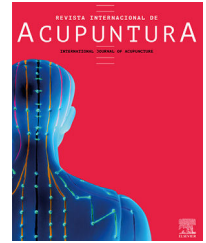




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ORIGINAL ARTICLE

Immediate effect of acupuncture on lactate removal after exercise: A pilot study

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Heart rate;
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Abstract

Background: The recovery process is of utmost importance in activities where the athlete has to compete more than once a day during the competition. It is generally accepted that intense physical activity results in lactate production and the accumulation of lactate in exercising muscle is considered one of the main determining factors of fatigue.

Objective: The main goal of this pilot study was to evaluate the immediate effects of acupuncture on lactate removal after just one treatment session and to evaluate lactate, heart rate, and oxygen saturation behavior at 5, 30, and 60 min after exercise.

Methods: Four individuals were evaluated and were part of both the experimental group (real acupuncture) and the placebo group (sham acupuncture) and were tested at two distinct times with a one-week interval. Baseline values of lactate, heart rate, and oxygen saturation were measured, and then the participants performed a warm-up and subsequently completed the Wingate test. The individuals were re-evaluated 5, 30, and 60 min after the Wingate test, and either real or sham acupuncture was applied after the test.

Results: After the intervention period, there was an increased ability to reduce or remove lactate after maximum effort. No significant differences were observed in heart rate or oxygen saturation. **Conclusions:** The results of this case study seem to suggest that acupuncture has a positive effect on lactate removal after intense physical exercise.

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PALABRAS CLAVE

Lactato;
Fisiología del ejercicio;
Medicina tradicional china;
Acupuntura;
Frecuencia cardíaca;
Saturación de oxígeno

Efecto inmediato de la acupuntura en la eliminación de lactato tras el ejercicio: Estudio piloto**Resumen**

Antecedentes: El proceso de recuperación es de suma importancia en aquellas actividades en las que el atleta tiene que participar más de una vez al día durante la competición. Está generalmente aceptado que la actividad física intensa origina una producción de lactato, cuya acumulación en el músculo es considerada uno de los principales factores que determinan la fatiga. **Objetivo:** El objetivo principal de este estudio piloto fue evaluar los efectos inmediatos de la acupuntura en la eliminación de lactato tras una sesión terapéutica, y evaluar el lactato, la frecuencia cardíaca y el comportamiento de la saturación de oxígeno transcurridos 5, 30 y 60 minutos del ejercicio.

Métodos: Se evaluaron cuatro individuos, que formaron parte tanto del grupo experimental (acupuntura real) como del grupo placebo (acupuntura sham), realizándose la evaluación en dos momentos distintos, con una semana de intervalo. Se midieron los valores basales de lactato, frecuencia cardíaca y saturación de oxígeno, seguidamente los participantes realizaron un calentamiento, y posteriormente completaron la prueba Wingate. Se reevaluó a los individuos transcurridos 5, 30 y 60 minutos tras la prueba Wingate aplicándose, bien acupuntura real o acupuntura sham tras la misma.

Resultados: Tras el periodo de intervención, se produjo un incremento de la capacidad de reducción o eliminación del lactato tras un esfuerzo máximo. No se observaron diferencias significativas en cuanto a frecuencia cardíaca o saturación de oxígeno.

Conclusiones: Los resultados de este estudio de caso parecen sugerir que la acupuntura tiene un efecto positivo en la eliminación de lactato tras el ejercicio físico intenso.

