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REVIEW
PREGLEDNI ZNANSTVENI RAD

VALIDATION OF PORTABLE BLOOD LACTATE ANALYZERS VERSUS LABORATORY REFERENCE METHODS IN SPORT AND EXERCISE PHYSIOLOGY: A SYSTEMATIC REVIEW

VALIDACIJA PRIJENOSNIH LAKTATOMJERA U USPOREDBI S LABORATORIJSKIM REFERENTNIM METODAMA U SPORTU I TJELESNOJ FIZIOLOGIJI: PREGLEDNI RAD

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ABSTRACT

Lactate is a central component of energy metabolism across a wide range of exercise intensities. The understanding of lactate has evolved from its traditional classification as a metabolic by-product of anaerobic metabolism to its recognition as a key intermediary in cellular energy production. In sport and exercise physiology, blood lactate concentration is widely used to monitor exercise intensity and guide useful training methods.

The aim of this systematic review was to evaluate the validity, accuracy, reliability, and precision of portable blood lactate analyzers used in sport and exercise physiology. A systematic literature search was conducted using different scientific databases to identify studies comparing portable blood lactate analyzers with laboratory-based reference analyzers in laboratory and field testing relevant to sport performance. Nine studies met the inclusion criteria and were included in this review.

Across studies, portable lactate analyzers demonstrated acceptable analytical precision but variable agreement with reference analyzers. Measurement of bias and limits of agreement between portable and laboratory devices commonly reached ±1–2 mmol·L⁻¹ blood lactate, with larger discrepancies observed at higher lactate concentrations after 8-10 mmol·L⁻¹. Blood sampling methodology, including the site of sample collection (earlobe or fingertip), was identified as a major contributor to measurement variability, in some cases exceeding device-related errors.

In conclusion, portable blood lactate analyzers can be effectively used in sport performance when their

SAŽETAK

Laktati imaju važnu ulogu u energetskom metabolizmu tijekom tjelesne aktivnosti različitog intenziteta. Suvremeno razumijevanje laktata nadilazi njegovu tradicionalnu ulogu nusprodukta anaerobnog metabolizma, te ga prepoznaje kao važnog posrednika u staničnoj proizvodnji energije. U sportskoj fiziologiji koncentracija laktata u krvi rutinski se koristi za procjenu intenziteta opterećenja i usmjeravanje na primjenu korisnih metoda trenažnih programa.

Cilj ove analize je bio procijeniti valjanost, pouzdanost i preciznost prijenosnih laktatomjera koji se koriste u sportskoj fiziologiji. Sustavno pretraživanje literature provedeno je u relevantnim znanstvenim bazama podataka s ciljem identifikacije studija koje uspoređuju prijenosne laktatomjere s referentnim laboratorijskim analizatorima u laboratorijskim i terenskim uvjetima testiranja povezanima sa sportskom izvedbom. U pregled je uključeno devet studija koje su zadovoljile unaprijed definirane kriterije uključenja.

Rezultati uključenih studija upućuju na to da prijenosni laktatomjeri pokazuju prihvatljivu analitičku preciznost, ali varijabilan stupanj slaganja s laboratorijskim referentnim metodama. Pristranost mjerenja i granice slaganja između prijenosnih i laboratorijskih uređaja najčešće su iznosile ±1–2 mmol·L⁻¹ koncentracije laktata u krvi, pri čemu su veća odstupanja zabilježena pri višim koncentracijama laktata, osobito iznad 8–10 mmol·L⁻¹. Metodologija uzorkovanja krvi, uključujući mjesto uzimanja uzorka (ušna resica ili vrh prsta), identificirana je kao značajan izvor varijabilnosti mjerenja, koji u pojedinim slučajevima nadmašuje pogreške povezane s mjernim uređajem.

methodological limitations are acknowledged. Standardized sampling procedures and cautious interpretation of absolute lactate values are essential, particularly at high exercise intensities.

