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Original Article

Effect of Vibration on the Quality of Blood Transfusion in Whole Blood

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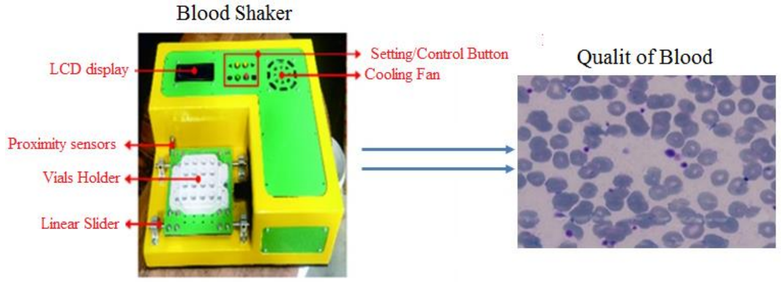
ABSTRACT

Blood transfusion service is a health service effort that includes planning, mobilizing, and maintaining blood donors, supplying blood, distributing blood, and medical acts of giving blood to patients to cure diseases and restore health. Blood for transfusion is transported to the hospital using a cooler box without any equipment. This condition is very likely to reduce blood quality during the transportation process due to vibration during transportation. Indications of damage can be seen in changes in the color of blood plasma. The type of research used in this study was a quasi-experimental design with a pretest-posttest with the control group. This study was divided into 3 groups: Group 1, initial observation without treatment, and final observation in groups 2 and 3. Inclusion criteria were: The age range of 17 to 25 years old, the minimum body weight of 45 kilograms, the minimum HB of 12.5 gr/dl, systolic blood pressure of 110–160 mmHg and diastolic 70–90 mmHg, not currently taking medication within three days, and women not menstruating, pregnant, or breastfeeding. Examination of hemoglobin and erythrocytes was done using a hematology analyzer and LDH examination using spectrophotometry. The results showed that the number of erythrocytes after treatment (posttest) was different according to the treatment group ($p = 0.042$). Treatment in the 5 Hz vibration group reduced the lowest erythrocyte levels, namely to 4,220,000 /mm^3, compared to the control group and 10 Hz vibration. Hemoglobin levels after treatment (posttest) differed according to the treatment group ($p = 0.015$); treatment at 10 Hz vibration reduced the lowest hemoglobin level, namely 10.77 g/dL, compared to the control group and the 5 Hz vibration group. LDH levels after treatment (posttest) differed according to the treatment group ($p = 0.000$).

GRAPHICALABSTRACT



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Introduction

The need for blood transfusions is generally used in medical settings to replace lost blood or to provide certain blood components to patients who continue to suffer from severe injuries, such as those resulting from car accidents or natural disasters, blood disorders, cancer treatment, and organ transplants. Blood transfusion services provided by blood service institutions must maintain blood quality and pay attention to the quality of the handled blood. The handling of blood from collection to distribution should be standardized to ensure the reliability and reproducibility of the results. Blood obtained from donors is expected to pass through several stages, including donor selection, blood collection, labeling, blood examination for infectious diseases through blood transfusion, blood component manufacturing, and the storage stage, where the donor blood will be transfused to patients who will be followed up by the hospital blood bank [1, 2].

Blood distribution from transfusion services to hospital blood banks is carried out using conventional cooler boxes without any tools to maintain temperature stability or prevent vibration effects that can affect the quality of blood components. Damaged blood cells due to inappropriate temperature settings and the presence of a large enough vibration frequency during transportation can be seen in changes in the color of blood plasma [3]. The color of blood is affected by the level of hemoglobin (Hb) due to the presence of iron (Fe) contained in the Hb. Apart from that, damaged blood can be seen from cell viability, namely the number and morphology [3]. A good quality of erythrocyte blood can be seen from the number and morphology of blood cells and LDH levels [4, 5].