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Introduction

Physical exercise is an essential component of a healthy lifestyle and is widely accepted as a means to improve physical fitness and overall health.^{1,2} Exercise can be defined as a form of physical activity that results in increased energy expenditure, leading to changes in cardiovascular, respiratory, and muscular function.^{3,4} The production of lactic acid, also known as lactate, is a well-known phenomenon in the context of exercise physiology, as it has been widely studied for many years.^{5,6}

Lactate is a product of anaerobic metabolism that occurs in muscle tissue during intense physical activity. This metabolic process is triggered when the energy demand exceeds the supply of oxygen in the muscles. During intense exercise, the increased metabolic demand leads to an increase in the production of lactic acid, which accumulates in the muscles and bloodstream.^{7,8} The accumulation of lactate in the muscles is associated with a decline in muscle function and fatigue during exercise. The formation of lactate is a complex process that is regulated by various physiological mechanisms. It occurs in the muscles as a result of the breakdown of glucose, which releases energy for the cells to use. Glycolysis is the main energy source for intense exercise that lasts less than 2–3 min. During glycolysis, glucose is converted into pyruvate, which is then converted into lactate. The conversion of pyruvate into lactate is facilitated by lactate dehydrogenase, an enzyme that helps to regulate lactate formation.^{9–11}

The removal of lactate from the muscles and bloodstream is another important aspect of lactate metabolism in the context of exercise. Lactate removal is a complex process that is regulated by various physiological mechanisms, including the balance between lactate production and removal, the availability of oxygen, and the rate of blood flow to the muscles. The removal of lactate from the bloodstream is facilitated by the liver, which converts lactate into glucose and other energy-rich molecules that can be used by the cells.^{12–14}

Overall, the formation and removal of lactate during physical exercise is a complex physiological process that is regulated by various mechanisms. The production of lactate is associated with the decline in muscle function and fatigue during intense exercise, while the removal of lactate is important for the recovery and maintenance of physical fitness.

Various strategies and techniques can be employed to help reduce lactate levels after exercise and improve recovery time. One commonly used method is active recovery, which involves performing low-intensity exercise after high-intensity exercise to help remove lactate from the muscles.¹⁵ Another approach is to use massage or foam rolling to improve blood flow and reduce muscle stiffness, which can help to reduce lactate levels.^{16,17} Additionally, nutritional strategies such as consuming carbohydrates and protein after exercise may also help to reduce lactate levels by promoting glycogen synthesis and reducing muscle damage.^{18,19} Furthermore, the use of supplements such as

beta-alanine and sodium bicarbonate has also been shown to be effective in reducing lactate levels during high-intensity exercise.²⁰

Acupuncture has been studied for its potential effects on lactate levels after exercise. There is some evidence to suggest that acupuncture may help to reduce lactate levels, though more research is needed to fully understand this relationship. Factors that may play a role in the reduction of lactate levels include increased blood flow, improved oxygenation of the muscles, and reduced muscle fatigue.^{21–24} Bearing this in mind, the main goal of this pilot study was to evaluate the immediate effects of acupuncture on lactate removal after just one treatment session and to evaluate lactate, heart rate, and oxygen saturation behavior at 5, 30, and 60 min after exercise.

Materials and methods

This study employed a randomized, controlled, crossover experimental design that was approved by the Ethics Committee of the Institute of Biomedical Sciences Abel Salazar. A convenience sample consisting of 4 healthy male volunteers, ranging in age from 18 to 40 years, was utilized in this study. The participants were provided with information regarding the study procedures and voluntarily participated after completing a brief questionnaire and signing an informed consent document. The volunteers were instructed to refrain from physical exercise one week before and during the study. Food intake was restricted to a light meal up to 3 h before the evaluation time. Beverages containing alcohol and caffeine were also prohibited 12 h before the evaluation time.

Inclusion criteria: Healthy men aged 18 to 40 years, who were physically active and had similar levels of physical fitness, with or without prior cycling experience, and capable of following basic instructions and refraining from physical exercise one week before and during the study period, were eligible for inclusion in this study.

Exclusion criteria: Participants with cardiovascular, pulmonary, metabolic, neurological, psychiatric, and musculoskeletal disorders, active bleeding history, participation in a strength training program within the last 6 months, intense physical training within one week before the study, use of any medication, needle phobia, and recent acupuncture treatments within the last 6 months were excluded from this study.

The experimental design sequences utilized in this study are represented in Fig. 1.

