

Use of Personal Protective Equipment (Ppe) Based on Physical Principles to Reduce Injuries in the Workplace

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Abstract

Work safety is an important aspect in every industrial activity. One of the main efforts to reduce the risk of injury is through the use of personal protective equipment (APD). The working principle of the APD is inseparable from the application of physics concepts, such as energy absorption, heat insulation, electrical insulation, and pressure distribution. Safety helmets, for example, are designed to absorb and spread the impact energy thereby reducing the force received by the head. The isolator gloves function to prevent electricity to the worker's body, while safety shoes are able to withstand mechanical pressure and protect from heavy objects. Research and literature study show that compliance with the use of PPE significantly decreases the number of work accidents. However, the effectiveness of the PPE is also influenced by comfort, material suitability, and supervision factors in the workplace. By understanding the principles of physics behind the design of the PPE, workers can be more aware of the importance of their use, while companies can ensure the quality and availability of PPE according to standards. Thus, the application of PPE based on physics principles is an effective preventive strategy in creating a safe and productive work environment.

Keywords: occupational safety; personal protective equipment (PPE); work accidents

Introduction

Occupational Safety and Health (K3) is one aspect that cannot be separated from operational activities in various industrial sectors, including construction, manufacturing, mining, chemistry, and health services. Complex and high -risk work environment often presents potential physical hazards, such as falling objects from height, extreme temperature exposure, noise, radiation, and the risk of direct contact with harmful chemicals. In this context, Personal Protective Equipment (PPE) becomes an important component that functions as the last barrier between workers and a source of hazards when other control efforts have not been able to eliminate comprehensive risks.

PPE is the equipment used by workers to protect certain body parts from the potential for injury or disease due to the work environment. Types of PE include Sss Health Helmets, eye protection, breathing masks, gloves, ear protectors, protective shoes, and special clothing such as fireproof vests or laboratory coats. Although its use is often regarded as a standard procedure, basically the effectiveness of the PPE is inseparable from the principles of physics applied in its design. Each type of PPE is developed based on certain protection mechanisms that are closely related to the basic concepts of physics, such as force, pressure, energy, waves, heat transfer, and material conductivity. For example, the safety helmet

does not only function as a head covering, but is specifically designed using the principle of the distribution of forces and energy absorbers to protect the brain from the impact of collisions. The inner layer of the helmet usually uses materials such as polystyrene expansion (EPS) which can absorb the energy of collisions through deformation. Similar principles are also applied to knee protectors or steel protective shoes, which rely on structural strength and material elasticity to reduce injury due to pressure or impact.

Earmuffs or earmuffs work by muffling sound waves through the use of sound absorbent materials that reduce amplitude of waves and prevent hearing damage due to noise. Respirator masks use the principle of fluid flow and particle filtering through diffusion and interception mechanisms. Even heat -resistant gloves and protective clothing are designed by utilizing low thermal conductivity of certain materials, so as to prevent heat transfer to the user's skin.

Although PPE has been proven significantly reducing injury rates at work, there are still challenges in its implementation. One of the main challenges is the lack of understanding of the workers of the workings and scientific principles behind the PPE they use. This causes the use of PPE is often considered a mere formality, not as part of an effective self -protection system. Lack of education also has an impact on choosing the type of PPE that is not in accordance with the existing risks, as well as low compliance with safety procedures. Therefore, it is important to examine more in the relationship between the principles of physics and the design and use of the PPE, in order to create a higher awareness and appreciation of the vital role of PPE in the protection of labor. With the right scientific approach, this understanding can not only increase the effectiveness of PPE in preventing injury, but also supports the creation of a stronger and sustainable work safety culture in various industrial sectors.

Method

1. Research Design

This study uses a review literature with a descriptive qualitative approach.

Objective: To comprehensively understand how physics principles are applied in the design and use of PPE without conducting direct trials in the field.

2. Data source

Data is taken from journal articles, proceedings, books, and occupational safety standards

Objective: So that the data analyzed relevant, up -to -date, and has a strong scientific basis.

3. Literature search strategy

Search is done using keywords:

"Personal Protective Equipment" or "APD"

"Personal Protective Equipment" or "PPE"

"Physics Principle in PPE"

"Impact Absorption Helmet"

"Heat Insulation Gloves"

"Respiratory Protection Fluid Mechanics"

"Optical Protection Goggles"

Combination with Boolean Operators (and, OR).

