

# Relationship between hand dynamometer results and blood plasma lactic acid as indicators of muscle fatigue

Arpandjam'an<sup>1</sup>, Yonathan Ramba<sup>1</sup>, Gaurav Kapoor<sup>2</sup>, Hendrik Hendrik<sup>1\*</sup>

<sup>1</sup> Department of Physiotherapy, Health Polytechnic, Makassar, South Sulawesi, Indonesia.

<sup>2</sup> Department of Physiotherapy, Faculty of Physiotherapy and Diagnostics, Jayoti Vidyapeeth Women's University, Jaipur, Rajasthan, India

\* Correspondence: Hendrik Hendrik; [padanghendrik10@gmail.com](mailto:padanghendrik10@gmail.com)

## ABSTRACT

Fatigue is a protective mechanism of the body that prevents continuous injury and allows recovery after rest. This study aimed to determine the correlation between the results of examining the level of muscle fatigue in the hands of computer operators between the measurement of the blood plasma lactic acid method and the hand dynamometer method. This study was conducted using an observational, cross-sectional design. The study population consisted of male computer operators aged 20–30 years. The sample was selected based on the following inclusion criteria: no history of specific medical conditions such as diabetes mellitus, heart disease, or kidney disorders, and at least one year of experience as a computer operator. Based on these criteria, the final sample included 127 subjects. The results of the paired t-test showed a significant decrease in handgrip strength measured with a dynamometer, with values of  $43.25 \pm 3.32$  before work and  $41.45 \pm 3.62$  after work ( $p < 0.05$ ). Similarly, blood plasma lactic acid levels showed a significant increase, from  $2.93 \pm 0.29$  before work to  $3.67 \pm 0.57$  after 4 hours of typing ( $p < 0.05$ ). These results indicate a relationship between handgrip strength and lactic acid levels, supporting their use as indicators of arm muscle fatigue in computer operators.

## KEYWORDS

Muscle Fatigue; Hand Dynamometer; Blood Plasma Lactic Acid Level

## **1. INTRODUCTION**

Fatigue is a prevalent issue that affects many individuals' performance in various areas, including work and daily life activities and body resistance (Hendrik et al., 2016). Fatigue in the workplace is a growing concern that can have serious consequences for both employees and employers, but until now the problem of fatigue has not been fully addressed by the world of work. Burnout is a phenomenon that can affect anyone, in any job, at any level of an organization, which can affect workers' health (Cotelez et al., 2026). Fatigue is a critical issue in many industries, and accurate research into its causes and potential solutions is crucial for ensuring worker safety and avoiding accidents (Vøllestad, 1997). Fatigue is a serious issue that can have significant safety, health, and productivity implications. Muscle fatigue is a common problem in many physical activities and can affect the performance of athletes or individuals engaged in strenuous work. Various methods can be used in determining fatigue, ranging from the most complicated and expensive methods to simple methods with relatively inexpensive. Muscle fatigue can also be seen from the results of an analysis of measurements of oxygenation in the blood (Muramatsu & Kobayashi, 2014). Local muscle fatigue can also be seen from the results of electromyographic signal analysis (Jebelli & Lee, 2019). These efforts are different from the efforts offered by researchers, namely how to assess the presence of muscle fatigue by using blood plasma lactic acid levels and the ability to contract muscles with a hand dynamometer. Muscle fatigue is a phenomenon that occurs when muscles are subjected to prolonged or intense exercise. A muscle fatigue study can help us better understand the mechanisms underlying this phenomenon, and how we can optimize training and recovery strategies to improve athletic performance. According to Hendrik & Notobroto (2016) there is a relationship between changes in blood plasma lactic acid levels and the ability to contract fingers and arms before and after working at the computer for 4 hours.

The two measurement methods mentioned above can be used as parameters for the occurrence of forearm muscle fatigue of computer operators after carrying out activities. The problem above can be used as a measurement method because it can be done quickly, easily, and at a lower cost. Because of the importance of early diagnosing the presence of work-related muscle fatigue as a triggering factor for worker injury, it is necessary to conduct this research.

