

FULL PAPER

Effect of vibration frequency on erythrocyte and platelets damage

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This study aimed to investigate the impact of vibration frequency on the quality of blood components, specifically erythrocytes and Platelets. A device was developed to alter vibration frequency, and the study utilized a pre- and post-test design with a control group. Each group consisted of ten tubes of blood. The study employed one-way ANOVA and Tukey's HSD test to analyze differences in erythrocyte and Platelets numbers. In addition, the Wilcoxon test was used to assess the morphology of erythrocytes and Platelets. The findings revealed significant differences in erythrocyte counts between the 10 Hz vibration group and the 0 Hz and 6 Hz groups, with p-values of 0.00 and 0.00, respectively. Similarly, a significant difference in Platelets counts was observed between the 12 Hz vibration group and the 0 Hz and 6 Hz groups, with p-values of 0.003 and 0.022. These results suggest that certain vibration frequencies adversely affect the quantity of erythrocytes and Platelets in blood samples. In conclusion, it is recommended to avoid excessive vibration during the transportation of blood bags from mobile units to blood donation units to preserve blood quality. It stresses how important it is to keep vibrations to a minimum during the blood transport process. Such precautions can play a crucial role in maintaining the integrity and quality of blood products during transit.

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Introduction

Blood is a life-sustaining fluid that carries oxygen, nutrients, and immune cells throughout the human body, playing a critical role in maintaining homeostasis. It is composed of various components, including red blood cells (erythrocytes) and Platelets (Platelets), which are vital for different physiological functions. Erythrocytes are responsible for oxygen transport, while Platelets play a crucial role in hemostasis,

wound healing, and immunity [1,2]. The preservation and quality of these blood components are of utmost importance in the healthcare sector, especially in blood banks, hospitals, and medical research institutions. Any compromise in the integrity of erythrocytes and Platelets can have severe consequences for patient care and medical procedures. One often overlooked but significant factor that can potentially damage these components is mechanical vibration during transportation and storage[3-5].

Blood products, whether whole blood, packed red blood cells, or Platelets concentrates, are frequently moved from one location to another within healthcare systems. This transportation involves various modes, such as road, air, and rail, where blood products may be exposed to mechanical vibrations, including bumps, jolts, and vibrations that can result from the mode of transportation itself. Additionally, within healthcare facilities, blood products are stored under controlled conditions, and vibration from nearby equipment or transportation within the facility can also impact the blood components [6-8].

Mechanical vibration has been well documented as a potential stressor for biological entities, particularly cells. Erythrocytes and Platelets are not immune to the effects of mechanical forces, and exposure to vibration can lead to structural alterations and functional impairments. These changes can include cell deformation, membrane damage, and even activation in the case of Platelets. Despite the apparent significance of this issue, there is a paucity of comprehensive research focused on the effects of vibration on erythrocytes and Platelets during transportation and storage [9,10]. Literature primarily focuses on the effects of vibration in diverse areas, such as industrial equipment, the transportation of perishable goods, and even the impact on the human body. However, a dedicated exploration of the implications of mechanical vibration on blood components is conspicuously missing.

Methods

The design of this research is "research and development" research to modify and develop blood storage boxes with vibration dampers, carried out at blood donation unit Semarang Regency with a research time plan from June to August

2021. The data collection process was carried out with the help of several enumerators who understand tool testing techniques such as the "Blood Shaker Machine," (Figure 1) taking blood from research respondents (donors), and understanding blood quality checks. The population in this study were research respondents or donors at blood donation unit Semarang Regency, and 15 respondents were selected by simple random sampling. The dependent variable is the quality of erythrocytes and Platelets in terms of number and morphology. The independent variable is the storage and vibration of blood in a test tube. The Shapiro Wilk test was used to determine the normality of the data, and the one-way ANOVA test was used to determine the average change in the number of erythrocytes and Platelets among the three groups, and the Wilcoxon test was used to determine differences in the morphology of erythrocytes and Platelets between the three groups.