Objective: To expand and deepen the search results for literature so that it is more specific according to the topic.

4. Criteria for Inclusion and Exclusion

Inclusion: Articles that discuss PPE with physics principles, published 2015-2024, Indonesian/English, and can be accessed full text.

Exclusion: articles that only discuss management/policies without physical aspects, are not peer-reviewed, or are not fully accessed.

Objective: Filtering literature so that only articles are relevant and quality analyzed.

5. Literature selection process

Objective: Ensuring the chosen literature is in accordance with the focus of the research and can support the analysis.

6. Data analysis

- Using thematic analysis with steps:
 - Grouping articles based on the type of APD (helmet, shoes, respirators, glasses, gloves, protective clothing).
 - Identifying the underlying physical principles (collisions, force distribution, fluid mechanics, heat conduction, optical).
 - Comparing the effectiveness of PPE from various studies.
 - Synthesize the results in narration and tables.

Data Analysis

Data were extracted from eligible studies using a standardized extraction form, including author, year of publication, study setting, sample size, exposure variables, and adjusted odds ratios with 95% confidence intervals. Effect estimates from individual studies were entered into Review Manager software (RevMan version 5.3). Pooled adjusted odds ratios and 95% confidence intervals were calculated using a fixed-effect model. Statistical heterogeneity was assessed using the I^2 statistic and corresponding p-values. Publication bias was evaluated visually using funnel plots.

Objective: To produce a structured understanding of how physics principles support the PPE function.

7. Data validity

- Triangulation of sources from various articles.
- Select Peer-Reviewed literature.
- Record research limitations (only secondary literature).

Objective: guarantee the validity of data and reduce the bias in the results of the study.

Results and Discussion

The results showed that each type of PPE has a protection mechanism that is closely related to the principle of physics.

1. **Energy and Style Principles** → become the basis for the design of helmets and shoes. By distributing impact energy to a wider area, injuries can be minimized.
2. **The principle of fluid mechanics** → used in respirators that filter particles based on differences in air flow, diffusion, and inertia force.
3. **Optical principles** → applied to protective glasses to reduce light intensity, fight UV radiation, and hold flying particles.

NO	TITLE	WRITER	OBJECTIVE	METHOD	RESULTS
1.	Improvement of Occupational Safety and Health (K3) through the Socialization of Personal Protective Equipment (APD) to construction workers (Location: Renovation of Palembang Aviation Polytechnic Library Building).	Viktor Suryan	Increasing the awareness of workers in the field of construction of the use of safety equipment while working.	<i>Lecture, discussion, and demonstration methods.</i>	This PKM activity was held at the Palembang Aviation Polytechnic Campus which was once called Palembang Aviation Training. This activity is a collaboration between Sriwijaya State Polytechnic lecturer and Palembang flight polytechnic lecturer.
2.	Behavior of Use of Personal Protective Equipment in PT.X Workers	Chntiya Permata Dahyar	Knowing the factors related to the behavior of the use of personal protective equipment (APD) in PT. X (BUMN Shipyard Industry).	<i>Analytical observational method</i>	This attitude is formed from the perception of the benefits and perception of ease of use, both have a significant relationship and positive direction with attitudes, which then affect the behavior of the use of APD
3.	Evaluation of the use of PPE in the context of occupational health and safety in the construction industry	Ina Sartina and Dewi Purnamawati	Assess the level of construction work compliance in the use of personal protective equipment (PPE) and identify the factors that influence the compliance to improve occupational safety and health (K3)	<i>Direct method</i>	The main factor of low compliance: discomfort (non-ergonomic design, heat material, inappropriate size) and lack of supervision and education
4.	Use of personal protective equipment (PPE) on work accidents. Behavioral cases in field workers PT.PLN Unit Lueng Bata, Banda Aceh	Nasrullah	The study aims to determine the relationship between the use of personal protective equipment (PPE) to prevent work accidents in field workers of PT.PLN Unit Lueng Bata Kota Banda Aceh.	<i>Analytic descriptive method</i>	Conclusion Behavior that contains elements of knowledge, attitudes and actions of workers in the use of personal protective equipment (APD) has an influence on the prevention of workers' accidents. Workers' attitudes and actions in the use of PPE as well as the prevention of work accidents.
5.	The effect of the use of personal protective equipment (APD) on the risk of work accident risk	Sri Wahyuni, Cut Putri Zila Lheena, Kamalurrizal, Afriliansyah, & Radhiah Zakaria	Evaluating the effectiveness of the use of personal protective equipment (PPE) in preventing the risk of work accidents in various high-risk industrial sectors, as well as identifying factors that influence the success of the application of PPE as part of a comprehensive work safety strategy.	<i>Systematic Review (Systematic Review)</i>	The use of PPE consistently has been proven to reduce work accidents by $\pm 60\%$, but its effectiveness is influenced by workers' compliance, the quality and comfort of the APD, training, supervision, and the culture of safety at the workplace.
6.	Assessing the use of personal protective equipment and its correlation with knowledge, attitudes, performance, and culture of safety among workers in small and medium companies.	Amir Hossein Khoshaklagh et al.	Assessing the use of PPE and testing the relationship between knowledge, attitudes, behavior, and culture of workers' safety in UKM, in order to identify factors that influence compliance with the use of PPE and provide	<i>structural equation modeling</i>	Most workers (72.4%) use PPE, but low safety training and 27.7% of workers do not use PPE at all. Factors of knowledge, attitudes, behavior, and culture of safety are proven to affect compliance with the use of PPE.