Keywords: *Exercise physiology, Training intensity, Metabolic parameters, Athletes, Biochemical assessment, Laboratory testing, Field testing*

Zaključno, prijenosni laktatomjeri mogu se primjenjivati u procjeni intenziteta sportske izvedbe, uz jasno razumijevanje njihovih metodoloških ograničenja. Standardizacija postupaka uzorkovanja i oprezna interpretacija apsolutnih vrijednosti laktata nužni su, osobito pri visokim intenzitetima opterećenja.

Ključne riječi: *fiziologija vježbanja, metabolički parametri, laboratorijska testiranja, terenska testiranja*

INTRODUCTION

Over the past two decades in sport performance physiology, the knowledge of lactate has shifted, from its traditional perception as a metabolic "waste" by-product of the anaerobic metabolism and a primary cause of fatigue in exercising, to its recognition as a crucial molecule in cellular energy metabolism.[3,8] This paradigm shift is largely based on the lactate shuttle hypothesis proposed by George A. Brooks. In this theory, lactate is not only produced under anaerobic or hypoxic conditions but is continuously formed even at rest under aerobic (normoxic) conditions, with production markedly increasing during anaerobic exercise. Lactate is subsequently transported both intracellularly and intercellularly, serving as an important oxidative substrate and a precursor for gluconeogenesis, depending on tissue-specific metabolic demands.[3,5] In sport and exercise physiology, blood lactate is linked with measures of exercise intensity, heart rate, and oxygen uptake (VO_2). Blood lactate concentration is widely used to determine training intensity zones, monitor metabolic stress, and guide training prescription in both laboratory and field sport programs.[7,23] For coaches, blood lactate concentration at high-intensity exercises gives information about an athlete's anaerobic work capacity.[9,23] The anaerobic threshold (Ant) can be described as the highest exercise intensity that can be maintained while the energy demand is fully met by oxidative metabolism, as reflected by oxygen uptake measurements. At this intensity, the appearance of lactate in the bloodstream is balanced by its removal, resulting in a stable blood lactate concentration (about - 4 $mmol \cdot L^{-1}$). Although reduced oxygen availability may contribute to increased lactate formation, but current evidence does not support the idea that lactate accumulation beyond the anaerobic threshold is caused by insufficient oxygen delivery. [7,8] This exercise intensity is significant, as it is widely used to evaluate cardiovascular and pulmonary function, the effectiveness of training programs, and to classify exercise intensity into mild, moderate, or vigorous domains.[21,12] Due to practical limitations related to cost, size, and management of laboratory lactate analyzers, portable blood lactate analyzers have been developed and adopted in both field and laboratory sport situations. Despite their widespread use, concerns remain regarding the validity, analytical precision, and agreement of portable analyzers compared with laboratory reference methods. [20,16,2] Methodological factors, such as sampling sites and measurement protocols, may further influence blood lactate readings, leading to heterogeneous results across validation studies.[11,6,24]

Therefore, this systematic review aimed to evaluate the validity, accuracy, precision, and reliability of portable blood lactate analyzers compared with laboratory reference methods in sport and exercise physiology, and to identify methodological factors that influence measurement agreement in applied field or laboratory sport testing.

METHODS

Study design

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. The review synthesizes validation studies evaluating portable blood lactate analyzers used in sport and exercise physiology, with a focus on accuracy, agreement, precision, and reliability relative to laboratory-based reference analyzers in laboratory- and/or field-based exercise testing.

Literature strategy research

A systematic literature search was conducted using the ***Web of Science, PubMed, and Scopus.*** No restrictions on publication year were applied. The included studies were published between 2000 and 2025. The final literature search was completed in December 2025. Search terms were combined using Boolean operators and included keywords related to blood lactate measurement and portable devices, such as blood lactate, lactate analyzer, portable lactate, handheld lactate, lactate meter, validity, reliability, accuracy, exercise, exercise and sport, portable blood lactate analyzers, sport performance, and physiology. Only peer-reviewed articles published in the English language were considered.

Eligibility criteria

Inclusion criteria

This article evaluated portable or handheld blood lactate analyzers from different manufacturers and compared their measurements with those from laboratory-based reference analyzers. At least one indicator of accuracy, agreement, reliability, or validity criteria. The articles were conducted in sport, exercise, or laboratory settings relevant to sport and exercise physiology. The research involved human participants and were published as full-text, peer-reviewed articles in English.