Results

Table 1 indicates that quantitatively, it was found that there was a decrease in the number of erythrocytes in all groups, both the control group and the treatment group with a vibration setting of 6 Hz and a vibration setting of 12 Hz. Quantitatively, it was found that there was a decrease in the number of Platelets in settings starting from 6 to 12 Hz vibration. Table 2 illustrates that quantitatively it was found that there was a decrease in the number of erythrocytes and the number of Platelets in settings starting from vibrations of 6 to 12 Hz. The number of erythrocytes and Platelets counts in settings starting from vibrations of 6 to 12 Hz.



FIGURE 1 Results of the design tool "Blood Tube Shaker Machine"

TABLE 1 Description of the number of erythrocytes

| Group | | Before Shaking | | After Shaking | | Decrease in the Number of Erythrocytes or Platelets | |
|-------|-------------------|----------------|------|---------------|------|---|------|
| | | Mean | SD | Mean | SD | Mean | SD |
| 0 Hz | Erythrocyte Count | 4.91 | 0.71 | 4.77 | 0.73 | 0.13 | 0.28 |
| | Platelets Count | 274.6 | 46.2 | 271.9 | 46.4 | 3.00 | 2.20 |
| 6 Hz | Erythrocyte Count | 4.44 | 0.50 | 4.40 | 81.3 | 0.04 | 0.04 |
| | Platelets Count | 285.0 | 81.3 | 272.0 | 81.4 | 13.0 | 9.50 |
| 12 Hz | Erythrocyte Count | 3.99 | 0.74 | 3.47 | 0.70 | 0.52 | 0.18 |
| | Platelets Count | 399.4 | 74.3 | 348.0 | 78.7 | 14.2 | 7.10 |

TABLE 2 Description of changes in the morphology of erythrocyte and Platelets cells

| Group | | Erythrocyte Before Shaking | | | | Erythrocyte After Shaking | | | |
|-------|-------------|----------------------------|-----|----------|---|---------------------------|-----|----------|----|
| | | Normal | | Abnormal | | Normal | | Abnormal | |
| | | n | % | n | % | n | % | N | % |
| 0 Hz | Erythrocyte | 10 | 100 | 0 | 0 | 9 | 90 | 1 | 10 |
| | Platelets | 10 | 100 | 0 | 0 | 7 | 70 | 3 | 30 |
| 6 Hz | Erythrocyte | 10 | 100 | 0 | 0 | 6 | 60 | 4 | 40 |
| | Platelets | 10 | 100 | 0 | 0 | 4 | 40 | 6 | 60 |
| 12 Hz | Erythrocyte | 10 | 100 | 0 | 0 | 4 | 40 | 6 | 60 |
| | Platelets | 10 | 100 | 0 | 0 | 0 | 100 | 0 | 0 |

Table 3 demonstrates that in the vibration group with a frequency of 12 Hz, the results of the paired t test obtained a p-value of 0.31, so it can be concluded that there was a significant decrease in the number of erythrocytes in the blood vibrated with a frequency of 12 Hz for 15 minutes. Blood vibrated with a frequency of 6 Hz for 15 minutes and blood that was not vibrated showed no significant decrease in the number

of erythrocytes. In the vibration group with a frequency of 12 Hz, the results of the paired t-test obtained a p-value of 0.00, so that it can be concluded that there was a significant decrease in the number of Platelets in the blood vibrated with a frequency of 12 Hz for 15 minutes. Blood vibrated with a frequency of 5 Hz for 15 minutes and blood that was not vibrated showed no significant decrease in Platelets count.