Data collection instruments

The study used an Orbea bicycle equipped with a power and RPM control system ensured by the Tacx Trainer software 4 advanced and the Tacx Neo roller system. The participants' physiological parameters were measured using a Tanita scale, a Sanitas pulse oximeter, a Sanitas heart rate monitor, an ApexBio Edge lactate meter, and The Edge lactate meter. The Edge lactate meter is a portable device that measures lactate concentration in the blood, allowing athletes, coaches, and other evaluators to accurately assess



Fig. 1 Intervention sequences of the crossover design (EG - experimental group; CG - control group).

muscle performance and capacity for improved performance.

Procedures

Four participants, comprising both the experimental group (receiving true acupuncture) and the control group (receiving sham acupuncture), were evaluated on two separate occasions. During the first evaluation (M1), the participants underwent the Wingate test and were immediately subjected to true acupuncture. One week later, to eliminate any residual effects of fatigue or inadequate recovery, the same individuals repeated the Wingate test and received a session of sham acupuncture (M2), with the order being randomized.

Before the evaluations, the participants were measured and weighed, and baseline values for lactate, heart rate, and oximetry were recorded (T0). A 5-min warm-up on a bicycle at 50 W was performed, with two short sprints at the end of the third and fifth minutes.²⁵ This warm-up on a bicycle was deemed necessary to achieve specific physiological and motor adaptations and to prevent injury.²⁶

The Wingate test was initiated two minutes after the warm-up and lasted for 30 s, with a load of 0.10 kg per body weight.^{26,27} The test started without resistance, and the resistance was released three seconds into the test to avoid any unwanted deceleration due to the negative effect of inertia.²⁸ The participants were expected to give their maximum effort and received verbal encouragement from the beginning of the test to ensure optimal energy throughout the test periods.²⁶ After the 30-s test, the participants continued to pedal for 2 to 3 min with low RPM and very light resistance to calm down and avoid dizziness.

After the test, the participants reclined on the examination table in a supine position to recover. Lactate concentration, heart rate, and oxygen saturation for 5 min post-test (T1) were then assessed. Subsequently, either a session of true or sham acupuncture was administered for 20 min, and after 10 min of needle insertion, needles were gently rotated for 15 to 20 s. The acupuncture technique was applied bilaterally at the 4 acupuncture points, with the order of application being randomly determined. Once the true or sham acupuncture session was completed, the participants remained on the examination table in a state of recovery. Lactate concentration, heart rate, and oxygen

saturation were re-assessed at 30 min (T2) and 60 min (T3) following the Wingate test.

The participants were positioned in the supine position for the acupuncture protocols, and the points were selected by TCM specialists from the Institute of Biomedical Sciences Abel Salazar of the University of Porto, based on the Heidelberg model of TCM.^{29,30} The points used were S36, Li3, LI11, and PC5 bilaterally. Sterilized and disposable 0.25 × 25 mm acupuncture needles were used, and the skin was disinfected with alcohol before puncturing.

The choice of acupuncture points was based on the following factors: Zusanli (S36) is a point that has a toning effect and is administered daily to address issues of fatigue, hard work, and exhaustion. According to the Five Shu Theory, S36 is the He-Sea point of the stomach conduit and is also referred to as the "Soldier's Point". It is considered to be the primary body-stabilizing point. It is located in the Earth phase and serves to regulate the relationship between the vegetative capacity for function (Qi) and the functional capacity for connection to bodily fluids (Xue). Tai Chong (Li3), which is an Earth point, is the Shu-Stream acupoint of the liver conduit. It facilitates the flow of Qi to the conduits and is utilized for treating disorders related to daily life and the "body island". At this particular acupoint, it is believed that the original Qi, can be accessed. It is typically dispersed to reduce excessive expression of the Wood phase. Quchi (LI11), an Earth point, is the He-Sea acupoint of the large intestine conduit. This point has a cooling effect on the surface (Extima) and is commonly used to treat yin disorders, and has anti-inflammatory properties. Jianshi (PC5), a Metal point, is the Jing-Well acupoint of the pericardium conduit. It has an important harmonizing effect, directing Yang and Qi downward. Excess Yang energy at this point is redirected to other internal arm conduits (Lung and Heart). PC5 is a "transitory", "pump" point that stimulates Qi flow and is commonly used to treat conduit disorders caused by any type of agent.

