

# The Effects of Post-Collection Time and Transport Temperature on Lactic Acid Integrity: A Comprehensive Literature Review

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## ABSTRACT

**Background:** Accurate measurement of lactic acid levels is crucial in both clinical and athletic settings, as it provides valuable insights into metabolic status and performance. However, factors such as post-collection processing time and transport temperature significantly influence lactate integrity, potentially leading to misinterpretation of results. This review aims to synthesize existing literature regarding the effects of pre-analytical conditions on lactic acid measurements and to establish practical guidelines for maintaining measurement accuracy.

**Methods:** A comprehensive literature review was conducted, focusing on studies examining the impact of processing time, temperature, and physiological factors on lactate stability.

**Results:** The key findings indicate that lactate concentrations can increase significantly if blood samples are not processed within 15 minutes at room temperature and that samples stored at room temperature exhibit higher lactate levels than those kept on ice. Additionally, physiological factors such as exercise timing and individual training status can further complicate lactate assessments. The results underscore the importance of standardizing protocols for blood sample handling, emphasizing the need for immediate processing and strict temperature control. It was found that misinterpretations of lactate levels due to improper handling could adversely affect clinical decisions and athletic evaluations.

**Conclusion:** Ensuring the integrity of lactate measurements necessitates adherence to best practices in sample processing and storage. Recommendations include implementing standardized protocols, enhancing clinician and athlete education on lactate monitoring, and conducting further research into the long-term effects of pre-analytical conditions on lactate stability. By addressing these factors, healthcare providers and sports professionals can significantly improve the reliability of lactate assessments.

**Keywords:** Lactic Acid; Lactate Measurements; Post-Collection Time; Transport Temperature; Sample Processing; Metabolic Assessment

## Introduction

Lactic acid, a key metabolite produced during anaerobic metabolism, plays a crucial role in various physiological processes, particularly in the context of exercise and recovery (Mastalerz, et al. [1]). The study of lactic acid concentrations has garnered significant attention in both clinical and athletic settings, as it serves as an important biomarker for metabolic stress, exercise intensity, and overall physiological status (Van Hall, et al. [2]). Understanding the factors that influence lactic acid integrity, particularly post-collection time and transport temperature, is essential for ensuring accurate assessments in both research and clinical practice (Siquier Coll, et al. [3]). Lactic acid is primarily produced during glycolysis, especially when oxygen availability is limited, leading to anaerobic conditions (Mao, et al. [4]). The accumulation of lactic acid in the bloodstream can provide insights into an individual's metabolic state, particularly during high-intensity exercise. Elevated levels of lactate are typically associated with fatigue and decreased performance, making its measurement a valuable tool for athletes and trainers (Mastalerz, et al. [1]). Furthermore, lactate concentrations can also serve as a prognostic indicator in clinical settings, helping to evaluate the severity of conditions such as sepsis or heat-related illnesses (Yu, et al. [5]). The integrity of lactic acid measurements can be significantly affected by pre-analytical factors, including the time elapsed between blood collection and analysis, as well as the temperature at which samples are stored and transported (Jones, et al. [6]). Delays in processing blood samples can lead to alterations in lactate concentrations due to metabolic changes in the sample, such as continued glycolysis and lactate production by blood cells (Calatayud, et al. [7]).

Therefore, understanding how these factors influence lactic acid integrity is essential for ensuring reliable results in both athletic and clinical contexts. Research has indicated that temperature plays a pivotal role in the stability of lactate concentrations in blood samples. For instance, Seymour, et al. [8] demonstrated that lactate levels in whole blood are significantly affected by storage conditions, with samples kept at room temperature showing more considerable increases in lactate concentration compared to those stored on ice. This finding underscores the importance of maintaining appropriate storage conditions to preserve the integrity of lactate measurements, particularly in emergency and pre-hospital settings where timely analysis is critical. Moreover, the duration of time that blood samples are left unprocessed can also have a substantial impact on lactate concentrations. Jones, et al. [6] found that lactate levels in venous blood remained stable for up to 15 minutes under specific storage conditions, highlighting the necessity for prompt processing to avoid inaccurate results. Failure to account for these pre-analytical variables can lead to erroneous interpretations of an individual's metabolic state, potentially affecting clinical decision-making and athlete training regimens. In the context of exercise physiology, the response of lactate concentrations to various types of exercise has been extensively studied. Heden, et al. [9] explored how resistance exercise impacts fasting and postprandi-

al blood lactate levels in individuals with type 2 diabetes, revealing that the timing of exercise relative to meals significantly influences lactate responses. This highlights the need for careful consideration of exercise protocols when assessing lactate levels in both clinical and athletic populations. Additionally, the effects of transport conditions on lactate integrity have been documented in various studies.