Examination of the quality of blood cells can be done by investigating the Peripheral Blood Smear (PBS) and routine hematological examinations. The results of the PBS examination were seen by the morphology of erythrocytes and platelets, while routine hematological examinations were seen by the number of erythrocytes and platelets [6]. This examination is very necessary to maintain the expected blood quality. Blood quality is influenced by several factors, including transportation [1].

Transportation is done from the transfusion service to the hospital's blood bank. If a lot of blood damage is found, of course it will cause losses to both the donor and the recipient. In transportation, it is estimated that 1-5% of erythrocytes will be damaged due to the impact of vibration during the transportation process, whereas every day the viability of erythrocytes will continue to decrease due to decreased levels of Adenosine Triphosphate (ATP) shape from disc to spherical (no central polarity and small size). Therefore, this will affect the quality of the erythrocytes to be transfused [7]. This opinion is reinforced by transfusion studies in experimental animals showing that one of the causes of transfusion reactions in the form of acute lung injury, or Transfusion Reaction Acute lung injury (TRALI), is lysophospholipid-induced oxidative damage caused by the process of blood storage [7]. During storage, morphological changes, biochemical changes, and oxidative stress can damage the red blood cell membrane, causing deformability disorders [3].

Excessive vibration during the blood transport process has the potential to damage the integrity of blood products, such as red blood cells and platelets, and reduce their effectiveness [8, 9]. To minimize the impact of vibration during transport, it is recommended that blood products be transported in insulated coolers and handled with care to prevent overcrowding and excessive movement. In addition, it is important to follow proper storage guidelines and transport protocols as outlined by regulatory agencies and healthcare organizations.

Temperature and vibration control can be used to maintain the erythrocytes quality during transportation. The vibration frequency in blood storage boxes or cooler boxes during transportation must be maintained at not exceeding 10 Hz for 10 minutes because a vibration frequency that is large enough can cause damage to the cell membranes of erythrocytes and platelets [10]. Hence, we need a tool that can stabilize vibrations with a frequency of ≤ 10 Hz to maintain the safety and quality of blood. To control this vibration, researchers will analyze the effect of vibration using a blood shaker machine on the erythrocytes quality in whole blood.

Materials and Methods

Study design and participant

The type of research used in this research is a quasi-experimental design pretest-posttest with the control group. This study was divided into 3 groups. In group 1, observation is initial without treatment, and final observation in groups 2 and 3, there is an initial observation treatment and final observation with inclusion criteria as the age range of 17 to 25 years old, the minimum weight 45 kilograms, HB of at least 12.5 gr/dl, systolic blood pressure 110-160 mmHg and diastolic 70-90 mmHg, not currently taking medication within three days, and women who are not menstruating, pregnant, or breastfeeding, and the exclusion criteria are damage to the storage tube blood as many as 30 respondents were selected by simple random sampling by voting using the application tool Decision Roulette written with the name of the donor and the number of needed samples. Each respondent took 6 cc of blood for the pretest and 6 cc for the posttest. The 6 cc of blood was put into 2 test tubes, 3 cc each (3 cc in the EDTA tube and 3 cc in the anti-clot tube). Test tubes were divided into 3 groups A, B, and C. Group A, namely 2 types of tubes for each type of tube, totaling 20 test tubes, each tube containing 3 cc of blood at" *Blood Shaker Machine*" with no vibration frequency, Group B, namely 2 types of tubes, each type of tube totaling 20 test tubes, each tube containing 3 cc of blood at "Blood Shaker Machine" with a vibration frequency setting of 5 Hz, Group C, namely 2 types of tubes for each type of tube, totaling 20 test tubes, each tube containing 3 cc of blood at "Blood Shaker Machine" with a vibration frequency setting of 10 Hz, after which the test tube was vibrated with each frequency for 15 minutes.

Population

The target population in this study was all blood donors. The affordable population in this study was donors who donated blood at the Semarang Police MU Location organized by UDD PMI Semarang Regency.