This study aims to determine the relationship between the results of checking the level of hand muscle fatigue of computer operators between blood plasma lactic acid measurement methods and the hand dynamometer method as a parameter of computer operator muscle fatigue after working for 4 hours.

## **2. METHODS**

### **2.1. Design and Participants**

This research was an observational study with a cross-sectional design. The research was conducted in the community, namely a computer rental place in Makassar city from April to September 2022. The study participants consisted of 127 male subjects aged 20–30 years. All participants were certified as healthy by a physician, with no history of medical conditions and no musculoskeletal disorders. Additionally, participants were required to work at a computer for a minimum of four hours per day. This research has received ethical review approval from the Makassar Health Polytechnic Health Research Ethics Commission with Number 0023/M/KEPK-PTKMS/III/2022.

### **2.2. Measurements and Procedure**

The main sources needed in this study were 1) a hand dynamometer to measure muscle contraction ability, 2) blood plasma lactic acid levels to measure total lactic acid levels in blood, 3) environmental thermometer to measure room temperature, lux meter to measure indoor light intensity room.

Measurement of blood plasma lactic acid was carried out using an accutrend measurement tool that has been validated by comparing the results of laboratory measurements as a standard measuring tool. Measuring blood lactic acid levels is done by cleaning the finger to be pricked using alcohol, then the finger is pricked with a lancet so that blood comes out (0.5 ml) and dripped onto strep paper and then inserted into a blood chemistry analysis tool, for a few moments then you can see or read the results of the analysis of lactic acid content in the blood. Every time blood is taken and measured, it is noted that the area to be punctured must be sterile using alcohol and lancets and strep can only be used once. To measure the ability to contract muscles, a Yanmar hand dynamometer is used where the examination is carried out with the elbow joint position at 90° and the shoulder position in a neutral position, where measurements are made 3 times, then the best value is taken as research data. All subjects work at the computer by typing the manuscript with the same volume.

Proof of the effectiveness of the method used is carried out in several steps: 1) the purpose of the validation report of this measuring instrument is to assess the validity and reliability of certain instruments used for data collection., 2) measure the computer skills of the operator's hand muscles using a hand dynamometer before and after working in in front of the computer for 4 hours, 3)

measuring blood lactic acid levels by taking blood + 0.5 ml, before and after working in front of the computer for 4 hours, 4) comparing the results of the measurements of the two methods to determine the increase in blood plasma lactic acid levels and decreased ability of muscles to contract.

### 2.3. Statistical Analyses

The Statistical Package for the Social Sciences (SPSS) was used for data analysis. A paired sample t-test was used to compare muscle contraction ability and blood plasma lactic acid levels before and after work, and Spearman's test to determine the correlation between changes in muscle contraction ability with changes in blood plasma lactic acid levels after work. Statistical significance was set at a p-value  $\leq 0.05$ .

## 3. RESULTS

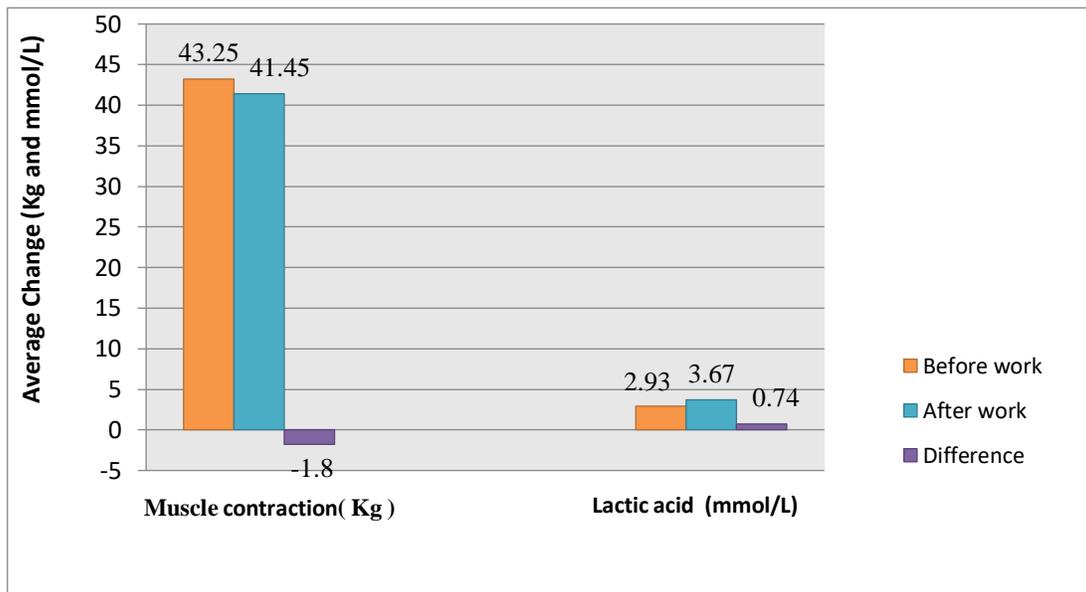
Based on the analysis of the aims and benefits, the researchers chose the two methods to see if there was a correlation between the two methods as a parameter to determine the presence or absence of muscle fatigue, namely the hand dynamometer method, and blood plasma lactic acid levels. Both methods show differences in the measurement of results before and after doing work on the computer for four hours. More details can be seen in Table 1.