Ling, et al. [10] investigated how processing and storage conditions affect D- and L-lactate concentrations in bovine blood samples, providing insights into the stability of lactate measurements over time. Their findings indicated that lactate concentrations remained stable for up to 48 hours when samples were separated promptly, emphasizing the importance of timely processing in maintaining accurate assessments. The relationship between exercise intensity, metabolic response, and lactate production is further complicated by factors such as blood volume and transport capacity. Schierbauer, et al. [11] examined how blood volume influences lactate concentrations during incremental exercise, revealing significant correlations between systemic lactate levels and blood volume. This relationship underscores the complexity of lactate metabolism and the need to consider multiple physiological variables when interpreting lactate measurements. Therefore, the measurement of lactic acid is a critical aspect of both clinical assessments and athletic performance evaluations. However, the integrity of lactate measurements is susceptible to various pre-analytical factors, particularly post-collection time and transport temperature. Understanding the influence of these variables is essential for ensuring accurate and reliable results, which can inform clinical decision-making and optimize athletic training programs. This literature review aims to explore the effects of post-collection time and transport temperature on lactic acid integrity.

## Research Objectives

This research seeks to fulfill the following objectives:

1. To investigate the effects of varying post-collection times on the integrity of lactic acid.
2. To examine the influence of transport temperature on lactic acid levels.
3. To identify specific thresholds for post-collection time and transport temperature that impact the stability of lactic acid.

## Methodology

This study employs the literature review methodology to investigate the effects of post-collection time and transport temperature on lactic acid integrity. The literature search is conducted in key academic databases such as PubMed, Scopus, Web of Science, and Google Scholar, utilizing a combination of keywords and phrases, including "lactic acid integrity," "post-collection time," and "transport temperature," along with Boolean operators to refine results. Inclusion criteria focus on the published peer-reviewed studies that address human or animal samples and employ appropriate measurement techniques

for lactic acid. Non-peer-reviewed articles, studies lacking methodological rigor, and those that do not specifically address lactic acid are excluded. A standardized data extraction form is developed to collect relevant information, including study design, sample size, conditions of post-collection time and transport temperature, and key findings. The methodological quality of included studies is assessed using tools like the Cochrane Risk of Bias Tool and the Newcastle-Ottawa Scale. A thematic synthesis of findings is to be conducted, focusing on the effects of post-collection time, the influence of transport temperature, and identifying specific thresholds impacting lactic acid stability. The discussion addresses the implications of these findings for clinical practice and future research, while also highlighting gaps in the literature.

## Literature Review

Numerous studies have investigated the impact of post-collection time and transport temperature on lactic acid integrity. In a recent study, Yu, et al. [5] examined variations in blood lactate (Lac) levels and lactate clearance rates (LCR) among athletes experiencing heat-related illnesses following high-intensity exercise. This retrospective analysis included 36 patients admitted to an acute care unit over a period from December 2019 to July 2024. Participants were categorized into two groups based on prognosis: the Favorable Prognosis Group ( $\leq 7$  days, 22 cases) and the Poor Prognosis Group ( $\geq 7$  days, 14 cases). Blood lactate levels were measured at admission and at 2- and 6-hours post-admission. The findings indicated that higher lactate levels were linked to increased risk of adverse outcomes, with the 2-hour LCR emerging as a significant prognostic factor for assessing the severity of heat illness and informing treatment strategies. Mastalerz, et al. [1] conducted a study to investigate differences in lactate concentration and anaerobic power among elite and sub-elite 400-meter runners after an intense glycolytic effort. The sample comprised 130 male runners, divided into elite ( $n = 66$ ) and sub-elite ( $n = 64$ ) groups based on their sprinting times. The study measured the power generated during countermovement and squat jumps, followed by two Wingate tests. Results showed that elite runners exhibited significantly higher power outputs, while post-exercise lactate concentrations were notably lower in the sub-elite group, demonstrating that elite and sub-elite runners differ primarily in lactate production rather than utilization.

In another study, Schierbauer, et al. [11] investigated how total blood volume (BV) and blood lactate quantities influenced lactate concentrations during incremental exercise. Twenty-six healthy, non-smoking females underwent a cardiopulmonary exercise test, with measurements taken for maximum oxygen uptake, lactate concentrations, and hemoglobin levels. The results revealed a significant correlation between systemic lactate quantities and lactate concentrations, while an inverse relationship was noted with blood volume. Shifts in blood volume during exercise were found to reduce lactate transport capacity, indicating that total blood volume is a crucial factor in interpreting lactate levels during exercise testing. Heden, et al.

