



The effect of warm-up and cool-down on preventing muscle injury among Indonesian military personnel during humanitarian operations



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ABSTRACT

Background: Humanitarian missions conducted by the Indonesian National Armed Forces require a high level of physical readiness and perform various intensive physical activities that may increase the risk of muscle injuries if not supported by adequate and proper physical preparation. This study aimed to analyze the effect of warm-up and cool-down activities performed before physical exertion on muscle injury prevention among Indonesian National Armed Forces personnel during the execution of humanitarian missions.

Methods: This study applied a mixed methods approach with an exploratory sequential design. Qualitative data were obtained through in depth interviews with 15 participants, while qualitative data analysis used Nvivo with the Nvivo word cloud feature. Quantitative data were collected from 100 Indonesian military personnel who had participated in humanitarian operations, disaster response, coronavirus disease 2019 (Covid-19) handling, and security task forces in Papua, Indonesia, using structured questionnaires with Likert scale (1-5) distributed through Google Forms. Quantitative analysis employed Structural Equation Modeling Partial Least Squares (SEM PLS) 4.

Results: The qualitative analysis showed that physical fatigue, muscle tension, operational intensity, limited recovery time, and difficult terrain were the main factors influencing the risk of muscle injuries among Indonesian military personnel. Warm-up and cool-down activities were considered important in improving physical fitness, body flexibility, operational readiness, and soldiers' motivation during humanitarian operations. The quantitative results demonstrated that warm-up and cool-down activities had a positive and significant effect on muscle injury prevention ($\beta = 0.490$; $p = 0.000$; $T = 8.184$; $R^2 = 0.240$; $F^2 = 0.315$).

Conclusion: Warm-up and cool-down activities are important factors in preventing muscle injuries, improving physical readiness, maintaining body flexibility, reducing fatigue, and strengthening the operational spirit of Indonesian military personnel during humanitarian missions.

Keywords: flexibility, humanitarian missions, Indonesian defense, operational readiness, preventive physiotherapy.

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INTRODUCTION

Humanitarian operations are an important part of military operations other than war carried out by the Indonesian National Armed Forces (*Tentara Nasional Indonesia*, TNI) in supporting disaster management, victim evacuation, logistics distribution, health services, and humanitarian assistance in various regions of Indonesia.¹ Indonesia's geographical condition, located within the ring of fire area, causes a high potential for natural disasters such as earthquakes, floods, landslides, and volcanic eruptions, thereby requiring high physical readiness among

TNI personnel to conduct field operations quickly, effectively, and sustainably. During these operations, military personnel perform high intensity physical activities such as long distance walking, carrying logistics, evacuating victims, and mobilizing in difficult and unstable terrains. These intensive physical activities may lead to muscle fatigue, joint tension, and muscle injuries if not supported by proper physical preparation. Therefore, warm-up and cool-down activities are essential components in maintaining physical fitness and preventing muscle injuries among TNI personnel during humanitarian operations.²

During humanitarian operations in disaster areas, TNI personnel often perform sudden physical activities with high intensity and long duration. These conditions usually occur under emergency situations, time limitations, and high operational pressure, resulting in warm-up and cool-down activities not being conducted optimally. Several studies have shown that warm-up activities before physical exercise can improve muscle flexibility, enhance blood circulation, increase body movement readiness, and reduce the risk of muscle injuries. Meanwhile, cool-down activities after physical exercise help muscle recovery,

reduce muscle tension, and maintain body stability following strenuous activities. Inadequate implementation of warm-up and cool-down activities may lead to muscle pain, cramps, muscle tension, physical fatigue, and decreased operational performance among military personnel during humanitarian missions.³

From a physiological perspective, warm-up activities increase muscle temperature, improve blood circulation, enhance oxygen delivery, and stimulate neuromuscular activation before strenuous physical activity. Increased muscle temperature improves muscle elasticity and reduces stiffness, thereby lowering the risk of muscle strain and injury. Dynamic stretching further enhances joint mobility and movement efficiency, allowing muscles and connective tissues to adapt more effectively to operational demands.⁴

Regulation of breathing is also important in optimizing oxygen intake, maintaining cardiovascular stability and limiting physiological stress responses during physical activity. Cool-down activities or procedures after completion of operational duties support gradual recovery by stimulating venous return, limiting the build-up of metabolic by-products, reducing muscle tension and maintaining physiological homeostasis. Collectively, these mechanisms improve physical readiness, recovery capacity and facilitate efforts to prevent muscle injury among personnel of the Indonesian National Armed Forces engaged in humanitarian missions, both domestically and within United Nations operations.⁵