**Table 1.** Analysis of computer operator forearm muscle fatigue measurement results on hand dynamometer and blood plasma lactic acid measurements

Variable	Before work		After work		t	p
	Mean	SD	Mean	SD		
Hand Dynamometer (kg)	43.25	3.32	41.45	3.62	8.88	0,015
Blood plasma lactic acid levels (mmol/L)	2.93	0.29	3.67	0.57	-15.79	0.011

Table 1 shows that the measurement using the hand dynamometer method for the ability of the forearm muscle contraction of computer operators before work is  $43.25 \pm 3.32$  kg and after working for 4 hours on the computer has the ability of  $41.45 \pm 3.62$  kg, which means there is a change in the form of a decrease in the ability to contract muscles. In the paired sample t-test statistical test, it was found that there was a significant change in the decrease in the ability to contract muscles with a value of  $p = 0.015 < 0.05$ , which means that measurements with a hand dynamometer showed that there was a decrease in the ability of the forearm muscle contraction of computer operators after working 4 hours at the computer.

In measurement using the blood plasma lactic acid method, blood lactic acid levels in computer operators before work were  $2.93 \pm 0.29$  mmol/L and after working for 4 hours at the computer, blood lactic acid levels were  $3.67 \pm 0.57$  mmol/L, which means there is a change in the form of increased levels of lactic acid in the blood of computer operators. In the paired sample t-test statistical test, it was found that there was a significant change in lactic acid levels in the computer operator's blood with a p-value =  $0.011 < 0.05$ , which means that measurement of blood plasma lactic acid levels showed a decrease in the ability of the computer operator's forearm muscle contractions after working 4 hours on the computer as a parameter of muscle fatigue.



**Figure 1.** Methods of measuring muscle fatigue

The value of hand muscle fatigue after working on a computer between groups is the difference in the average value of computer operator muscle fatigue between hand dynamometer measurements and measurements of blood plasma lactic acid levels. The average value of hand muscle fatigue between measurement methods after working on the computer for 4 hours can be seen in Table 2.

**Table 2.** Relationship between finger and forearm muscle fatigue, muscle contraction ability, and blood plasma lactic acid levels

Variable	Mean	SD	Min	Max	$r_s$	$p$
Changes in the ability to contract muscles (kg)	-1.80	0.12	-9.00	0.00	0.657	0.000
Changes in lactic acid levels (mmol/L)	0.74	0.21	0.10	1.40		

Spearman's test results on the relationship between changes in the ability of computer operators to contract muscles before and after working for four hours at the computer with changes in blood plasma lactic acid levels before and after working for four hours at the computer show a relationship with a significant value of  $0.000 < 0.05$ , where the change the ability of computer operators to contract finger and forearm muscles was  $-1.80 \pm 0.12$  kg with the lowest change being  $-9.00$  kg and the highest being  $0.00$  kg. The change in blood plasma lactic acid levels was  $0.74 \pm 0.21$  mmol/L with the lowest change being  $0.10$  mmol/L and the highest being  $1.40$  mmol/L. Thus there is a relationship between changes in the ability to contract muscles with changes in blood plasma lactic acid levels of computer operators, meaning that the higher the decrease in muscle contraction ability, the higher the increase in blood plasma lactic acid levels in the forearm muscle fatigue of computer operators.

