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Effectiveness of an adjustable trolley for specimen handling in a blood screening unit

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ABSTRACT

Background: Employees involved in sample collection for testing often perform physically demanding tasks such as bending, lifting, twisting, and standing for long periods. These repetitive activities can increase the risk of musculoskeletal disorders.

Objectives: This study aimed to assess the ergonomic risks associated with sample collection in a blood screening laboratory.

Methods: This quasi-experimental study involved eight volunteers who worked from August 21, 2023, to June 13, 2024, in a blood screening unit in the Nakhon Sawan province. Data were collected using the Numeric Pain Rating Scale, Nordic Musculoskeletal Questionnaire, Rapid Entire Body Assessment (REBA), and flow process chart. Further analysis was conducted using the Wilcoxon signed rank test to evaluate the success of the intervention.

Results: Six participants were women who frequently exhibited awkward postures, including bending, twisting, tilting, reaching with hands and arms, lifting over the shoulders, pulling, and bending their knees. The average REBA score for working postures was 11.63, indicating a high level of risk and the need for immediate corrective measures. Pain prevalence was highest in the lower back (100.0%), followed by the shoulders and upper back (87.5% each), and the neck (75.0%). After using the adjustable trolley, the risk assessment score for working postures decreased significantly to an average of 2.50. Pain levels in various body parts also showed a significant reduction, including the upper back (P-value = 0.027), lower back (P-value = 0.010), hands and wrists (P-value = 0.034), neck (P-value = 0.023), and shoulders (P-value = 0.016). Additionally, the trolley reduced the number of work steps from 16 to 9 (a 43.75% decrease) and shortened the work time per bag from 970 to 570 seconds (a 41.20% reduction).

Conclusion: The use of the adjustable trolley significantly reduced awkward postures and pain, thereby lowering the risk of musculoskeletal disorders and enhancing worker safety and efficiency.

Keywords: Adjustable trolley, Blood screening unit, Specimen handling task

1. Introduction

The Blood Screening Unit functions as a medical laboratory for blood services and a blood bank for treatment. The regional blood centre VII, Nakhon Sawan province, Thai red cross society serves six provinces in the lower northern part of Thailand [1]. Working in a blood bank is considered an exceedingly responsible job. Complications from work could increase the patient's risk of dying. The demand for blood bank services has surged due to a rise in the patient population. Because of this, the staff is overworked and only needs to designate one person every week to receive samples for analysis. It is required to perform repetitive tasks, stand for extended periods of time, and stoop to look up at the computer. Fatigue or musculoskeletal issues are exacerbated by these work-related features. Workers who handle sample testing often need to bend and tilt their bodies forward at angles exceeding 60° which can lead to skeletal and muscular imbalances, resulting in fatigue, illness, and frequent shoulder and back pain. This bending motion requires significant engagement of the abdominal, back, and other muscles.

Properly designed work equipment that aligns with the nature of the tasks and the worker's needs can improve work procedures, mitigate ergonomic risks, and contribute to a more comfortable and stress-free work environment, thereby boosting overall productivity [2]. In terms of design, manufacture, and use, ergonomics can be crucial. Comprehending the impact of anthropometry, posture, repetitive action, and workspace design on the user is vital for comprehending ergonomics in relation to end-user requirements [3]. While studies on laboratory workers typically focus on chemical, physical, and biological concerns, research on ergonomic hazards specific to laboratory workers is limited [4]. Therefore, this study aimed to develop an adjustable cart and evaluate its performance for operators handling sample inspections with the goal of reducing the risk of discomfort associated with specific postures, alleviating pain in various body areas, and enhancing productivity as well as reducing significant ergonomic risks.

2. Methods

2.1 Study Area

The study was conducted at the Thai Red Cross Society's regional blood centre VII in the province of Nakhon Sawan, Thailand.

2.2 Study Design

This research used a quasi-experimental one-group pre-post-test design carried out for ten months from August 2023 to June 2024. The subjects were selected from respondents who participated in the research conducted in 2023- 2024.