In acupuncture research studies, sham acupuncture is often used as a control group to help determine the effectiveness of true acupuncture. Sham acupuncture

involves the use of needles that are placed in non-acupuncture points, or points that have no therapeutic effect. For this particular study, sham acupuncture was used as a control group and involved the use of points that were near the true acupuncture points, but had no therapeutic evidence and did not correspond to any conduit, channels, or trigger points. Specifically, for sham acupuncture, false points were selected for S36, Li3, LI11, and PC5. The false point for S36 was located 5 cun below B57. Similarly, the false point for Li3 was located 6 cun below B57. The false point for LI11 was located 1.5 cun below the olecranon. Lastly, the false point for PC5 was located 2 cun above and 1 cun radial to PC4.

Statistical analysis

As nothing was known about the variables of interest in the population, both nonparametric and parametric methods were employed to compare two groups of observations. The Wilcoxon matched-pairs test, a nonparametric method, was used to analyze the data. The previous test was used together with the t-test for dependent samples to evaluate observations that were based on the same subjects tested sequentially (e.g., before and after each intervention). A significant portion of the within-group variation in each assessment can be attributed to the individual differences between subjects.³¹ The statistical significance of the differences between groups was assessed using both non-parametric and parametric tests. The Statistica software for Windows version 7.0 was utilized to perform the statistical tests.

Results

The Student's t-test and Wilcoxon test revealed no significant differences in the baseline measurements for lactate, heart rate, and oxygen percentage between the experimental and control groups. This allowed for the accurate analysis of the effects and comparison between the two groups.

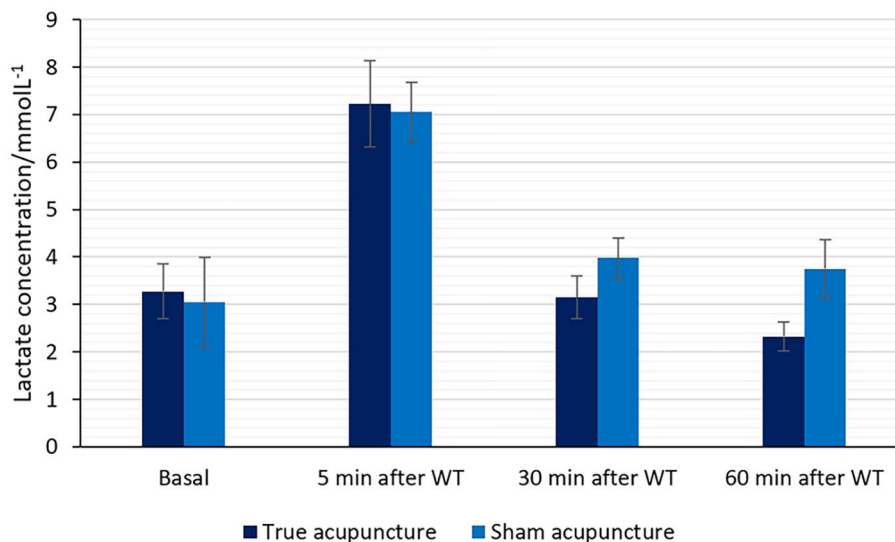


Fig. 2 Average lactate concentration at different moments of the intervention with true and sham acupuncture.