Most previous studies have focused on warm-up and cool-down activities among athletes, students, and the general population, while studies specifically examining the effect of warm-up and cool down activities on muscle injury prevention among TNI personnel remain limited. Research involving military personnel in several countries has generally focused on physical fitness, military training performance, and injury rehabilitation rather than humanitarian operations, which have different physical activity characteristics.⁶ In addition, only a few studies in Indonesia have linked the implementation of warm-up and cool-down activities with muscle injury prevention among TNI personnel

during humanitarian operations. These conditions indicate the need for research that can provide scientific evidence regarding the importance of warm-up and cool-down activities as part of preventive physiotherapy strategies in supporting the health and operational readiness of TNI personnel.⁷

Although scientific evidence regarding warm-up and cool-down activities continues to expand, several important research gaps remain. Most previous studies have focused on athletes, students, and civilian populations, whereas research specifically involving personnel of the Indonesian National Armed Forces remains relatively limited. Studies conducted within the Indonesian military setting have generally emphasized physical fitness improvement, military training outcomes, and post injury rehabilitation programs, including those implemented through rehabilitation facilities such as the Rehabilitation Center of Commander-in-Chief Soedirman National Defense Central Hospital, Ministry of Defense. In contrast, studies examining the role of warm-up and cool-down activities as preventive strategies against muscle injuries during humanitarian operations are still scarce. Furthermore, empirical evidence regarding the effectiveness of these activities in operational environments characterized by difficult terrain, prolonged workloads, emergency situations, and limited recovery opportunities remains insufficient. Therefore, further research is needed to generate empirical evidence that is relevant to the context of humanitarian operations carried out by TNI personnel.

The benefits of warm-up activities for flexibility, blood circulation and preparing muscles and joints for high intensity physical activity have been shown in many studies. The benefits of cool-down activities for physiological recovery and the reduction of muscle tension after physical exertion have been shown as well. However, the benefits of these interventions in preventing injury have not been totally consistent in operational settings. Several studies have reported that structured warm-up programs are associated with a lower risk of muscle injuries, whereas other studies have found more limited effects when factors such as activity intensity, environmental conditions,

and individual fitness levels were not adequately controlled. This is particularly important as most of the research carried out to date has been on athlete populations using cross-sectional research designs and thus the generalisability of their findings to TNI personnel undertaking humanitarian operations at home and abroad is limited. These limitations highlight the need for further context-specific military research to develop a more comprehensive understanding of the role of warm-up and cool-down activities in contributing to muscle injury prevention and maintenance of physical readiness during humanitarian missions.

If warm-up and cool-down activities are not properly implemented, the risk of muscle injuries among TNI personnel may increase and negatively affect operational readiness, physical endurance, and the effectiveness of humanitarian operations. Repeated muscle injuries may also lead to mobility disorders, increased medical rehabilitation needs, and decreased long-term health quality among military personnel. Furthermore, suboptimal physical conditions may affect soldiers' ability to provide humanitarian assistance quickly and effectively during emergency situations and natural disasters.⁸

The novelty of this study is that it focuses on muscle injury prevention in Indonesian National Armed Forces personnel involved in humanitarian operations, which has received relatively little attention in previous research related to exercise physiology and muscle injury prevention. Unlike studies on athletes or civilians, humanitarian operations conducted by the TNI require personnel to perform long-lasting physical activities in unpredictable environmental conditions, challenging terrain, high and dynamic operational demands, and limited recovery opportunities. This study contributes to the development of military exercise physiology, preventive physiotherapy, and operational health by providing empirical evidence on the benefits of warm-up and cool-down activities in supporting operational duties, preventing muscle injuries, and maintaining the physical readiness and fitness of Indonesian military personnel.

Based on the explanation above, research regarding the effect of warm-up

and cool-down activities on muscle injury prevention among TNI personnel during humanitarian operations is necessary.⁹ This study is expected to provide scientific information regarding the importance of implementing warm-up and cool-down activities as part of preventive physiotherapy efforts to maintain the physical fitness and health of military personnel. In addition, the findings are expected to serve as a basis for developing physical training programs, injury prevention strategies, and improving the operational readiness of TNI personnel in supporting humanitarian operations.¹⁰

METHODS

This study employed a mixed method design with an exploratory sequential strategy. In this strategy, the qualitative data collection and analysis were carried out first to explore the experiences, perceptions, and challenges faced by Indonesian National Armed Forces personnel in implementing warm-up and cool-down activities during humanitarian missions. The results of the qualitative phase were then used as the basis for developing the quantitative research instrument and determining the main variables included in the structural model. This approach was chosen because empirical research on the role of warm-up and cool-down activities in supporting muscle injury prevention during humanitarian operations involving TNI personnel is still limited. Therefore, an initial exploratory phase was necessary to identify relevant themes, which were subsequently validated through quantitative analysis to examine the relationships among the identified variables.¹¹