[9] assessed the effects of resistance exercise on fasting and postprandial blood lactate concentrations in individuals with type 2 diabetes. Twelve obese participants completed three two-day trials: no exercise, resistance exercise before dinner, and resistance exercise 45 minutes post-dinner. The study found that lactate levels were significantly higher during the postprandial period when exercise was performed after eating, suggesting that timing and type of exercise play important roles in blood lactate responses. Ling, et al. [10] focused on the effects of processing and storage conditions on D- and L-lactate concentrations in blood samples from calves. The study demonstrated that lactate levels remained stable for up to 48 hours when samples were separated promptly. However, when left in contact with blood cells, both D- and L-lactate concentrations increased significantly over time, emphasizing the importance of timely processing to maintain accurate lactate measurements. Jones, et al. [6] explored how in vitro conditions, including time, temperature, and the use of a tourniquet, affect venous lactate concentrations.

Their findings indicated that lactate levels remained stable for 15 minutes under both refrigerated and room temperature conditions, and the use of a tourniquet did not significantly alter results, reinforcing the reliability of point-of-care lactate measurements in clinical settings. Seymour, et al. [8] examined the stability of whole blood lactate under various storage conditions relevant to out-of-hospital settings. Their study found that lactate concentrations increased differently depending on the storage temperature, with samples kept at room temperature showing significantly higher lactate levels compared to those stored on ice. These findings are crucial for pre-hospital measurement protocols. Connysson, et al. [12] investigated the lactate response in horses subjected to different diets and transport conditions before exercise. Their results indicated that neither diet nor transportation significantly impacted post-exercise plasma lactate levels in trained horses, suggesting that these factors may not influence lactate responses in seasoned athletes. In a similar vein, Calatayud, et al. [7] analyzed how lactate levels vary with time, substrate concentration, and blood cell counts. Their study indicated that delays in processing blood samples could lead to substantial overestimations of lactate concentrations, particularly at room temperature, highlighting the need for prompt analysis to ensure accuracy. Falk, et al. [13] examined how ambient temperature affects blood lactate concentrations during recovery from intense exercise. They found no significant differences in lactate levels between active and passive recovery in different environmental conditions, suggesting that recovery mode rather than temperature may play a more critical role in lactate clearance. The previous studies collectively underscore the critical importance of standardizing lactate measurement protocols, enhancing clinician and athlete education about pre-analytical factors, and continuing research into the interplay of physiological and environmental factors in lactate dynamics. Addressing these areas will contribute to more accurate assessments and improved outcomes in both clinical and athletic contexts.

## Results

The integrity of lactic acid measurements is crucial as variations in post-collection time and transport temperature can significantly affect lactate levels. This literature review synthesizes findings from various studies to address three key research questions:

1. The effects of varying post-collection times on the integrity of lactic acid
2. The influence of transport temperature on lactic acid levels
3. The specific thresholds for post-collection time and transport temperature that impact the stability of lactic acid

### Effects of Varying Post-Collection Times on Lactic Acid Integrity

Several studies have highlighted the significant impact of post-collection time on lactic acid integrity. For example, Ling, et al. [10] demonstrated that when blood samples were processed promptly, lactate levels remained stable for up to 48 hours. However, when samples were left in contact with blood cells, both D- and L-lactate concentrations increased significantly over time. This indicates that timely processing is critical for maintaining accurate lactate measurements (Ling, et al. [10]). In addition, Calatayud, et al. [7] found that delays in processing blood samples could lead to substantial overestimations of lactate concentrations, especially at room temperature. Their study revealed that lactate levels increased significantly when samples were left unprocessed for more than 15 minutes at room temperature, emphasizing the need for immediate analysis to ensure accuracy (Calatayud, et al. [7]). This is particularly important in clinical settings where rapid decision-making is vital. Jones, et al. [6] also contributed to this understanding by exploring how different time intervals affect venous lactate concentrations. They found that lactate levels remained stable for 15 minutes under both refrigerated and room temperature conditions, suggesting a short window for reliable measurements (Jones, et al. [6]). This stability underscores the importance of minimizing post-collection time to avoid inaccurate lactate readings. Moreover, Heden, et al. [9] assessed the effects of resistance exercise on fasting and postprandial blood lactate concentrations. Their findings indicated that the timing of exercise significantly influenced lactate responses, further supporting the notion that post-collection time plays a critical role in lactate integrity (Heden, et al. [9]). These studies collectively indicate that prolonged post-collection times can lead to significant alterations in lactate concentrations, thereby impacting clinical assessments and athletic performance evaluations.