2.3 Sample size and sampling

The sample size was determined using the following formula [5] based on a study by Thamkoson K. that demonstrated a significant difference between the working conditions before and after the implantation of improved working conditions using ergonomic principles in the bag conveying process from the quality inspection back to the cement bag-making machine [6].

$$n = \frac{(z_{1-\frac{\alpha}{2}} + z_{1-\beta})^2 \sigma^2}{\Delta^2}$$

Where n is the number of samples,

Δ = the minimal difference that will result in a significant impact

σ = average standard deviation

Z(1-α/2): Z score for the alpha error chosen

Z(1-β): Z score for the power chosen

(Alpha error: 0.05, Power of the study: 80%, Δ: 0.625, and σ: 0.619)

The participants who took time off work or changed their address were not included in the sample which helped coordinators find new subjects based on their preparedness to participate in the intervention program.

2.4 Data Collection

2.4.1 Anthropometric measurement for developing the adjustable trolley's design

Anthropometric data, including elbow height from the sitting surface and palm width were collected for designing the adjustable trolley. Measurements were based on the 5th and 95th percentiles [7, 8] (Table 1).

Table 1: The 5th and 95th percentiles of anthropometry (n=8)

Body part	Mean (SD)	5th percentiles	95th percentiles
Standing elbow height (cm)	99.50 (5.4)	91.34	105.72
Sitting elbow height (cm)	17.9 (1.9)	16.05	20.75
Palm width (cm)	7.48 (0.6)	6.76	8.23

2.4.2 Adjustable Trolley Design

The adjustable trolley utilized operator anthropometry measurement, specifically standing elbow height and hand grip diameter, to produce ergonomic trolleys [7] with the dimensions of 72 cm in width and 97 cm in length, as shown in Figure 2, based on the dimensions of the sample bag (35.56 cm in width, 48.26 cm in length, and 35.56 cm in height, as shown in Figure 1).

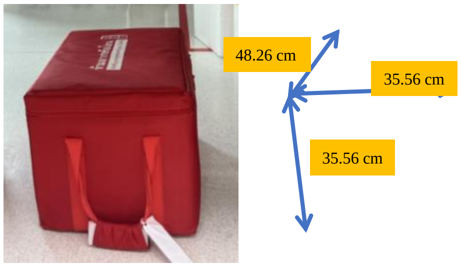

Figure 1: Dimension of a sample bag

Figure 2: Adjustable trolley

2.4.3 Posture analysis

The Rapid Entire Body Assessment (REBA) was used to evaluate the risk factors for musculoskeletal disorders (MSDs) associated with specific job tasks. A worksheet was used to assess body posture, forceful exertions, types of movements or actions, repetition, and coupling [9].

2.4.4 Pain perception analysis

The perceived pain in various areas was compared before and after utilizing the adjustable trolley using the Nordic questionnaire. It is a self-administered test with various sections divided into the nine anatomical regions. It consists of forced multiple choice questions which are structured as follows: "Do musculoskeletal troubles occur in a given population, and if so, in what parts of the body are they localized?" This is the question that the questionnaire was intended to address [10]. It also includes the use of a numerical measure rather than a dichotomous one to gauge the intensity of symptoms at the time of the evaluation [11].

2.4.5 Motion analysis

This study focuses on worker performance evaluations during the assembly process. Further motion analysis was conducted for ergonomic study by documenting the motion of the assembly process using a flow process chart [12]. The motion process was used to examine every aspect of a worker's body posture and other body part movement, applying the symbols for "operation," "inspection," "transport," "delay," and "storage" [13]. The motion study's conclusions highlighted several labour intensive and wearisome aspects of the worker and workstation setup.

2.5 Data Analysis

Continuous data, including age, weight, height, average working hours per day, years of experience, and user satisfaction with the adjustable trolley were described as means with standard deviations. Categorical data, such as sex, congenital diseases, and additional occupations were presented using frequencies and percentages.

Utilizing non-parametric methods such as the Wilcoxon signed-rank test for paired data, the locations of the REBA scores and various painful sensations experienced were compared before and after the adjustable trolley serving. Considering that the data utilized in this investigation originated from small, non-normal distributions [14].