TABLE 3 Differences in the number of erythrocytes and Platelets in each group

| Group | | Before Shaking | | After Shaking | | P-value |
|-------|--------------|----------------|------|---------------|------|---------|
| | | Mean | SD | Mean | SD | |
| 6 Hz | Erythrocytes | 4.91 | 0.71 | 4.77 | 0.73 | 0.47 |
| | Platelets | 274.6 | 46.2 | 271.9 | 46.4 | 0.063 |
| 12 Hz | Erythrocytes | 4.44 | 0.50 | 4.40 | 81.3 | 0.31 |
| | Platelets | 285.0 | 81.3 | 272.0 | 81.4 | 0.057 |
| 0 Hz | Erythrocytes | 3.99 | 0.74 | 3.47 | 0.70 | 0.01 |
| | Platelets | 399.4 | 74.3 | 348.0 | 78.7 | 0.01 |

TABLE 4 The average difference in the decrease in the number of erythrocytes dan Platelets between the three groups

| Parameters | Vibration frequency 0 Hz | | Vibration frequency 6 Hz | | Vibration frequency 12 Hz | | P-value |
|---------------------|--------------------------|------|--------------------------|------|---------------------------|------|---------|
| | Mean | SD | Mean | SD | Mean | SD | |
| | Number of Erythrocytes | 0.13 | 0.30 | 0.04 | 0.04 | 0.52 | |
| Number of Platelets | 3.00 | 2.20 | 13.0 | 9.50 | 14.20 | 7.10 | 0.002 |

Table 4 indicates the result of the one-way ANOVA test as p-value of 0.00, so it can be concluded that there is a significant difference in the average decrease in the number of erythrocytes between the three groups. The result for Platelets of the one-

way ANOVA Test the p- value is 0.002, so it can be concluded that there is a significant difference in the average decrease in the number of Platelets between the three groups.

TABLE 5 Analysis of the average difference in the decrease in the number of erythrocytes and Platelets between the two groups

| Parameters | Vibration frequency 0 Hz | | Vibration frequency 6 Hz | | Vibration frequency 12 Hz | | P-value |
|------------------------|--------------------------|------|--------------------------|--------|---------------------------|------|---------|
| | Mean | SD | Mean | S0.04D | Mean | SD | |
| Number of Erythrocytes | 0.13 | 0.30 | 0.04 | 0.04 | - | - | 0.53 |
| | 0.13 | 0.30 | - | - | 0.52 | 0.18 | 0.00 |
| Number of Platelets | 3.00 | 2.20 | 13.0 | 9.50 | - | - | 0.070 |
| | 3.00 | 2.20 | - | - | 14.20 | 7.10 | 0.003 |
| | - | - | 13.0 | 9.50 | 14.20 | 7.10 | 0.022 |

Table 5 indicates that the average difference in the decrease in the number of erythrocytes in the non-vibrated group and the vibrated group with a frequency of 6 Hz showed a p-value of 0.53, which means there was no significant difference. While the difference in the number of erythrocytes between the blood that was not vibrated and the group vibrated with a frequency of 12 Hz and the difference between blood that was vibrated with a frequency of 5 Hz and blood

that was vibrated with a frequency of 12 Hz showed a p-value of 0.00, which means that there is a significant difference in the average decrease in the number of erythrocytes. The average difference in the decrease in the number of Platelets in the non-vibrated group and the vibrated group with a frequency of 6 Hz showed a p value of 0.070, which means that there was no significant difference. While the difference in the number of Platelets between the blood that was not vibrated and

the group that was vibrated with a frequency of 12 Hz showed a p-value of 0.003, which means there was significant difference and the difference between blood vibrated with a frequency of 6 Hz and blood vibrated with a frequency of 12 Hz showed a p value of 0.022, which means there is a significant difference in the average decrease in the number of Platelets. Table 6 explains the results of Wilcoxon test results obtained a p-value of 0.01 in the vibration group with a frequency of 12 Hz, indicating that there was a significant change in erythrocyte morphology between before and after shaking. The results of the p-value in the control group and the

group vibrated at a frequency of 5 Hz obtained results ≥ 0.05 , so it can be concluded that there were no significant changes in erythrocyte morphology. Vibration with a frequency for Platelets of 12 Hz from the Wilcoxon test results obtained a p-value of 0.00, so that it can be concluded that there was a significant change in thrombus morphology between before and after being vibrated. The results of the p-value in the control group and the group that was vibrated at a frequency of 5 Hz obtained results ≥ 0.05 , so it can be concluded that there were no significant changes in Platelets morphology.

