Cadarette B, Taylor KM, Guerriere KI, Haven CC, et al. Effect of Environmental Temperature and Humidity on Permethrin Biomarkers of Exposure in U.S. Soldiers Wearing Permethrin--Treated Uniforms. Am J Trop Med. 2020;6(6):70-5.
3. Peel JS, Mcnarry MA, Heffernan SM, Nevola VR, Kilduff LP, Waldron M. The Effect of Dietary Supplements on Endurance Exercise Performance and Core Temperature in Hot Environments: A Meta-analysis and Meta-regression. Sports Med. 2021;9(6):54-8.
4. Zhang S, Zhu N, Lv S. Human response and productivity in hot environments with directed thermal radiation. Build Environ. 2020;187:107408.
5. Takebayashi H. Effects of air temperature, humidity, and wind velocity distribution on indoor cooling load and outdoor human thermal environment at urban scale. Energy Build. 2022;257:111792.
6. Golubkina N, Zayachkovsky V, Stepanov V, Deryagina V, Rizhova N, Kirsanov K, et al. High Temperature and Humidity Effect on Biochemical Characteristics of Organically-Grown Parsnip Roots Compared to Garlic Bulbs. Plant Foods Hum Nutr. 2020;75(5):292-7.
7. Mills I, Hamad F. A Review and CFD Case Study: The Effect of Temperature, Humidity, Aerodynamics on Corona Virus Transmission, Mitigation in Open and Enclosed Environments. Biomedical Research Network+, LLC. 2020;33(4):26084-92.
8. Lim HR, Kim HS, Qazi R, Kwon YT, Jeong JW, Yeo WH. Advanced soft materials, sensor integrations, and applications of wearable flexible hybrid electronics in healthcare, energy, and environment. Adv Mater. 2020;32(15):1901924.
9. Zou Y, Young M, Chen J, Liu J, May A, Clark JD. Examining the functional range of commercially available low-cost airborne particle sensors and consequences for monitoring of indoor air quality in residences. Indoor Air. 2020;30(2):213-34.
10. Fujihira K, Hamada Y, Haramura M, Suzuki K, Miyashita M. The effects of different temperatures of post-exercise protein-containing drink on gastric motility and energy intake in healthy young men. Br J Nutr. 2021;127(5):782-90.