			a basis for improving occupational safety.		
7.	Practice of using personal protective equipment in employees of the construction company production department	Rico Novian Yuswantoro & Sofwan Indarjo	The main review of this research is to examine how the practice of using PPE runs among employees of the production department in the construction industry, especially related to readiness, compliance, and procedures for using PPE during work. The focus is to identify whether the use of PPE in the field is in accordance with work safety standards .	<i>descriptive observational</i>	The practice of using PPE in construction production employees is influenced by motivation, perceptions of benefits, and perceptions of obstacles. All three are significantly related: Motivation and perception of high benefits increase compliance with using PPE, while resistance to lowering it.
8.	Analysis of Occupational Safety and Health Behavior in PT. Sigma Quantum Insani through the Behavior Baset Safety (BBS) approach	Hana Meyninta Br Ginting & Fira	This journal aims to reduce work accidents through behavioral approaches, by increasing, awareness, observation, and application of safe work behavior in the corporate environment	Descriptive method	Factors that influence safe behavior include triggers and consequences. The biggest factor plays a role in triggering the behavior of welding and cutting workers is the safety requirements, the poor role of management, and the unlawful of the Work Regulations, the Working Health and Safety Protection Improvement features are not yet available.
9.	Fabrication and analysis of the strength of safety impact from composite material (bamboo/fiber material studies)	Jeroh Miko Subahgia	Testing the compressiveness and resistance to the impact on local safety helmet material (bamboo/carbon fiber composite) compared to SNI standards	<i>Experimental method</i>	Certain composite materials (bamboo fiber/hybrid carbon fiber) show the ability to withstand the impact that meets/explains the equivalent performance of several standards; Material and design recommendations to increase the absorption of impact energy.
10.	Identification of Hazards, Assessment and Control of Occupational Safety and Health Risk (K3) at the Foundry Department of PT. Sicamindo	Henri Ponda and Nur Fadilah Fatma	Identifying hazards, conducting risk assessments, and designing Occupational Safety and Health Risk Control (K3) at the Foundry Department of PT. Sicamindo, with a focus on reducing the number of accidents and occupational diseases through the implementation of the Right K3 Program and the use of personal protective equipment (PPE).	<i>descriptive observational</i>	Research found various dangers in the Foundry Department, with a level of tolerable, moderate, and substantive risk. Control is carried out through work procedures, training, and provision of PPE. The program is targeting a decrease in accidents and occupational diseases into one case per month, so that the risk of injury and occupational diseases can be reduced significantly.
11.	The effectiveness of filtration, oxygenation and comfort of the use of fabric masks (meta/research in Indonesian)	Nurul Fahira	Assess the ability of fabric mask filtration compared to medical/respirators and effects on oxygenation/comfort.	<i>Literature Review/Filtration Study Data Analysis</i>	Fabric masks show lower filtration than medical masks/N95; There is a comfort and breathing impact that needs attention, the implications of filtration design (principle of fluid &