2.6 Ethical Clearance

This study was approved by the Human Research Committee of Burapha University, Thailand (Reference No. G-HS044/2566 (C1)).

3. Results

Of the eight participants, six (75%) were women and two (25%) were men. Their ages were 32.38 ± 4.93 years with a range of 26 to 40 years. The mean body weight of the participants remained 55.62 ± 7.69 kg with a range of 48 to 68 kg. Their average height was 161.25 ± 7.23 cm with a range of 150 to 170 cm. The majority of respondents were still working on their bachelor's degree and had no underlying health issues. Based on their occupation, 37.5% of the sample worked eleven hours per day, 75% took five-minute breaks, 62.5% worked six days a week, and 100% did not work for pay elsewhere. The majority of participants had worked for one to three years.

3.1 Compare the differences in postural risk before and after using the adjustable trolley.

After using the adjustable trolley, variations were observed in the angles of the neck, trunk, legs, upper arms, and lower arms (Table 2).

Table 2: Comparison of asymmetry angles before and after using the adjustable trolley

Body part	**Asymmetric angle (degree)**	
	Before	**After**
1. Neck		
2. Trunk		
3. Legs		
4. Upper arms		
5. Lower arms		

The risk of working postures, as measured by the REBA was compared before and after using the adjustable trolley with the Wilcoxon signed-rank test. The risk score for working postures decreased significantly from 11.63 to 0.54 points. Scores for the legs, trunk, and neck (Category A) dropped from 9.00 to 2.13 points. Ratings for the wrists, lower arms, and upper arms (Category B) decreased from 5.13 to 1.25 points (Table 3).

Table 3: Comparison of REBA scores before and after using the adjustable trolley (n=8)

REBA assessment	Before			After			Z	95% CI	P-value
	Mean	SD	Median	Mean	SD	Median			
1. Neck analysis	3.00	0.00	3.00	1.13	0.35	1.00	-2.714	1.605, 2.135	0.007*
2. Trunk analysis	5.00	0.00	5.00	2.13	0.35	2.00	-2.714	2.605, 3.135	0.007*
3. Legs analysis	4.00	0.00	4.00	1.00	0.00	1.00	-2.828	3.000, 3.000	0.005*
4. Using values from steps 1–3, locate the score from REBA table A	9.00	0.00	9.00	2.13	0.35	2.00	-2.714	6.605, 7.135	0.007*
5. Add the force score	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000, 0.000	1.000
6. Scoring A	9.00	0.00	9.00	2.13	0.35	2.00	-2.714	6.605, 7.135	0.007*
7. Upper arms analysis	4.25	0.46	5.00	2.13	0.35	2.00	-2.588	1.682, 2.558	0.010*
8. Lower arms analysis	1.50	0.53	2.00	1.13	0.35	1.00	-1.732	-0.112, 0.852	0.083
9. Wrists analysis	2.00	0.00	2.00	1.00	0.00	0.00	-2.828	1.000, 1.000	0.005*
10. Using values from steps 7–9, locate the score from REBA table B	5.13	0.83	5.00	1.25	0.71	1.00	-2.539	3.052, 4.708	0.011*
11. Add the coupling score	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000, 0.000	1.000
12. ScoringB	5.13	0.83	5.00	1.25	0.71	1.00	-2.539	3.052, 4.708	0.011*
13. Matrix score A and score B using REBA table C for scoring C	10.63	0.52	11.00	1.50	0.54	2.00	-2.588	8.562, 9.699	0.010*
14. Add activity score	1.00	0.00	1.00	1.00	0.00	1.00	0.000	0.000, 0.000	1.000
15. Final REBA Score	11.63	0.52	12.00	2.50	0.54	3.00	-2.588	8.562, 9.699	0.010*

* P-value < 0.05

3.2 Comparative analysis of pain perception before and after using the adjustable trolley.

The study compared the average pain levels in various body parts before and after using the adjustable trolley. The mean pain intensity scores for different body parts decreased after three weeks of using the adjustable trolley.