#### **4. DISCUSSION**

Analysis of the characteristics of the sample in this study shows that the age factor of the sample is homogeneous because of previously defined limits so that the age of the sample is considered the same. The research was conducted in the community, namely computer rental places in the city of Makassar from April to September 2022. Because the age of the samples is the same, it can be said that the changes that occur in the sample are not due to the age factor. This is because muscle mass, muscle morphology, energy metabolism, and neuromuscular activation are considered to be relatively the same (Hendrik et al., 2016). Muscle fatigue is a complex symptom as a result of the influence of neuromuscular factors, where age is a factor of resistance to fatigue (Ratel et al., 2013).

Measurements with a hand dynamometer show that there is a decrease in the ability of computer operators to contract the forearm muscles after working 4 hours at the computer. This can happen because by working, the muscles experience continuous contractions, causing a decrease in their ability to contract. The decrease in muscle contraction after working 4 hours at the computer causes a decrease in blood supply along with ions or molecules that play a role in the process of muscle contraction, such as  $H^+$ ,  $O_2$ ,  $K^+$ , and  $Na$ , causing fatigue in the muscles (Russ et al., 2008). Fatigue can also occur due to changes that are localized at the neuromuscular junction, causing a decrease in the efficiency of muscle contractions (Lindinger & Cairns, 2021). A decrease in the ability to contract the arm muscles can be seen when pulling the grip on the hand dynamometer as a result of the reduced ability of the muscles to contract, so it can be concluded that the decreased

ability of the arm muscles to hold the hand dynamometer after working 4 hours in front of the computer is due to fatigue.

Likewise with the examination of blood plasma lactic acid levels as a parameter of muscle fatigue. This happens because there are differences in blood plasma lactic acid levels before work and after working 4 hours at the computer. An increase in blood plasma lactic acid levels as a result of muscle contractions indicates fatigue. The method of blood plasma lactic acid levels can be used as a parameter of muscle fatigue, muscle fatigue can occur because repeated muscle contractions for a long time cause glycogenolysis and glycolysis which in turn causes lactic acidosis and disturbances in muscle and plasma pH as well as disturbances in energy charge and ion balance (Fernandes et al., 2014; Brooks, 2001). This method can be used as a parameter of muscle fatigue as the basis for research results which state that there is a correlation between intra-muscle lactate or H<sup>+</sup> accumulation and a decrease in strength during muscle fatigue. In addition, induced acidosis can impair muscle contractility, causing higher fatigue (Brooks, 2001). Lactic acid also increases when muscles contract because mitochondria cannot oxidize all the pyruvate produced, so pyruvate becomes lactate in the myoplasm. Increased lactate is directly related to H<sup>+</sup> production which causes a decrease in intramuscular pH which has an impact on fatigue (Westerblad et al., 2002; Cairns, 2006; Jäkel et al., 2021). Thus, it can be concluded that the measurement of muscle fatigue can be known by measuring the levels of lactic acid in blood plasma. Because the two methods mentioned above can be used in measuring muscle fatigue, and the results of the analysis obtained that there is a significant relationship between changes in the ability of computer operators to contract muscles with changes in blood plasma lactic acid levels before and after working for four hours at the computer, meaning that the higher the reduction muscle contraction ability, the higher the increase in blood plasma lactic acid levels in the arm muscle fatigue of computer operators.