Exclusion criteria

The studies that were excluded from writing this article were conducted exclusively in clinical or medical populations without relevance to exercise or sports training. An article that did not include a comparison with a reference analyzer. Articles that were only reviews, conference abstracts, editorials, or non-peer-reviewed publications were not included in this research.

STUDY SELECTION

Titles and abstracts identified through the literature search were screened for relevance. Full-text articles of potentially eligible studies were then retrieved and assessed in detail against the predefined inclusion and exclusion criteria. Only studies that met all eligibility criteria were included in the final review. Study selection was performed by a single reviewer based on predefined eligibility criteria.

DATA EXTRACTION

Data were extracted independently from each included study using a predefined data extraction framework. The following information was collected: author and year of publication, participant characteristics and sample size (when reported), exercise protocol and testing conditions, type of portable blood lactate analyzer(s) evaluated, laboratory-based reference analyzer, blood sampling method and sampling site, lactate concentration range, and statistical indicators of measurement performance. Indicators of measurement performance included measures of accuracy, agreement, and reliability; bias; limits of agreement; coefficient of variation; typical error; correlation coefficients; and intraclass correlation coefficients, when available. Extracted data were summarized in tabular form and used for narrative synthesis.

Technical specifications of blood lactate analyzers used in validation studies

Portable and laboratory-based blood lactate analyzers included in the reviewed validation studies are summarized according to their technical specifications. Information regarding manufacturer, measurement method, required blood sample volume, analysis time, and measurement range was extracted from manufacturer documentation and published literature. To avoid redundancy, each analyzer is described only once, regardless of the number of studies in which it was used. Technical characteristics of the analyzers are presented in Table 1.

Table 1. Technical characteristics of the blood lactate analyzers
Tablica 1. Tehničke karakteristike uređaja za mjerenje laktata u krvi

ANALYZER	MANUFACTURER	ANALYZER TYPE	MEASUREMENT METHODS	SAMPLE VOLUME (μL)	ANALYSIS TIME	MEASUREMENT RANGE
Lactate Pro (LP series*)	Arkray / KDK (Japan)	Portable	Enzymatic amperometric	~5	~45	~0.8–23
Lactate Pro 2	Arkray (Japan)	Portable	Enzymatic amperometric	~5	~15	~0.5–25
Lactate Scout	SensLab GmbH (Germany)	Portable	Enzymatic amperometric	~0.5	~10	~0.5–25
Lactate Plus	Nova Biomedical (USA)	Portable	Enzymatic amperometric	~0.7	~13	~0.3–25
Accusport Accutrend	Roche Diagnostics (Germany / Switzerland)	Portable	Reflectance photometry	~15–20	~60	~0.8–22
YSI 1500 YSI 2300	Yellow Springs Instruments (USA)	Laboratory	Enzymatic amperometric	~25	~60	~0–30

Table 1 continued.
Nastavak Tablice 1.

ANALYZER	MANUFACTURER	ANALYZER TYPE	MEASUREMENT METHODS	SAMPLE VOLUME (μL)	ANALYSIS TIME	MEASUREMENT RANGE
Analox GM7	Analox Instruments (UK)	Laboratory	Enzymatic amperometric	~20	~20	~0–30
Kodak Ektachem	Kodak (USA)	Laboratory	Enzymatic spectrophotometry	~10	~90	~0–30
Radiometer ABL series	Radiometer (Denmark)	Laboratory	Enzymatic amperometric	~20	~60	~0–30
Biosen C-Line	EKF Diagnostics (Germany)	Laboratory	Enzymatic amperometric	~20	~45	~0.5–40
EBIO Plus	EKF Diagnostics (Germany)	Laboratory	Enzymatic amperometric	~20	~45	~0.5–40

RESULTS

The main characteristics of the studies included in this review are summarized in Table 2. Most studies employed incremental exercise protocols performed under laboratory conditions, primarily using cycle ergometers or treadmills, while a smaller number incorporated field-based testing (swimming). Capillary blood sampling was the most used method, with samples collected predominantly from the fingertip or earlobe. According to studies, different portable blood lactate analyzers were compared with laboratory-based reference analyzers, including YSI, Analox GM7, Biosen, EBIO Plus, Radiometer ABL, and Kodak Ektachem systems. Lactate concentrations measured during testing ranged widely, from resting values to those observed during high-intensity and maximal exercise.