The average pain intensity scores decreased significantly in several areas: from 1.00 to 0.13 points in the neck, from 1.75 to 0.13 points in the shoulders, from 1.13 to 0.00 points in the hands and wrists, from 1.50 to 0.13 points in the upper back, and from 2.38 to 0.25 points in the lower back (Table 4).

Table 4: Comparison of pain perception in various body parts before and after using the adjustable trolley

Body part for assessment of pain perception	Before			After			Z	95% CI	P-value
	Mean	SD	Median	Mean	SD	Median			
1. Neck	1.00	0.76	1	0.13	0.35	0	-1.933	0.236, 1.505	0.023*
2. Shoulders	1.75	1.3	4	0.13	0.35	0	-2.414	0.599, 2.641	0.016*
3. Elbows	0.25	0.46	0	0.00	0.00	0	-1.414	-0.099, 0.599	0.157
4. Wrists/Hands	1.13	0.99	1	0.00	0.00	0	-2.121	0.379, 1.881	0.034*
5. Upper back	1.50	0.93	2	0.13	0.35	0	-2.209	0.617, 2.124	0.027*
6. Lower back	2.38	0.92	5	0.25	0.71	0	-2.588	1.249, 3.011	0.010*
7. Hips/Thighs	0.87	1.13	0	0.00	0.00	0	-1.841	0.013, 1.727	0.066
8. Knees	1.00	1.19	1	0.00	0.00	0	-1.841	0.100, 1.900	0.066
9. Ankles/Feet	1.50	1.69	1	0.25	0.46	1	-1.382	-0.078, 2.578	0.167

*P-value < 0.05

3.3 Time and distance of motion are compared with and without the adjustable trolley.

Before using the trolley, participants performed sixteen steps, covering 6.5 meters, and spending 970 seconds. Each day, they managed 30 cartons of sample bags, each weighing 20 kilograms. This included traversing 195 meters, spending 29,100 seconds, bending over 60 times, bending their knees 60 times, pulling or dragging sample bags 30 times, bending their neck 60 times, twisting their body 60 times, and walking 60 times.

With the adjustable trolley, the number of steps decreased to nine, and the time spent was reduced to 570 seconds (Table 5). Consequently, in a single day, they no longer needed to bend their knees, while bending over 60 times, pulling and dragging sample bags 30 times, and bending their neck 60 times were maintained. The total time spent on these activities was reduced from 29,100 to 17,100 seconds.

Table 5: Comparison of the time spent, and distance traveled with and without using the adjustable trolley.

Work procedure without using adjustable trolley	Distance (m)	Time (Sec)	Symbols					With using Adjustable trolley
			○	⇨	D	□	▽	
1. To locate the bag for placing the sample for analysis, stoop down.	3	30						Vanished
2. Reach for the sample pouch strap while bending your knees.	0.3	60						Vanished
3. Retrieve the bag strap and deliver the sample for analysis.	-	30						Vanished
4. Pull the sample bag into the examination room with force.	0.6	120						Vanished

Work procedure without using adjustable trolley	Distance (m)	Time (Sec)	Symbols					With using Adjustable trolley
			○	⇨	D	□	▽	
5. To find the zipper on the sample bag that needs to be analysed, bend your neck.	-	30						Vanished
6.Access the zipper and place the sample bag for inspection by twisting or bending your wrist.	-	60						
7. When facing the infrared thermometer, twist or tilt your body.	0.3	80						
8. Bend or breaking their wrist to retrieve the infrared thermometer.	-	30						
9. As you take the bag's temperature, flex their knees.	-	30						Vanished
10. Verify the temperature.	-	30						
11. To retrieve the infrared thermometer, twist or tilt your body.	0.3	80						
12. To remove the sample from the bag, stoop down and apply some effort.	-	60						Vanished
13. Before moving the sample to the next workstation, twist or sway their body.	1.50	90						
14. Walk back to the test sample bag.	1.50	90						
15. To zip the sample bag shut, twist or flex your wrist.	-	30						
16. Walk and bring the bag to the front of the room where the samples need to be gathered.	2.00	120						
Summary	6.50	970	10	3	0	2	1	