12.	Factors related to Hand Arm Vibration Syndrome (HAVS) in Workers (Physics Analysis of Vibration and Exposure)	Dwinaffebri T., Wahyuni, I., & Ekawati, E	Literature study or field survey or vibration exposure analysis; measurement of acceleration or work area and correlation with symptoms	<i>descriptive with the study of literature study (literature review).</i>	material porosity) for respirators/breathing APD. Exposure to vibration that exceeds the threshold (certain acceleration value) is strongly correlated with complaints of HAVS; suggest technical control (damper, anti-vibration gloves, tool design) that applies the principle of vibration mechanics.
13.	Use of personal protective equipment in swallow's nest download: Ethnographic Study of Work Safety Behavior at Karangduwur Beach	Eka Denis Machfutra, Atik Triratnawati, and Nida Ul Hasanat	This study aims to determine the behavior of the use of traditional personal protective equipment (APD) by the swallow's nest drawn.	<i>Qualitative method</i>	The downloaders use PPE that are not standard and tend to choose traditional equipment. The reason is that the use of standard PPE is considered to be troublesome and interfere with the download process, which makes the work takes longer. The downloaders feel that they are experts and safe with traditional PPE, as well as constrained by limited funds to buy stand equipment
14.	Analysis of the Application of Personal Protective Equipment (PPE) to Employee Productivity with the Parsipator Ergonomics Approach in Printing	Nadzirah Ikasari and Syamsul Dirgahayu	Analyzing the effect of the application of PPE through a participatory ergonomic approach to the work productivity of printing employees	<i>Data Analysis with Smart PLS</i>	The application of PPE has a positive and significant impact; Valid indicator with $Cr > 0.6$ and loading factor > 0.5
15.	Improving work safety in the laboratory through training in the use of environmentally friendly materials	Ni Nyoman Widiaih	Introducing alternative materials that are safe and environmentally friendly to replace hazardous chemicals in practical activities	<i>Discussion and practice</i>	Material use training environmentally have an environment begins with Provision of pretest. The training continued with the introduction of practicum material chemistry, modification of practicum procedures environmental -based chemistry, Design of Chemical Practicum Procedures environmental based, trial procedures Chemical Practicum Practicum Based environment and end with posttest
16.	The Effect of Use of Personal Protective Equipment (PPE) on the Performance of Medical Officials in the Pinere Room During Pandemi Covid-19 at Sultan Iskandar Muda Hospital, Nagan Raya Regency	Riza Dahlia, and Sukma Elida	Knowing whether the use of personal protective equipment (APD) affects the performance of medical officers in the Pinere Room of Sultan Iskandar Muda Hospital in Nagan Raya Regency during Pandemi Covid-19.	<i>Quantitative methods, analytic surveys with cross sectional design</i>	There is a significant influence between the use of various types of PPE (masks, protective glasses, face protectors, gloves, coat robes, boots) on the work performance of medical officers. All variables indicate the value of $P \leq 0.05$, meaning

17.	Analysis of the effectiveness of the use of safety helmets based on the principle of impact and energy absorption to prevent head injury to construction workers	Budi Santoso	Assess how effective the safety helmet in reducing the impact of collisions and absorbing energy to prevent head injuries	<i>Conduct laboratory tests</i>	that PPE is closely related to the performance of medical officers. Safety helmets that meet the standards can significantly reduce the impact force transmitted to the head and reduce the risk of traumatic brain injury to construction workers
18.	The Effect of Use of Personal Protective Equipment (APD) on Safety and Health of Medical Staff at UPTD Afulu Puskesmas.	Rafit Rahmat Daeli	To find out whether the use of personal protective equipment (APD) affects the safety and health of medical personnel at the Afulu Puskesmas UPTD.	Observation, questionnaire, documentation, instrument test, classical assumption test, hypothesis test	The use of PPE has a positive and significant effect on the safety and health of medical personnel. Adjusted value $R^2 = 0.731$ → The use of PPE explains 73.1% of occupational safety & health, the remaining 26.9% is influenced by other factors.
19.	Compliance with using personal protective equipment (PPE) among informal sector workers in Indonesia	Azalia Diani Laksono	To identify components that can affect worker compliance behavior in using PPE in the informal sector.	Literature Review	The level of compliance with informal workers in using PPE is still low. Most workers do not use the complete PPE while working. Factors that influence: knowledge, attitudes, availability of PPE, and supervision. Increased knowledge and attitudes can help prevent work accidents and occupational diseases.
20.	Analysis of the Causes of Work Accidents and the Effect of Use of Personal Protective Equipment (PPE) on Construction Workers at PT. Bagas Patih Pratama	Raisa Shabrina And Susilawati	To analyze the causes of work accidents and the effect of the use of personal protective equipment (PPE) on construction workers at PT. Bagas Patih Pratama to improve employee safety and reduce the risk of work accidents.	Qualitative, questionnaires and interviews	Most workers have good knowledge about K3 (72.7%) and a positive attitude (78.7%). However, there are still workers who are inconsistent using PPE; Only 60.7% always use. As many as 36.4% of workers have a history of work accidents, with 4 severe injuries and 8 minor injuries. The main cause of accidents is a human factor, especially the non-compliance of the use of PPE. The use of PPE has proven to have an effect in reducing the risk of work accidents.