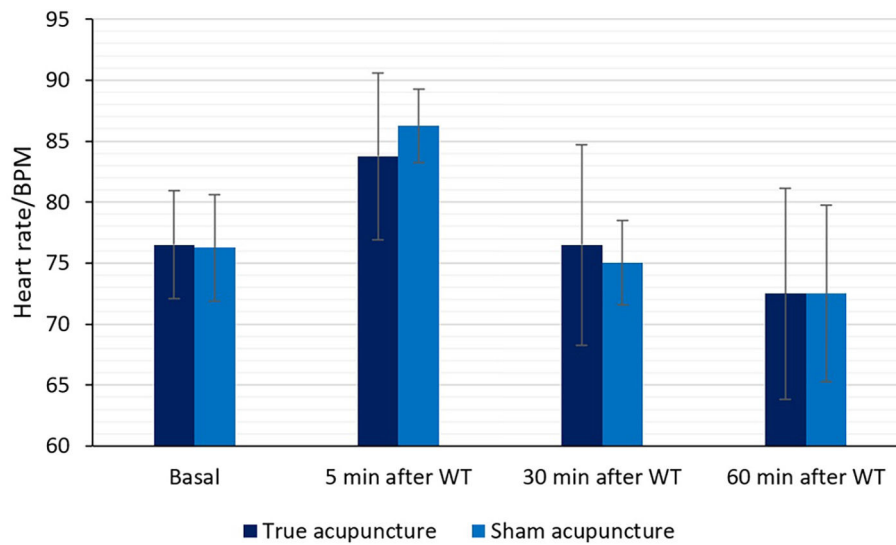


Fig. 3 Average heart rate at different moments of the intervention with true and sham acupuncture.

In the group receiving true acupuncture, a trend towards lower lactate concentrations was observed at 30 and 60 min after the WT, with values falling below baseline measurements (Fig. 2). However, these differences below the baseline were statistically significant only at the 60-min mark after WT ($p = 0.049$ for the t-test and $p = 0.068$ for the Wilcoxon test, near the threshold for statistical significance).

When comparing true acupuncture with sham acupuncture, statistically significant differences were observed only at the 60-min mark ($p = 0.047$ for the t-test and $p = 0.068$ for the Wilcoxon test, near the threshold for statistical significance).

Regarding the results for heart rate (Fig. 3) and oxygen saturation (Fig. 4), although a trend towards higher heart rate was observed at the 5-min mark, no significant differences were found for any tested period concerning

baseline measurements, nor when comparing true acupuncture and sham acupuncture.

Discussion

Our study aimed to investigate the efficacy of acupuncture in removing lactate from the body following exercise. We observed an increase in lactate levels in all participants after the exercise test, but a decrease in lactate levels was observed in all participants, regardless of whether true or sham acupuncture was applied. However, the decrease in lactate levels was more significant when true acupuncture was used. Baseline lactate values were similar for both true and sham acupuncture interventions, and there was an identical increase in lactate values after exercise for both groups. The graphical analysis demonstrated that lactate values decreased below baseline when true acupuncture was used, and this effect was most significant in Participant 3.

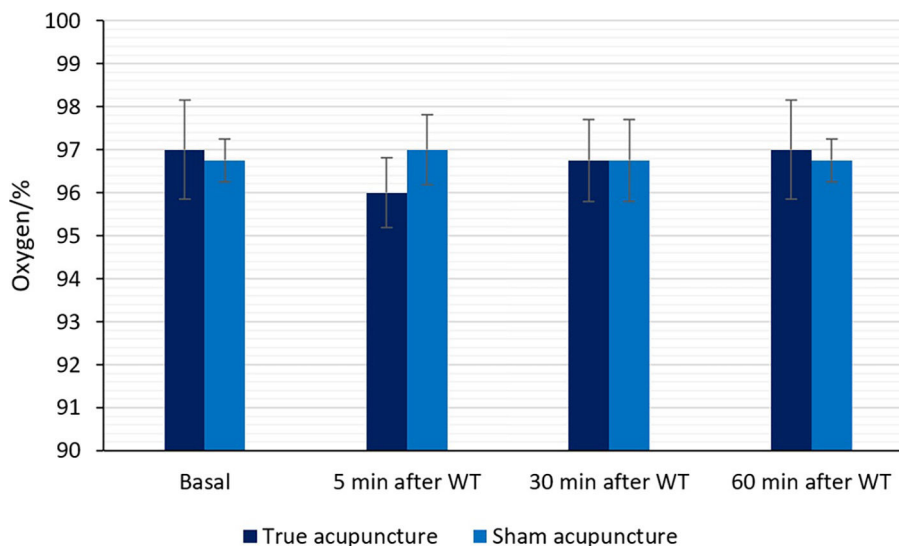


Fig. 4 Average oxygen saturation at different moments of the intervention with true and sham acupuncture.