### Influence of Transport Temperature on Lactic Acid Levels

Transport temperature is another critical factor influencing lactic acid levels. Seymour, et al. [8] conducted a study examining the stability of whole blood lactate under various storage conditions. They found that samples stored at room temperature exhibited significant-

ly higher lactate levels compared to those kept on ice (Seymour, et al. [8]). This finding is crucial for pre-hospital measurement protocols, as it suggests that maintaining low temperatures during transport can help preserve lactate integrity. In a related study, Zavorsky, et al. [14] investigated the stability of whole blood lactate specimens under different temperature conditions. They reported that lactate concentrations significantly increased in samples stored at room temperature compared to those kept on slushed ice, further indicating the importance of temperature control during transport (Zavorsky, et al. [14]). These results highlight the necessity of adhering to strict temperature guidelines to ensure accurate lactate measurements. Furthermore, Jones, et al. [6] reinforced these findings by demonstrating that the use of a tourniquet did not significantly alter lactate concentrations, indicating that temperature might be a more critical factor than venous occlusion in determining lactate integrity during transport (Jones, et al. [6]). Thus, maintaining an appropriate transport temperature is essential for preserving the accuracy of lactate measurements.

### Specific Thresholds for Post-Collection Time and Transport Temperature

Identifying specific thresholds for post-collection time and transport temperature that impact lactic acid stability is crucial for ensuring the reliability of measurements. Ling, et al. [10] established that lactate concentrations remained stable for up to 48 hours if samples were processed promptly. However, they also noted that prolonged contact with blood cells led to significant increases in lactate levels, emphasizing the importance of immediate separation of plasma or serum to maintain integrity (Ling, et al. [10]). Calatayud, et al. [7] provided further insights by indicating that a delay of more than 15 minutes at room temperature could result in significant overestimations of lactate concentrations. This finding suggests that a threshold of 15 minutes should be adopted as a guideline for processing blood samples to avoid inaccuracies (Calatayud, et al. [7]). Seymour, et al. [8] indicated that samples stored on ice maintained more stable lactate levels compared to those kept at room temperature, reinforcing the need for strict temperature control during transport. They suggested that maintaining samples at temperatures close to 0°C is optimal for preserving lactate integrity (Seymour, et al. [8]). These findings collectively highlight that specific thresholds for post-collection time (15 minutes) and transport temperature (0°C) are critical for ensuring reliable lactate measurements.

## Discussion

The findings regarding the integrity of lactic acid measurements underscore several critical considerations for clinical practice and athletic performance assessment. The necessity of standardizing protocols for blood sample handling is paramount, particularly concerning post-collection time and transport temperature. The literature indicates that delays in processing can lead to significant inaccuracies in lactate measurements, which is especially concerning in

clinical settings where timely interventions are crucial (Yu, et al. [5]). The variability in post-collection handling practices raises questions about the reliability of lactate levels as a biomarker. In emergency situations, where rapid decision-making is essential, the feasibility of adhering to strict processing timelines may be compromised. This inconsistency could hinder clinicians' ability to make accurate assessments, potentially impacting patient outcomes. Therefore, developing practical guidelines that accommodate the realities of clinical environments while ensuring the integrity of lactate measurements is essential (Green, et al. [15]). Moreover, while established thresholds for processing and temperature control are valuable, they may not be universally applicable. Differences in sample handling across various healthcare settings can lead to inconsistencies in results. For instance, while some studies advocate for immediate processing and stringent temperature control, the operational challenges faced by healthcare providers in emergency and pre-hospital contexts need to be acknowledged. This highlights the necessity of training and resources to support healthcare professionals in maintaining the quality of lactate measurements (Pilegaard, et al. [16]). Additionally, the interplay between physiological factors and lactate levels adds another layer of complexity.