4. Discussion

In this study, the workflow comprised five steps: 1) Pulling and dragging the sample bag for inspection; 2) Closing the bag; 3) Measuring the sample's temperature; 4) Transferring the sample to the next station for inspection; and 5) Gathering the bag. During these tasks, workers performed various improper body motions. For example, they bent down to pull the sample bag into the room, reached out to grab the bag strap, bent their knees while bending down, tilted their neck to read the temperature, lifted their hand and arm to provide a sample, twisted their neck to check the path before walking, and twisted their body while handling the sample. Additional movements included walking to deliver the sample, bending to remove the ice pack from the bag, and bending their knees while gathering the sample bag.

Therefore, an adjustable trolley tailored to the physical dimensions of all eight operators was developed, and its effectiveness in reducing ergonomic risk factors was assessed. Before using the adjustable trolley, the REBA risk assessment scored an average of 11.63 points for working postures. After using the trolley, the average score decreased to 2.50 points. This improvement resulted from the trolley's design, which reduced the need for workers to bend their necks or other body parts more than 60° and instead encouraged bending their knees while sitting or standing. This adjustment led to a more ergonomic working posture and a reduction in pain across various body parts. These findings align with studies on musculoskeletal disorders, which identified at least one affected organ. Furthermore, after three weeks of using the adjustable trolley, there was a significant reduction in the prevalence of musculoskeletal disorders affecting the neck, shoulders, hands and wrists, upper back, and lower back, consistent with *Sungkhapong A, et al*.'s study, where workers' average posture risk scores and the means of their erector spinae, trapezius, and anterior deltoid muscles were lower after receiving better workstations that were more suited to their physical bodies [15].

The number of work steps was reduced from 16 to 9, representing a 43.75% decrease, as shown by the comparison of movement distance and time before and after using the adjustable trolley. The time required was cut from 970 seconds to 570 seconds, a 41.2% reduction, consistent with Petchchu N.'s study [16]. Additionally, the average time spent per work cycle dropped from 120 to 43 seconds, a 64% decrease, following task improvements. Furthermore, in line with *Tummee S, et al*.'s study, which used movement economics to improve work methods by designing a foundation set that allows the pallet area to be adjusted in height to minimize bending and leg strain, significant reductions in steps were observed after implementing their adjustable foundation set (28 to 22 steps) [13].

The Wilcoxon signed rank test might be the most appropriate to use in this research. It was discovered that the best test for non-normal distributions, especially for small sample sizes [17]. It can be difficult finding the optimum summary measure because nonparametric approaches are, at best, indirect functions of conventional location measurements. Paired differences that equal 0 are not included in the computation according to the Wilcoxon signed rank test. This is justified by the fact that zeros don't reveal anything about the direction that a collection of observations tends to move. Eliminating the zeros, though, could lead to two issues. It can be counterintuitive to remove the zeros, which is one of the worries. The second, more significant worry is that eliminating the zeros occasionally produces illogical results although a result's statistical significance is determined using the P-value. Finding practical significance, on the other hand, can be just as crucial in cases where an estimate of the effect of interest and the accuracy of that estimate is immediately pertinent. The mean difference between evaluations conducted before and after the use of an adjustable trolley to change posture was found to be above 1.0, with a 95% confidence interval based on REBA scores and low back pain perception ratings. Because the confidence interval for the mean difference is more than 1.0, we can therefore conclude, based on the 95% confidence interval, that there is a statistically significant difference between awkward posture and low back discomfort [18-20].

5. Conclusion

The use of the adjustable trolley resulted in a significant reduction in the risk of postural imbalance during sample collection, as assessed by the REBA. The trolley's design is likely to reduce both the risk of postural imbalance and musculoskeletal issues. The study indicates that, in addition to reducing movement time and distance, the adjustable trolley could also alleviate pain in various body areas. Therefore, this adaptable trolley should be utilized in other departments to minimize the ergonomic risks.

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