After summarizing all the results from **Table 2,** an investigation was made for validity and reliability of different portable blood lactate analyzers. The results of validity and reliability outcomes of the portable blood lactate analyzers are summarized in **Table 3.**

Table 2. Main characteristics of the studies
Tablica 2. Glavne karakteristike uključenih studija

Author (Year)	**Population (N)**	**Context (Lab / Field)**	**Portable Lactate Analyzer(s)**	**Reference Analyzer (Gold Standard)**	**Blood Sample**	**Lactate Range (mmol·L⁻¹)**
Pyne et al. (2000)	Elite male and female athletes (swimmers and cyclists); N not reported (repeated blood samples)	Laboratory validation + applied training-based sampling	Lactate Pro	YSI 2300; Radiometer ABL 700	Capillary (earlobe)	Not reported
McNaughton et al. (2002)	Physically active adult males **(N = 7)**	Laboratory (incremental cycling test under controlled environmental conditions)	Lactate Pro (LP6, LP8); Accusport	Analox GM7; Kodak Ektachem	Capillary (fingertip)	Not reported
Baldari et al. (2009)	Trained men and women (athletes and physically active adults) **(N = 29)**	Laboratory (incremental treadmill and cycling tests; Wingate test)	Accutrend (Accusport); Lactate Pro	EBIO Plus	Capillary (fingertip) and venous	0.8–19.9

Table 2 continued.
Nastavak Tablice 2.

Author (Year)	Population (N)	Context (Lab / Field)	Portable Lactate Analyzer(s)	Reference Analyzer (Gold Standard)	Blood Sample	Lactate Range (mmol·L⁻¹)
Tanner et al. (2010)	Nationally competitive male and female athletes; N not reported	Laboratory + field (incremental swimming, cycling and treadmill tests; routine training sessions)	Lactate Pro; Lactate Scout; Lactate Plus	Radiometer ABL 700	Capillary (earlobe or fingertip; site standardised per athlete)	1.0–18.0
Hart et al. (2013)	Physically active men and women (N = 15)	Laboratory (discontinuous graded exercise test on treadmill)	Lactate Plus	YSI 2300 STAT Plus	Capillary (fingertip)	1.2–16.4
Bonaventura et al. (2015)	Recreationally active adults, male and female (N = 5)	Laboratory (analytical validation; treadmill exercise + rest)	Lactate Pro; Lactate Pro 2; Lactate Scout+; Xpress; Edge; i-STAT	Radiometer ABL90 FLEX (primary); ABL715 (secondary)	Venous (same sample for all analyzers)	~1.0–23.0
Crotty et al. (2021)	Competitive male rowers (N = 22); 44 tests; 258 samples	Laboratory (graded incremental rowing ergometer tests)	Lactate Pro 2 (two devices)	YSI 1500 Sport	Capillary (earlobe; common mixed sample)	≤4.0; 4.1–8.0; >8.0 (up to ~22)
Mentzoni et al. (2024)	Well-trained male endurance athlete (N = 1; 480 measurements)	Laboratory (controlled cycling at multiple intensities)	Lactate Plus; Lactate Pro 2; Lactate Scout 4; TaiDoc TD-4289	Biosen C-Line (primary); YSI Sport 1500 (secondary)	Venous (antecubital vein; cannula)	0.88–4.89
Zhong et al. (2025)	Physically active university students, male and female (N = 40)	Laboratory (incremental SkiErg + 30 s all-out)	Lactate Scout 4	Biosen S-Line	Capillary (earlobe and fingertip parallel sampling)	~2.0–15.5

Table 3. The results of validity and reliability outcomes of the portable blood lactate analyzers
Tablica 3. Rezultati valjanosti i pouzdanosti prijenosnih analizatora laktata u krvi