TABLE 6 Differences in changes in erythrocyte and Platelets morphology in each group

| Parameters | | Ties | Positive rank | Negative rank | P-value |
|--|-------------|------|---------------|---------------|---------|
| Changes in the morphology of the group without shaking before and after 15 minutes | Erythrocyte | 9 | 1 | 0 | 0.320 |
| | Platelets | 7 | 3 | 0 | 0.083 |
| Erythrocyte morphology changes before and after a 6 Hz vibration | Erythrocyte | 6 | 4 | 0 | 0.070 |
| | Platelets | 4 | 6 | 0 | 0.064 |
| Erythrocyte morphology changes before and after 12 Hz vibration | Erythrocyte | 4 | 6 | 0 | 0.010 |
| | Platelets | 0 | 10 | 0 | 0.000 |

Discussion

The safe and efficient transport and storage of blood and blood products are paramount in the healthcare industry. While blood banks and hospitals employ various measures to maintain the quality and integrity of blood components, the mechanical stress induced by vibration during transportation and storage can pose significant challenges [11]. Erythrocytes play an important role in oxygen transportation. These biconcave discs are highly deformable but are susceptible to mechanical stress, which can cause a range of problems. Studies have shown that vibration can lead to a phenomenon called echinocytosis, where erythrocytes lose their characteristic biconcave shape and adopt a

spiky appearance. Such deformation can impair the cells' flexibility and hinder their ability to traverse capillaries, potentially leading to reduced oxygen delivery to tissues [12].

Shear forces generated by vibrations can also encourage hemolysis, or the rupturing of erythrocyte membranes. Hemoglobin is released into the plasma during this process, which can result in oxidative stress and the production of reactive oxygen species (ROS) [13]. ROS have the ability to exacerbate inflammation and damage by inflicting oxidative damage on proteins, lipids, and DNA. Platelets, another name for Platelets, are essential for hemostasis and wound healing. Because Platelets are tiny, anucleate

cells that are extremely sensitive to mechanical forces, vibrations during storage and transit may have an impact on how well they operate. Studies have indicated that vibration induces an increase in Platelets activation and aggregation [14]. This kind of activation can lead to an elevated clotting state and early Platelets depletion, which might result in thrombotic problems. Moreover, vibrations have the potential to damage the Platelets membrane, which would raise the blood's concentration of Platelets-derived microvesicles [13]. These microvesicles have the ability to aggravate a number of clinical diseases and cause an inflammatory reaction.

The implications of erythrocyte and Platelets damage due to vibration during transportation and storage are profound. For patients requiring blood transfusions, the administration of damaged blood components may result in diminished oxygen-carrying capacity, increased inflammation, and potential complications related to Platelets dysfunction. These consequences can be especially critical in patients with cardiovascular diseases, coagulation disorders, or those undergoing surgery. Efforts to mitigate the damage to erythrocytes and Platelets during transportation and storage are critical. Implementing vibration-reducing technologies in transportation vehicles, as well as optimizing storage conditions, can significantly minimize mechanical stress on blood components. Moreover, ongoing research in the field is vital to develop innovative solutions to address this issue effectively [15-17].

Conclusion

Based on the results of the study, it can be concluded that there is a significant difference in the number of erythrocytes and Platelets between the groups vibrated using the engine prototype and vibration enhancement testing.

In addition, there were significant changes in the morphology of erythrocytes and Platelets in the vibration group. The group that was vibrated with a frequency of 12 Hz for 15 minutes also showed changes in the quality of blood cells both erythrocytes and Platelets.

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Authors' Contributions

All authors contributed to the conception and design of this study. Material preparation, data collection and analysis were done jointly. The first draft of the manuscript was written by [L.R], all authors commented on earlier versions of the manuscript. All authors read and approved the final manuscript

Conflict of Interest

The authors declare that there is no conflict of interest to disclose.

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