Sample size

The sample is a portion of the subjects taken from the entire object under study and is considered to represent the entire population. The sample in this study was a sample of blood bags from some donors who donated blood at the MU Tengaran Salatiga City organized by UTD PMI Semarang Regency, which was determined based on statistical calculations and the method of determining the sample using the simple random sampling. A total of 30 respondents took 6 cc of blood 2 times for pretest and posttest treatment with a total of 60 samples.

Assay for erythrocyte, hemoglobin, and LDH

Erythrocyte examination was carried out using a hematology analyzer flow cytometry method by automatically the tool will display the number of erythrocytes examined in units per cubic millimeter (/mm^3). Hemoglobin examination was carried out using an automated hematology analyzer will display the hemoglobin value checked in g/dL units. LDH examination uses an automatic spectrophotometer that displays the LDH value checked in u/L units.

Statistical analysis

Univariate analysis was carried out to describe the characteristics of the sample on a numerical scale in the form of mean, standard deviation (standard deviation), the maximum and the minimum, and the characteristics of respondents on a categorical scale explained the proportion of each measurement result. Bivariate analysis was performed to test the homogeneity of the sample characteristics on a numerical scale using One-way ANOVA and on categorical characteristics using Fisher's Exact at an alpha of 0.05.

Ethical approval

This research protocol has received approval from the Health Ethics Commission from the Faculty of Public Health, University Diponegoro, with registration number 88/EA/KEPK-FKM/2022.

Results and Discussion

Characteristics of research subjects

The results of research conducted on the analysis of the effect of vibration impact with blood shaker machine on blood quality whole *blood* donors (Table 1). According to Table 1, the highest mean erythrocyte content was in the control group, the highest average HB in the control group, and the highest average LDH in the 5 Hz vibration group.

Results of erythrocyte morphology in the control group with Giemsa staining in Figure 1a, Figure 2a, and Figure 3a showed erythrocyte color within normal limits (normochromic) and shape within normal limits (normocytes) and some cells changed shape (ovalocytes. stomatocytes) and smaller cell sizes (microcytic). In Figure 1b, post-control showed erythrocyte color within normal limits (normochromic), shape appearance within normal limits (normocyte), and smaller cell size (microcytic). Meanwhile. In Figure 2b, post 5 Hz vibration treatment and in Figure 3b *post,* the 10 Hz treatment showed that the color of erythrocytes was within normal limits (normochromic). However, some cells had changed shape (creation).

The number of erythrocytes from One-way ANOVA test obtained the value <0.05 means there is at least a difference between the two groups. A test was carried out after this and showed a significant difference between the control and 10 Hz vibration groups. In contrast, the control group with the 5 Hz vibration group as well as the 5 Hz and 10 Hz vibration group had no difference.

Table 2 presents the test results One-way ANOVA that the erythrocyte levels before the treatment (*pretest*) were in comparable (homogeneous) conditions according to the treatment group (p=0.090). The level of erythrocytes after the treatment (*posttest*) was different according to the treatment group (p=0.042); treatment in the 5 Hz vibration group reduced the lowest levels of erythrocytes 4.220.000 /mm^3 compared to the control group and the 10 Hz vibration group.

Table 1: Characteristics research sample

Variable	Group	Min	Max	Mean	SD
Erythrocytes (/mm^3)	Control	3.89	6.30	4.88	0.71
	Vibration 5 Hz	3.90	5.02	4.37	0.42
	Vibration 10 Hz	3.09	5.32	3.98	0.74
Hemoglobin (g/dL)	Kontrol	11.50	16.40	13.96	1.67
	Vibration 5 Hz	11.90	15.00	13.07	1.22
	Vibration 10 Hz	9.50	15.50	11.52	1.76
LDH (u/L)	Control	112.80	195.30	146.74	25.83
	Vibration 5 Hz	125.10	197.00	161.53	21.68
	Vibration 10 Hz	124.90	190.00	150.38	20.32