Portable analyzer	Study (Year)	Reference analyzer	Validity	Bias	Reliability	Performance at high lactate concentrations	Key methodological notes
Lactate Pro	Pyne et al. (2000)	YSI 2300; Radiometer ABL 700	Good validity at low – moderate lactate conc.	Small systematic bias reported	Good	Not specifically reported	Repeated blood samples; number of participants not reported
Lactate Pro; Accusport	McNaughton et al. (2002)	Analox GM7; Kodak Ektachem	Moderate validity	Bias increased at higher lactate	Acceptable	Reduced agreement >8 mmol·L⁻¹	Fingertip sampling; small sample size (N = 7)
Lactate Pro; Accutrend	Baldari et al. (2009)	EBIO Plus	Good validity	Bias generally <1 mmol·L⁻¹	Good	Acceptable up to ~20 mmol·L⁻¹	Mixed capillary and venous samples

Table 3 continued.
Nastavak Tablice 3.

Portable analyzer	Study (Year)	Reference analyzer	Validity	Bias	Reliability	Performance at high lactate concentrations	Key methodological notes
Lactate Pro; Lactate Scout; Lactate Plus	Tanner et al. (2010)	Radiometer ABL 700	Variable across devices	Bias widened with intensity	Acceptable–good	Reduced agreement at high lactate	Mixed sampling sites (earlobe / fingertip)
Lactate Plus	Hart et al. (2013)	YSI 2300 STAT Plus	Good when shared sample used	Bias reduced using same sample	Good	Acceptable	Sampling methodology strongly influenced outcomes
Lactate Pro Lactate Pro 2 Lacate Scout Lactate Edge X press	Bonaventura et al. (2015)	Radiometer ABL90 FLEX	Variable between devices	Limits of agreement up to ±2 mmol·L⁻¹	Device-dependent	Reduced accuracy at high lactate	Venous blood only; analytical validation design
Lactate Pro 2	Crotty et al. (2021)	YSI Sport 1500	Good agreement	Minimal bias at higher lactat conc.; >8 mmol·L⁻¹	High inter-device reliability	Reduced agreement at high lactate	Elite male athletes; common mixed sample
Lactate Plus Lactate Pro2 Lactate Scout 4 TaiDoc TD	Mentzoni et al. (2024)	Biosen C-Line; YSI Sport 1500	High agreement	Very small bias	Excellent	Not assessed (low range only)	Single-subject design; venous blood
Lactate Scout 4	Zhong et al. (2025)	Biosen S-Line	Site-dependent agreement	Higher bias at using fingertip site sample	Moderate	Poorer agreement at high lactate	Sampling site main source of error

Validity of portable blood lactate analyzers

According to studies, portable blood lactate analyzers generally demonstrated acceptable validity for monitoring blood lactate concentration during submaximal and moderately intense exercise. Early validation work by Pyne et al.[20] showed that the Lactate Pro analyzer followed expected physiological changes in blood lactate during incremental exercise testing, indicating good validity when compared with laboratory reference analyzers. Similarly, Baldari et al.[1] reported good validity of both Lactate Pro and Accutrend analyzers across a wide range of lactate concentrations when compared with a laboratory-based reference system. However, validity outcomes were more variable when different portable analyzers were compared within identical protocols or when measurements were obtained during high-intensity exercise. McNaughton et al.[16] reported moderate validity of portable analyzers under normal, hot, and humid exercise conditions, with greater variability observed at higher intensities. Tanner et al.[22] further demonstrated that validity differed across analyzer models, with some devices showing acceptable agreement at lower lactate concentrations but reduced agreement during high-intensity exercise and during greater blood lactate production (>8 mmol·L⁻¹). More recent studies have confirmed these heterogeneous findings. Bonaventura et al.[2] reported variable validity across multiple portable analyzers, particularly at higher lactate concentrations. Crotty et al.[6] found that the Lactate Pro 2 analyzer demonstrated good validity for tracking changes in blood lactate and identifying lactate threshold, despite differences in absolute lactate values compared with a reference analyzer. Mentzoni et al.[18] reported good validity for several portable analyzers across a low lactate concentration range, while Zhong et al.[24] found that Lactate Scout 4's validity depended on the blood sampling site, with better agreement observed when samples were taken from the earlobe.