In the qualitative phase, primary data were collected through structured interviews with 15 participants. Participants were selected using a purposive sampling technique. The inclusion criteria consisted of TNI physical training instructors who had at least five years of experience in military physical training and were directly involved in preparing TNI personnel for various operational assignments.¹²

The quantitative phase, is the data collection using questionnaires on 100 respondents. Participants were selected

using a purposive sampling technique. The inclusion criteria consisted of active Indonesian National Armed Forces personnel who had participated in humanitarian operations, either domestically or internationally, within the previous five years. Their operational experience included disaster response missions, coronavirus disease 2019 (Covid-19) response operations, security assignments in conflict prone areas such as Papua, and peacekeeping and humanitarian missions in Lebanon under the auspices of the United Nations. A sample size of 100 respondents was considered adequate for analysis using Partial Least Squares Structural Equation Modeling version 4. It was expected that the diversity of the respondents' operational experiences would provide a more comprehensive understanding of the implementation of warm-up and cool-down activities across various TNI operational environments. The research instrument consisted of a structured questionnaire using a five point Likert scale and distributed through Google Forms. The questionnaire was designed to examine the relationship between warm-up and cool-down activities and muscle injury prevention among Indonesian National Armed Forces personnel.

Qualitative data analysis followed the Creswell model supported by NVivo 12 software.¹³ The analysis stages included data collection, data reduction, data classification, data coding, theme development, data interpretation, and conclusion drawing. Nvivo features used in the analysis included run query, word frequency query, word cloud, and hierarchy chart to identify patterns, dominant themes, and relationships among research concepts.¹⁴

Quantitative data analysis was conducted using Structural Equation Modeling Partial Least Squares (SEM PLS) 4. The analysis stages included outer model testing consisting of convergent validity, discriminant validity, and composite reliability, as well as inner model testing including path coefficient, R-square, f-square, and hypothesis testing using bootstrapping. Model evaluation was conducted through model fit assessment to determine the suitability of the research model.¹⁵

Data validity was strengthened through triangulation techniques by comparing the qualitative analysis results using NVivo with the quantitative analysis results using SEM PLS to improve the credibility, reliability, and consistency of the research findings. This study also fulfilled research ethical requirements through informed consent, in which all participants understood the objectives, benefits, and procedures of the study before the data collection process was conducted.¹⁶

Several confounding variables may influence muscle injury prevention among Indonesian National Armed Forces personnel, including physical fitness level, age, operational workload, nutritional status, sleep quality, hydration status, and previous injury history. Although these factors were not directly included in the structural model, several measures were taken to minimize potential sources of bias. These measures included the establishment of participant selection criteria that were in accordance with the research objectives, the recruitment of respondents with operational experience, the use of standardized research instruments, and the triangulation between qualitative and quantitative data obtained from personnel involved in humanitarian missions. To increase the objectivity of data, participation was voluntary and anonymous. In addition, qualitative and quantitative data were analyzed separately in accordance with the stages of the mixed-methods design before being integrated to obtain a more comprehensive understanding of the phenomenon under investigation. The integrated findings were used as a basis for interpreting the results, developing the discussion, and drawing conclusions regarding the role of warm-up and cool-down activities in supporting muscle injury prevention among Indonesian National Armed Forces personnel.

RESULTS

Qualitative findings

Implementation of warm-up and cool-down activities

Military sports trainers recognized warm-up and cool-down activities as an important aspect of maintaining

soldiers' physical readiness before and after humanitarian operations. Warm-up activities typically consisted of dynamic stretching, light jogging, joint mobility exercises and activation of upper and lower body muscles. Then, static stretching, muscle relaxation, breathing regulation, and gradual reduction of heart rate were activities to cool-down.¹⁷ Warm-up activities were performed for an ideal period of 10-15 minutes before the physical activities started and cool-down activities were performed for about 5-10 minutes after the operations were finished. This period was considered adequate to improve the body flexibility, increase blood circulation, reduce muscle tension and facilitate physical recovery after high intensity field activities.¹⁸ The most salient terms identified were "warm-up," "fitness," "injury," "muscle," "physical," "operation," "motivation," and "fatigue" (**Figure 1**). These findings indicate that warm-up and cool-down activities were considered important in maintaining physical fitness, operational readiness, and soldiers' motivation during humanitarian missions.