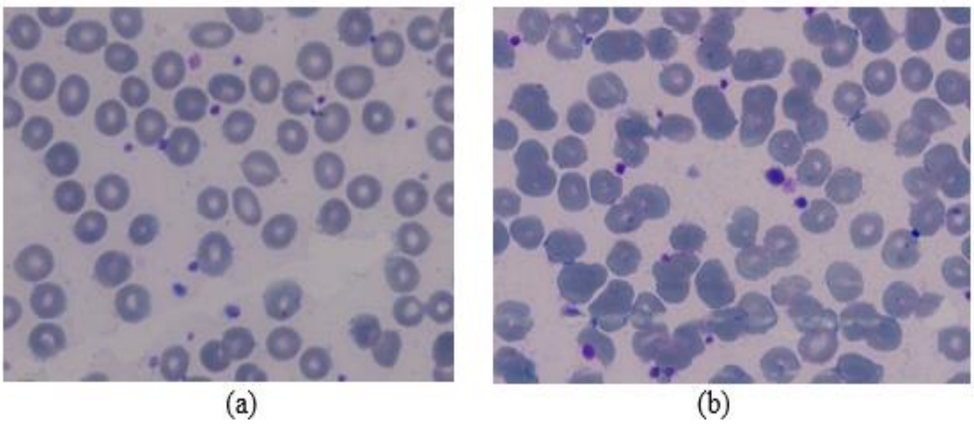

Figure 1: Examination results of the control group blood tests edge (erythrocyte shape) (a) Control-pre and (b) Control-post

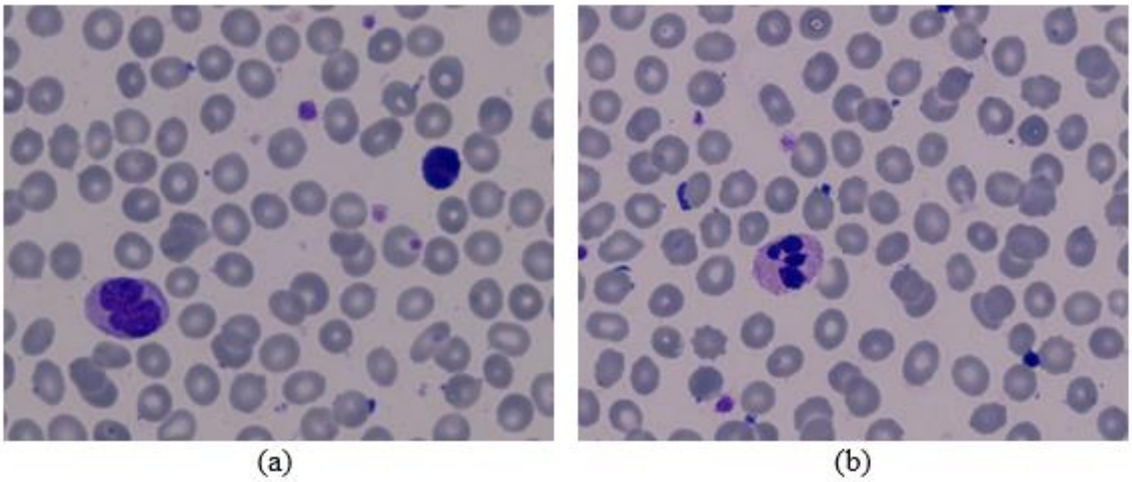

Figure 2: Peripheral blood test results erythrocyte shape) with 5 Hz vibration (a) 5 Hz vibration-pre and (b) 5 Hz vibration-post