Interestingly, in the same participant, lactate values increased slightly 60 min after exercise when sham acupuncture was applied.

The rapid removal of lactate following true acupuncture suggests that it may be beneficial for fatigue recovery after maximal effort, as it allows for more efficient decreases in lactate levels, increasing recovery capacity. Previous studies have suggested that this could be due to an increase in microcirculation, as stimulation of PC6 and S36 points has been found to release nitric oxide, which regulates blood vessels and blood flow.

Our results are consistent with previous literature on the subject. For example, Lin et al. conducted a study on 30 professional basketball players, randomized into control, placebo acupuncture, and true acupuncture groups, using S36 and PC6 points before maximal exercise. They found that acupuncture significantly reduced heart rate and lactate levels at 30 and 60 min after exercise.³² Tandy et al. recruited 36 professional basketball players and used PC6 and S36 points, concluding that lactate values after exercise were significantly better in the acupuncture group.³³ Ma et al. studied 14 young adults and found that acupuncture intervention could be an effective approach to relieving fatigue induced by exhaustive physical exercise.²³

However, some studies have found contradictory results. Urroz et al. investigated the effects of acupuncture on exercise recovery in 60 adults, using PC6, S36, L7, and RN17 points, and found that acupuncture or acupuncture with instruction did not have evidence in maximal exercise recovery.³⁴ Dhillon, S. recruited 20 adult men and investigated the acute effect of acupuncture on the performance of a 20 km cycling test, using S36, GB34, Li3, LI11, and DU20 points. The study concluded that lactate values were higher in the real acupuncture group than in the control group.³⁵

Despite these contradictory results, our study adds to the growing body of evidence suggesting that acupuncture may be beneficial for lactate removal and fatigue recovery after exercise. Further research is needed to fully understand the mechanisms behind these effects and to determine the optimal acupuncture points and techniques for maximal efficacy.

Study limitations

The main limitation of this study is due to the very small sample size, so we must exercise caution in its observation. It is necessary to include a larger sample to obtain more reliable results and allow for a detailed statistical analysis. Another limiting factor is that only the placebo and real acupuncture groups were included. It is necessary to include a control group, as any skin penetration in any part other than acupuncture points can induce physiological responses.

Another limitation is the time of application after the tests. We lose about 5 to 10 min to insert the acupuncture needles, and during this period, a significant part of the recovery has already occurred.

In the future, an identical study can be conducted with athletes and a larger sample size that includes the control group, in addition to the groups included in this study. It is also possible to study the variability of heart rate and oximetry throughout the study (when taking the test and

then when applying acupuncture techniques or not), attempting to reach more conclusive results in this regard. New variables can also be added to the study, such as assessing pain and maximal oxygen uptake consumption.

Conclusions

In this study, despite the small sample size, we can observe that when the real acupuncture technique was applied, we noticed a decrease in lactate values at 30 and 60 min after the Wingate test. Regarding heart rate and oximetry, we cannot draw conclusions about the influence of acupuncture on exercise recovery, as these results are inconsistent.

We can affirm that acupuncture is an effective method to increase the capacity of recovery during intense physical exercise. However, caution should be taken when interpreting these results, as a larger sample size and control group are necessary to obtain a more reliable and detailed statistical analysis. In future studies, additional variables such as pain evaluation and maximal VO₂ consumption can also be included to further investigate the effects of acupuncture.

Conflict of interest

There are no affiliations, financial associations, or other conditions that might pose a conflict of interest concerning the publication of this manuscript.

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Patients' data protection

The authors hereby confirm their strict adherence to the protocols set forth by their respective institutions for obtaining access to subject data. This access was undertaken exclusively with the clear and dedicated purpose of advancing scientific inquiry and fostering scholarly dissemination.

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