Bias and agreement between portable and reference analyzers

All included studies reported some degree of bias between portable blood lactate analyzers and laboratory-based reference systems. At low-to-moderate lactate concentrations, mean bias was generally small. Pyne et al.[20] and Baldari et al.[1] reported minor differences in absolute blood lactate values, typically below 1 mmol·L⁻¹, when portable analyzers were compared with reference methods. Hart et al.[11] similarly observed small bias values when portable and laboratory analyzers measured the same blood sample. As blood lactate concentrations increased, bias and disagreement became more pronounced. McNaughton et al.[16] and Tanner et al.[22] reported increasing bias and wider limits of agreement during high-intensity exercise. Bonaventura et al.[2] demonstrated that several portable analyzers systematically underestimate high lactate concentrations. Crotty et al.[6] also reported wider limits of agreement between Lactate Pro 2 and a reference analyzer at lactate concentrations above approximately 8 mmol·L⁻¹. Sampling methodology had a substantial influence on biased outcomes. Hart et al.[11] showed that bias was markedly reduced when portable and laboratory analyzers analyzed an identical blood sample, compared with separate capillary samples. Similar findings were reported by Bonaventura et al.[2] and Crotty et al.[6] Zhong et al.[24] further demonstrated that sampling site significantly affected agreement, with fingertip samples showing larger bias compared with earlobe samples.

Reliability of portable blood lactate analyzers

Within-device reliability was consistently reported as acceptable to high across studies. Pyne et al.[22,] Baldari et al.[1,] and Tanner et al.[22] reported stable repeated measurements when the same analyzer was used under standardized conditions. Hart et al.[11] and Bonaventura et al.[2] similarly observed good repeatability of portable analyzers, supporting their use for repeated measurements in applied settings. Inter-device reliability was evaluated in fewer studies. Pyne et al.[20] and McNaughton et al.[16] reported acceptable agreements between different units of the same analyzer model. Tanner et al.[22] found generally good inter-device reliability for some portable analyzers, although variability increased when different brands were compared. Crotty et al.[6] reported high inter-device reliability between two Lactate Pro 2 units, indicating consistent performance across identical devices. Mentzoni et al.[18] also demonstrated excellent reliability under tightly controlled laboratory conditions, despite noting measurement uncertainty. Greater variability in reliability outcomes was observed when measurement conditions were not fully standardized or when different analyzer brands were compared (Bonaventura et al.[2] , Zhong et al.[24).]

Performance at high blood lactate concentrations

Reduced analytical performance of portable blood lactate analyzers at high lactate concentrations was a consistent finding across studies. McNaughton et al.[16] , Tanner et al.[22], and Baldari et al.[1] reported larger discrepancies between portable and reference analyzers during maximal or near-maximal exercise. Bonaventura et al.[2] showed that agreement decreased substantially at lactate concentrations above approximately 15–20 mmol·L⁻¹. Although correlations between portable and reference analyzers often remained high at elevated lactate levels, agreement in absolute values decreased. Crotty et al.[6] and Zhong et al.[24] reported wider limits of agreement and increased variability at higher lactate concentrations. Mentzoni et al.[18] highlighted that measurement uncertainty contributes to variability even when systematic bias is small, particularly at higher intensities.

DISCUSSION

From the reviewed articles summarized in this review, portable blood lactate analyzers showed acceptable validity for monitoring blood lactate concentration across low, submaximal, and high-intensity levels during sport performance testings.[20,1,22] Across the included studies, portable devices showed good analytical precision and consistent within-device reliability when testing was performed under standardized conditions. These findings support the widespread use of portable lactate analyzers in sport and exercise settings, particularly for monitoring of training intensity.