The influence of exercise timing and metabolic state on lactate responses must be factored into clinical interpretations. Changes in lactate concentrations due to exercise may confound the assessment of metabolic conditions, making it imperative for practitioners to consider the context in which lactate measurements are taken (Zajac, et al. [17]). The findings also emphasize the importance of continuous education and awareness among clinicians and athletes about the factors influencing lactate integrity. Understanding the implications of storage conditions and processing delays can empower healthcare providers to implement best practices that enhance the reliability of lactate measurements (Edwards, et al. [18]). Furthermore, future research is needed to explore the long-term effects of various pre-analytical conditions on lactate stability. Investigating the cumulative impact of time and temperature beyond the thresholds currently established could provide deeper insights into optimizing handling protocols (Mao, et al. [4]). While the studies contribute valuable knowledge to the field, the practical application of these findings necessitates a careful balance between ideal practices and the realities of clinical and athletic environments. The body of research on lactic acid integrity presents valuable insights into the factors affecting lactate measurements in clinical and athletic contexts [19,20]. While the studies reviewed offer significant contributions and highlight the importance of standardizing protocols, they also reveal limitations that warrant further investigation. Addressing these gaps through larger, more diverse studies, improved methodologies, and comprehensive analyses of environmental and individual factors will be essential in refining the understanding of lactate dynamics. Ultimately, enhancing the accuracy and reliability of lactate assessments will benefit both clinical practice and athletic performance, leading to better health outcomes and improved training strategies.

## Conclusion & Recommendations

The integrity of lactic acid measurements is vital for accurate clinical assessments and athletic performance evaluations. Variations in post-collection time and transport temperature can lead to significant inaccuracies, impacting patient outcomes and exercise interpretations. The studies reviewed indicate that timely processing and appropriate storage conditions are critical to maintaining reliable lactate levels. Factors such as the timing of sample processing, the environmental conditions during transport, and the physiological context in which lactate measurements are taken all play crucial roles. The evidence supports the notion that even small delays or improper handling can result in notable alterations in lactate concentrations, potentially leading to erroneous clinical decisions or misinterpretations of athletic performance. In clinical practice, the consequences of inaccurate lactate measurements can be severe, particularly in critical care settings where rapid decision-making is essential. Elevated lactate levels are often used as indicators of metabolic distress, sepsis, or shock; thus, understanding how pre-analytical factors influence these measurements is imperative. Similarly, in sports science, lactate levels provide insights into an athlete's metabolic state and performance capabilities, making accurate assessments essential for training and recovery protocols. The literature also reveals that while established thresholds for processing times and temperature control provide a framework for best practices, their practical application can be challenging in real-world settings. Variability in sample handling across different healthcare environments and athletic contexts complicates the standardization of procedures. This underscores the necessity for ongoing research to refine guidelines and develop protocols that can be feasibly implemented in diverse situations.

Based on the findings and discussions, the following recommendations are proposed to enhance the accuracy and reliability of lactic acid measurements:

1. **Standardization of Protocols:** Healthcare facilities and sports organizations should develop and implement standardized protocols for the collection, processing, and storage of blood samples for lactate measurement. These protocols should clearly outline the maximum allowable post-collection time and optimal storage temperatures to minimize variability in results.
2. **Training and Education:** Continuous education and training for healthcare professionals and sports scientists on the importance of pre-analytical factors influencing lactate integrity are essential. Workshops, seminars, and training sessions should be organized to ensure that all personnel involved in the collection and analysis of blood samples are aware of best practices.
3. **Enhanced Transport Systems:** Implementing systems that ensure blood samples are transported under controlled temperature conditions is crucial. Utilizing insulated containers or portable refrigeration units can help maintain the integrity of samples during transport, especially in emergency or remote settings.

4. Research on Long-Term Effects: Further research is needed to explore the long-term effects of various pre-analytical conditions on lactate stability. Investigating the cumulative impact of time and temperature beyond established thresholds can provide deeper insights into optimizing handling protocols.
  5. Integration of Technology: Leveraging technology to monitor sample conditions during transport can help ensure compliance with established protocols. Real-time temperature monitoring devices can alert personnel if samples are exposed to unfavorable conditions, allowing for immediate corrective actions.
  6. Individualized Assessment: In sports science, individualized assessment protocols should be developed that consider an athlete's training status, metabolic responses, and specific contexts of exercise. Understanding how different factors interact to influence lactate levels can lead to more accurate interpretations and tailored training programs.
  7. Collaboration Among Disciplines: Encouraging collaboration between clinical practitioners and sports scientists can enhance the understanding of lactate measurements. Sharing knowledge and experiences can lead to improved methodologies and insights that benefit both fields.
  8. Quality Control Measures: Implementing rigorous quality control measures in laboratories that perform lactate testing can help identify potential sources of error. Regular audits and reviews of processing protocols should be conducted to ensure adherence to best practices.
  9. Patient and Athlete Education: Providing education to patients and athletes about the factors that influence lactate measurements can empower them to participate actively in their care or training. Understanding the significance of timing and environmental conditions can promote adherence to protocols that optimize their outcomes.
  10. Policy Development: Healthcare organizations should develop policies that mandate adherence to established guidelines for lactate measurement. These policies should be regularly reviewed and updated based on the latest research and technological advancements.
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