21.	The influence of helmet design on the performance of the impact damping in industrial safety helmets	Michael Bottlang	Assessing how the difference in industrial safety helmet design affects the ability of helmets to reduce collisions and reduce the risk of head injuries at work.	<i>Statistical analysis</i>	Not all new helmets are better than traditional helmets, helmets with rotation damper technology are more effective in reducing the risk of brain injury due to performance rotation, helmets are greatly influenced by the design and direction of collisions.
22.	The relationship between the use of personal protective equipment and the incidence of worm infections in waste workers	Lezdyana Nur Islami	Knowing the relationship between the use of personal protective equipment (PPE) and the incidence of worm infections in waste workers.	<i>Observational research with cross sectional design</i>	Workers who do not use a complete PPE have a higher risk of infected with worms (60%) compared to workers who use the complete
23.	Analysis of Factors Affecting the Production of Palm Oil Commodities People's Plantation with Self-Help Pattern in Aceh Tamiang Regency.	Mustari, Yonariza, and Rusda Khairati.	This research is to determine the factors that influence oil palm production in Aceh Tamiang Regency, Aceh Province. This location was chosen intentionally (purposive) because of an increase in the area of people's plantations from 2009 to 2016 which was not balanced with an increase in total production. The productivity of oil palm fresh fruit bunches (FFB) in 2017 was only 13.6 tons, far below the optimal potential of 20-25 tons per hectare per year.	<i>Survey method</i>	The analysis shows that several factors of production have a significant influence on oil palm production in Aceh Tamiang Regency, as follows: Positive factors that have a significant effect: Labor: 1% increase in the use of labor can increase productivity by 0.964%.
24.	Identification of the risk of loading and unloading activities to control and prevent work accidents using the Hazop Analysis method in MV. Tanto Permai.	Ahmad Maulana	To find out the factors that cause work accidents at the time of loading and unloading on the ship	<i>Qualitative research</i>	There are several potential hazards with different levels of risk in loading and unloading activities. Appropriate control efforts (inspection, risk socialization, application of SOPs, Disciplines of Ship crew) can reduce risk to low levels or can be ignored.
25.	The effect of workload, work capacity and physical work environment on occupational safety and health at PT Pelabuhan Indonesia I (Persero) Belawan Container Terminal	Inge Maria Theresia Tobing	Analyzing the effect of workloads, work capacity, and physical work environment simultaneously on K3 in PT Pelabuhan Indonesia I (Persero) Employees of Belawan Container Terminal	<i>Quantitative method</i>	The physical work environment is the most dominant factor that affects the safety and health of employees of employees at PT Pelabuhan Indonesia I (Persero) Belawan Container Terminal.

4. **The principle of heat transfer** → used in gloves and heat -resistant clothing to inhibit the conduction rate so that the worker's skin does not burn.

In general, the literature results show that the use of PPE in accordance with potential hazards can reduce work injuries significantly, even up to 50-70%. However, this effectiveness is only achieved if:

1. PPE is used according to standard (SNI, ISO, OSHA).
2. Workers comply with the use of PPE.
3. The company conducts regular supervision and maintenance of PPE.

Thus, it can be concluded that the PPE based on physics principles is not only a complementary tool, but the real implementation of physics to protect the safety of workers.

Conclusion

Based on the results of the literature study, it can be concluded that the use of personal protective equipment (APD) designed with physics principles has proven to be effective in reducing the risk of injury in the workplace. Each type of PPE has a different protection mechanism according to the dangers faced: Safety helmets work by absorbing and distributing collision energy, safety shoes protect with the principle of the distribution of force and pressure, respirators use fluid mechanics to filter air, protective glasses apply optical principles, while gloves and protective clothing utilize the principles of conduction and heat insulation. Thus, it can be emphasized that PPE based on physics principles is a real application of science in creating a safer work environment, protecting workers from various risks of accidents, and supporting the achievement of optimal work safety standards.

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