A decrease in the ability to contract muscles after work occurs due to static muscle contractions for a long time so the ability to contract muscles is weakened because the muscle fibers lack adenosine triphosphate (ATP) as a result of pressure on the blood vessels so that blood flow to the muscles that are contracting is obstructed (Cheng et al., 2019; Sundberg & Fitts, 2019). Fatigue can also occur due to physiological factors, when the muscles contract, the blood that is between the muscle fibers or outside the blood vessels of the muscles is pinched so that blood flow is obstructed which causes the exchange of substances to be obstructed resulting in muscle fatigue (Sucharit et al., 2019; Yu, 2020). Fatigue can also occur due to the depletion of ATP and CP (creatine phosphate) stores. When ATP and PC are used for continuous contraction, fatigue will arise. This is due to the

depletion of intracellular phosphagen. In other circumstances, the accumulation of lactic acid in the bones causes the intracellular H<sup>+</sup> concentration to increase. An increase in H<sup>+</sup> ions in muscles can suppress muscle function so that the muscles experience fatigue. Thus, the presence of continuous static muscle work without a rest phase causes high energy consumption so that ATP energy is produced anaerobically, causing the accumulation of lactic acid to increase (Fiorenza et al., 2019; Theofilidis et al., 2018). Thus, continuous muscle work can cause a decrease in the ability of muscle contractions and increase blood plasma lactic acid. This means that there is a relationship between changes in the strength of muscle contractions with changes in blood plasma lactic acid levels in computer operators after working for 4 hours at the computer.

## 5. LIMITATIONS

This cross-sectional study has several drawbacks, including the sample size which is considered insufficient for observational studies, besides the two methods of measuring a variety of muscle fatigue parameters, they cannot identify the type of fatigue being measured, both local fatigue and general fatigue.

## 6. CONCLUSIONS

There is a relationship between the measurement results of changes in the ability of muscle contraction with changes in blood plasma lactic acid levels in forearm muscle fatigue of computer operators after working 4 hours at the computer. Because the two measurement methods have a relationship, it is better if one of them can be used as a parameter for muscle fatigue.

## 7. REFERENCES

1. Brooks, G. A. (2001). Lactate doesn't necessarily cause fatigue: Why are we surprised? *The Journal of Physiology*, 536(1), 1-16. <https://doi.org/10.1111/j.1469-7793.2001.t01-1-00001.x>
2. Cairns S. P. (2006). Lactic acid and exercise performance: culprit or friend?. *Sports Medicine*, 36(4), 279–291. <https://doi.org/10.2165/00007256-200636040-00001>
3. Cheng, A. J., Hwee, D. T., Kim, L. H., Durham, N., Yang, H. T., Hinken, A. C., Kennedy, A. R., Terjung, R. L., Jasper, J. R., Malik, F. I., & Westerblad, H. (2019). Fast skeletal muscle troponin activator CK-2066260 increases fatigue resistance by reducing the energetic cost of muscle contraction. *The Journal of Physiology*, 597(17), 4615–4625. <https://doi.org/10.1113/JP278235>
4. Cotelez, L. A., Serra, M. V. G. B., Ramos, E., Zaia, J. E., Toledo, F. O., & Quemelo, P. R. V. (2016). Handgrip strength and muscle fatigue among footwear industry workers. *Fisioterapia em Movimento*, 29(2), 317–324. <https://doi.org/10.1590/0103-5150.029.002.AO10>
5. Fernandes, A. de A., Brito, C. J., Vieira, B. C., & Marins, J. C. B. (2014). Effect of peripheral muscle fatigue during the testing of handgrip strength. *Fisioterapia em Movimento*, 27(3), 407–412. <https://doi.org/10.1590/0103-5150.027.003.ao11>
6. Fiorenza, M., Hostrup, M., Gunnarsson, T. P., Shirai, Y., Schena, F., Iaia, F. M., & Bangsbo, J. (2019). Neuromuscular Fatigue and Metabolism during High-Intensity Intermittent