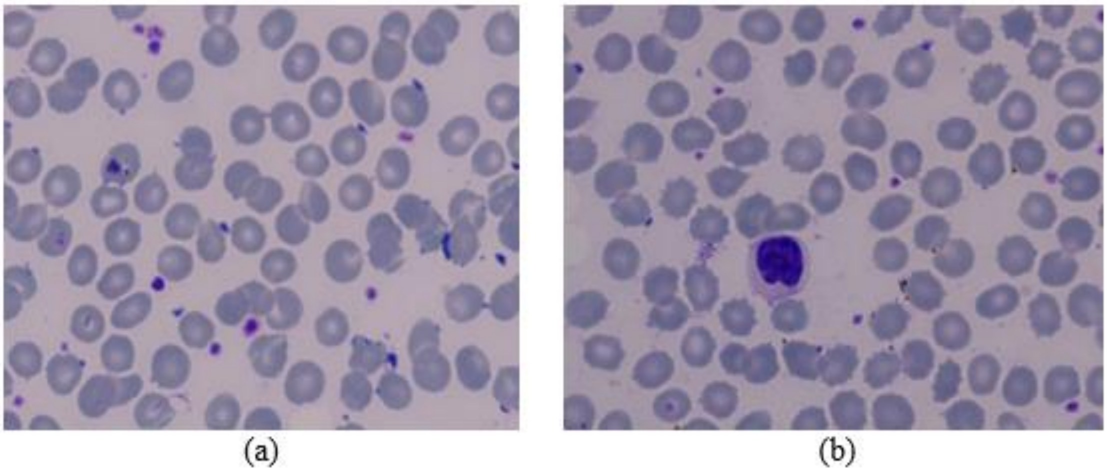

Figure 3: Peripheral blood test result erythrocyte shape) with 5 Hz vibration (a) 10 Hz vibration-pre and (b) 10 Hz vibration-post.

Table 2: Distribution of mean erythrocyte levels and posts between treatments

Measurement Time	Control (million a/µl)	vibration 5 Hz (million /µl)	vibration 10 Hz (million /µl)	*P-value**
Pretest	4.88±0.71	4.37±0.42	3.94±0.71	0.090
Posttest	4.78±3.74	4.22±0.51	3.61±0.74	0.042
Nilai *p***	0.305	0.172	0.017	

**One-way ANOVA and ** Repeated Measure ANOVA.*

Table 2 also describes each treatment group using the test Repeated Measure ANOVA (RANOVA) showed that only in the 10 Hz vibration treatment group was a difference between pre-test and post-test (p= 0.017). 5 Hz vibration treatment was able to reduce the lowest levels of erythrocytes, namely 4.220.000 /mm^3.

Table 3 provides the test results in One-way ANOVA that the hemoglobin level before treatment (*pretest*) in comparable (homogeneous) conditions according to the treatment group (p= 0.060). There were differences in hemoglobin levels after treatment (post-test) according to the treatment group (p= 0.015) and treatment at 10 Hz reduced the lowest hemoglobin level, namely to 10.77 g/dL.

Compared to the control group and the 5 Hz vibration group. Table 3 also describes each treatment group using the test Repeated Measure ANOVA (RANOVA) showed that only in the 10 Hz vibration treatment group was a difference between the *pretest* and *posttest* (*p*= 0.010). 10 Hz vibration treatment reduced the lowest hemoglobin level, which was 10.77 g/dL.

Table 4 shows the test results of One-way ANOVA that LDH levels before treatment (*pretest*) in comparable (homogeneous) conditions according to the treatment group (*p*= 0.322). LDH levels differed after treatment (posttest) according to the treatment group (*p*= 0.000). The 10 Hz vibration treatment group was able to increase the highest LDH levels, namely to 352.53 U/l. Compared to the control group and the 5 Hz vibration group. Furthermore, Table 4 describes each treatment group using the test repeated Measure ANOVA (RANOVA) showed that only in the 10 Hz vibration treatment group was a difference between the pretest and post-test (*p*= 0.005). 10 Hz vibration treatment was able to increase the highest levels of LDH, namely 352.53 U/l.