On the other hand, agreement between portable analyzers and laboratory-based reference systems was variable and depended on several factors, including the device-specific characteristics of the analyzer model, the blood lactate concentration range, and methodological sampling conditions. While the mean bias was generally small at low-to-moderate lactate concentrations, larger discrepancies were consistently reported in almost all articles at higher lactate levels. This suggests that portable analyzers are more reliable for tracking relative changes in blood lactate concentration than for providing precise absolute values during high-intensity exercise. At high blood lactate concentrations, particularly during maximal or near-maximal exercise, portable analyzers demonstrated reduced agreement with laboratory reference methods. Wider limits of agreement and increased variability were commonly reported in this concentration range. Although correlations with reference analyzers often remained high, the accuracy of absolute blood lactate values decreased as lactate concentrations increased. These findings suggest caution when interpreting absolute lactate values obtained from portable analyzers during high-intensity exercise, especially when used to define physiological thresholds or guide training prescriptions.

The important methodological finding of this review is the influence of blood sampling procedures on measurement outcomes. Studies that analyzed identical or mixed blood samples (e.g., earlobe or fingertip vs. venous blood collection) across devices reported greater agreement than studies that relied on separate capillary samples. This indicates that sampling-related factors, such as sampling sites and handling procedures, may contribute to measurement variability and, in some cases, have a greater impact on results than the device's analytical performance. It plays a crucial role in variability between portable and reference analyzers. These findings highlight the importance of standardized sampling procedures when using portable blood lactate analyzers in both research and applied sport practice.

Reliability outcomes further support the use of portable analyzers for longitudinal monitoring. Within-device reliability was consistently reported as acceptable to high across studies, indicating that repeated measurements obtained using the same analyzer under similar conditions are generally stable. Inter-device reliability, when evaluated, was also acceptable within the same model, although greater variability was observed when comparing different analyzer brands. This reinforces the recommendation that athletes and practitioners should consistently use the same analyzer model and, preferably, the same device for monitoring. Taken together, the findings of this review indicate that portable blood lactate analyzers are useful tools for monitoring training intensity and physiological responses in sport and exercise settings, provided their methodological limitations are acknowledged. Their greatest strength lies in their practicality and reliability for repeated measurements within the same athlete and testing context. However, differences between devices, sampling procedures, and lactate concentration ranges limit their use for direct comparison with laboratory reference systems or between different analyzers.

CONCLUSION AND PRACTICAL ADVICE

This systematic review demonstrates that portable blood lactate analyzers represent useful and practical tools for monitoring training intensity in sport and exercise situations, particularly during submaximal and moderately intense exercise. When used consistently under standardized conditions, these devices provide acceptable validity and reliability for longitudinal monitoring within the same athlete. The findings emphasize the importance of using the same portable lactate analyzer, and preferably the same device unit, across repeated measurements. Consistency in blood sampling methodology is essential. Whenever possible, blood sampling from the earlobe appears to yield more consistent agreement with laboratory reference methods than fingertip sampling. In addition, testing protocols should be standardized for exercise modality, intensity progression, and environmental conditions to minimize methodological variability. Portable blood lactate analyzers are particularly well-suited for field-based testing and routine training monitoring; however, caution is required when interpreting high blood lactate concentrations. This review showed that at lactate concentrations above approximately 8–10 mmol·L^{-1}, portable analyzers may exhibit measurement errors of 1–2 mmol·L^{-1} compared with laboratory reference systems. At these higher concentrations, blood lactate typically increases steeply with small changes in exercise intensity, meaning that even a relatively small measurement error can lead to a meaningful misinterpretation of an athlete's physiological status. From a practical perspective, such errors may lead to incorrect identification of training intensity zones, particularly when fixed lactate thresholds (e.g., 2 or 4 mmol·L^{-1}) are used for training prescription. This may lead to either overestimation or underestimation of an athlete's training intensity, potentially affecting training load management and performance adaptation. Therefore, coaches and practitioners should interpret absolute lactate values at high intensities with caution and avoid relying on isolated measurements when making training decisions. In applied practice, portable blood lactate analyzers should primarily be used to monitor relative changes and trends in blood lactate concentration within the same athlete, rather than as precise tools for defining absolute physiological thresholds at high exercise intensities. Awareness of device-specific limitations, adherence to standardized sampling procedures, and cautious interpretation of high lactate values are essential to ensure the valid and effective use of portable blood lactate measurements in sport and exercise settings.

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