- Exercise. *Medicine and Science in Sports and Exercise*, 51(8), 1642–1652. <https://doi.org/10.1249/MSS.0000000000001959>
7. Hendrik, H., & Notobroto, H. B. (2016). The effect of work position on fatigue on the arm muscles of computer operator. *Dama International Journal of Researchers*, 1(10), 33–37.
  8. Hendrik, H., Suwandi, T., JM, H., & Notobroto, H. B. (2016). Comparison of Results of Measurement Hand Dynamometer with Lactat Acid Blood Plasma for Muscle Fatigue Level Indicator Hand Computer Operator. *International Journal of Sciences: Basic and Applied Research*, 27(2), 53-62.
  9. Jäkel, B., Kedor, C., Grabowski, P., Wittke, K., Thiel, S., Scherbakov, N., Doehner, W., Scheibenbogen, C., & Freitag, H. (2021). Hand grip strength and fatigability: correlation with clinical parameters and diagnostic suitability in ME/CFS. *Journal of Translational Medicine*, 19(1), 1-12. <https://doi.org/10.1186/s12967-021-02774-w>
  10. Jebelli, H., & Lee, S. (2019). Feasibility of wearable electromyography (EMG) to assess construction workers' muscle fatigue. Springer International Publishing.
  11. Lindinger, M. I., & Cairns, S. P. (2021). Regulation of muscle potassium: Exercise performance, fatigue and health implications. *European Journal of Applied Physiology*, 121(3), 721–748. <https://doi.org/10.1007/s00421-020-04546-8>
  12. Muramatsu, Y., & Kobayashi, H. (2014). Assessment of local muscle fatigue by NIRS: Development and evaluation of muscle suit. *ROBOMECH Journal*, 1(1), 1–11. <https://doi.org/10.1186/s40648-014-0019-2>
  13. Ratel, S., Lazaar, N., Williams, C. A., Bedu, M., & Duché, P. (2003). Age differences in human skeletal muscle fatigue during high-intensity intermittent exercise. *Acta Paediatrica*, 92(11), 1248–1254. <https://doi.org/10.1080/08035250310005828>
  14. Russ, D. W., Towse, T. F., Wigmore, D. M., Lanza, I. R., & Kent-Braun, J. A. (2008). Contrasting influences of age and sex on muscle fatigue. *Medicine & Science in Sports & Exercise*, 40(2), 234–241. <https://doi.org/10.1249/mss.0b013e31815bbb93>
  15. Sucharit, W., Eungpinichpong, W., Chatchawan, U., & Peungsuwan, P. (2019). The effects of Thai massage on leg muscle oxygenation and time to fatigue in healthy male subjects. *International Journal of GEOMATE*, 17(61), 14–20. <https://doi.org/10.21660/2019.61.4527>
  - a. Sundberg, C. W., & Fitts, R. H. (2019). Bioenergetic basis of skeletal muscle fatigue. *Current Opinion in Physiology*, 10, 118–127. <https://doi.org/10.1016/j.cophys.2019.05.004>
  16. Theofilidis, G., Bogdanis, G. C., Koutedakis, Y., & Karatzaferi, C. (2018). Monitoring exercise-induced muscle fatigue and adaptations: Making sense of popular or emerging indices and biomarkers. *Sports*, 6(4), 1–15. <https://doi.org/10.3390/sports6040153>
  17. Vøllestad, N. K. (1997). Measurement of human muscle fatigue. *Journal of Neuroscience Methods*, 74(2), 219–227. [https://doi.org/10.1016/S0165-0270\(97\)02251-6](https://doi.org/10.1016/S0165-0270(97)02251-6)
  18. Westerblad, H., Allen, D. G., & Lännergren, J. (2002). Muscle fatigue: Lactic acid or inorganic phosphate the major cause? *News in Physiological Sciences*, 17(1), 17–21. <https://doi.org/10.1152/physiologyonline.2002.17.1.17>
  19. Yu, X. (2020). Fatigue and recovery of Wushu athletes based on fatigue damage model. *IOP Conference Series: Materials Science and Engineering*, 914(1), 1–5. <https://doi.org/10.1088/1757-899X/914/1/012016>

## **ACKNOWLEDGEMENT**

Our thanks go to the subjects who were involved in this research, the City Government of Makassar who gave permission to carry out the research and the Director of the Health Polytechnic of the Ministry of Health who helped in the form of funds during the implementation until the completion of the research.

## **AUTHOR CONTRIBUTIONS**

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

## **CONFLICTS OF INTEREST**

The authors declare no conflict of interest.

## **FUNDING**

This research received no external funding.

## **COPYRIGHT**

© Copyright 2026: Publication Service of the University of Murcia, Murcia, Spain.