Table 3: Distribution of mean pre- and post-hemoglobin between treatments

Measurement Time	Control (gr/dl)	Vibration 5 Hz (gr/dl)	Vibration 10 Hz (gr/dl)	*P-value**
Pretest	13.96±1.67	13.07±1.22	11.52±1.76	0.060
Posttest	14.05±1.76	13.28±1.44	10.77±1.73	0.015
*P-value***	0.279	0.138	0.010	

** 0.279; 0.138; 0.010,*One -way ANOVA, and ** Repeated Measure ANOVA*

Table 4: Distribution of mean pre and post LDH Levels between treatments

Measurement Time	Control (gr/dl)	Vibration 5 Hz (gr/dl)	Vibration 10 Hz (gr/dl)	Nilai *p**
Pretest	146.74±25.83	161.53±21.68	150.31±20.32	0.332
Posttest	144.29±27.89	164.20±24.83	352.53±142.91	0.000
Nilai *p***	0.357	0.328	0.005	

** 0.357; 0.328, 0.005 **One-way ANOVA, and ** Repeated Measure ANOVA*

The standard of care for most patients receiving blood transfusions is blood component therapy. Three main products of blood are normally processed: transfusable plasma, platelet concentrate, and red blood cell concentrate. It is a difficult task to ensure that these products are of high quality and provide the desired benefits to patients throughout their shelf life. The development of products stored under non-standard conditions or subjected to additional manufacturing processes (such as cryopreserved platelets, irradiated red blood cells, and lyophilized plasma) has added complexity [11]. Based on the results of this study, only in the vibration group with a frequency of 10 Hz for 15 minutes, there was a change in both the number and morphology of the erythrocytes. According to the results of the research by Johannessen *et al.* (2021), vibrations and turbulence can affect the quality of whole blood [12].

Hemoglobin is an oxygen-binding biomolecule absorbed from the lungs. The amount of hemoglobin in adults is approximately 15.0 grams per cc of blood. The normal value of hemoglobin varies depending on age and sex. The concentration of hemoglobin in people who live in high-altitude areas has a higher hemoglobin value than people who live in low-altitude areas; this is related to the oxygen content in the air [13].

Erythrocyte damage can be seen in the viability of the erythrocytes, namely the number and morphology of the erythrocytes. Erythrocytes contain LDH in large enough quantities [14] which is related to its function as a catalyst in the final stage of erythrocyte glycolysis. Hemolysis that occurs in erythrocytes will release LDH into the plasma. In this case, with higher hemolysis, the plasma LDH level is increased. Therefore, LDH can be used as an indicator of the level of hemolysis that occurs during storage [15-17]. Changes in LDH levels in blood bags stored in cooler boxes during the transportation process can increase in almost all conditions of organ or tissue damage or when cell destruction occurs. Cell damage and hemolysis that occur can also be seen through increased levels of various substances in the plasma that were previously contained by erythrocytes [18]. Changes in the shape of erythrocytes can be caused by reduced ATP in erythrocytes. The number of erythrocytes will also decrease as a result of an error in the ratio between the anticoagulant and the blood volume. High concentrations of anticoagulants cause plasma hypertonicity so that the erythrocyte cells will shrink because the water in the cells will move out of the cells with a higher osmotic pressure. This can cause the erythrocyte cells to change their shape abnormally [19]. Blood to be used for transfusion when experiencing a lesion has the potential to increase the risk of postoperative complications and a higher mortality rate [20, 21].

Study limitation

The testing trials to see damage to blood or a decrease in the quality of blood using Blood Shaker Machine are limited to a maximum of 10 Hz vibration. The test results are limited to 15 minutes; this is still low when applied to applications where the blood during the transportation is more than 15 minutes.

Conclusion

The distribution of blood from transfusion services to hospital blood banks is greatly influenced by the transport process especially vibration. Vibration variation testing on blood quality in whole blood showed that with higher vibration intensity, the quality of erythrocytes hemoglobin and LDH levels are decreased. For blood distribution, vibration dampers are needed to maintain blood quality.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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