Factors influencing muscle injury prevention

High intensity physical activities such as long distance walking, victim evacuation, logistics transportation, and mobilization in difficult terrains increased the risk of muscle tension and injury when the body was not adequately prepared before deployment. In addition, long operational duration gradually caused physical fatigue, requiring adequate recovery after strenuous activities.¹⁹ Difficult operational environments that were muddy, rocky, slippery, and uphill also increased the risk of muscle injuries and joint disorders among military personnel. Furthermore, soldiers with better physical fitness levels were considered to have greater endurance, stronger physical adaptability, and better ability to cope with operational pressures compared to personnel with lower physical fitness levels.²⁰

Compliance with training programs

Discipline in implementing training programs, including consistent warm-up and cool-down activities, played an important role in improving the body's ability to cope with operational pressure



Figure 1. Word cloud analysis NVivo

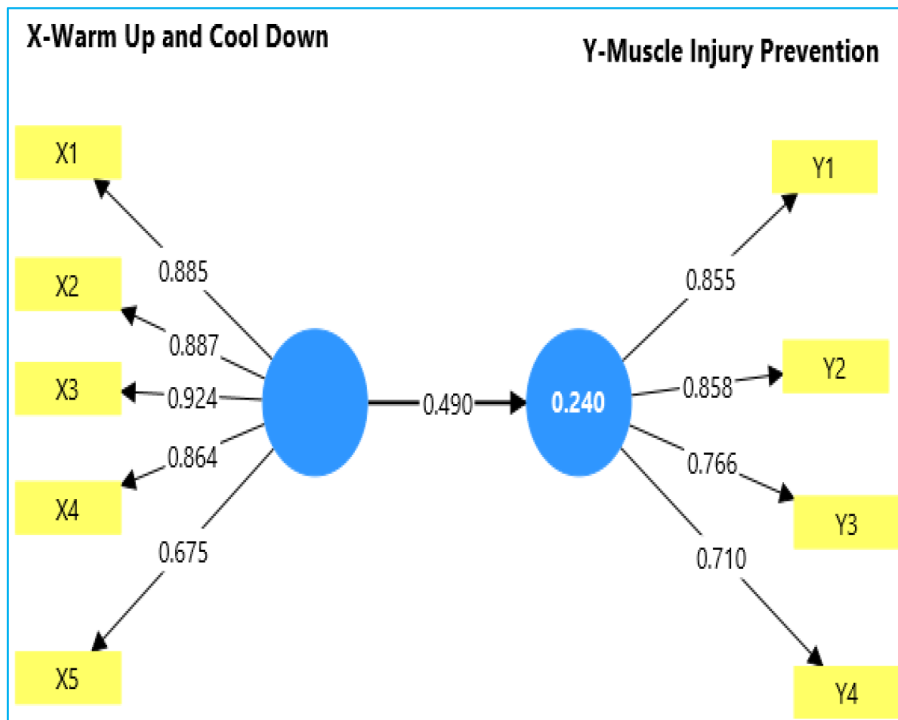


Figure 2. Outer loading Structural Equation Modeling Partial Least Squares (SEM PLS) 4.

in the field.²¹ Military personnel who regularly followed structured physical training programs were considered to have better physical readiness, stronger endurance, improved muscle adaptation, and lower risk of physical fatigue and muscle injuries during humanitarian operations.²²

Obstacles in implementing warm-up and cool-down activities

Emergency situations and rapid response demands often caused physical preparation stages to be conducted briefly, limiting the proper implementation of warm-up and cool-down activities among military personnel. In addition, soldiers' primary focus on victim rescue and mission completion reduced their attention

to physical preparation and recovery during operations. Some personnel also still perceived warm-up and cool-down activities as additional tasks rather than essential components of operational readiness. Furthermore, environmental factors such as extreme weather, heavy rainfall, difficult terrain, and limited field facilities became significant obstacles to performing stretching exercises and physical recovery optimally during humanitarian missions.²³

Strategies for preventing muscle injuries

Effective strategies for preventing muscle injuries among Indonesian military personnel included conducting dynamic warm-up activities for 10-15 minutes before field operations and performing cool-down and stretching exercises for 5-10 minutes after activities were completed. In addition, strengthening routine and measurable military physical fitness programs, managing balanced rest and recovery periods, and providing preventive physiotherapy education were considered important in maintaining soldiers' physical readiness during humanitarian missions.²⁴ Furthermore, enhancing motivation, mental readiness, and operational spirit also played a significant role in supporting physical endurance, reducing fatigue, and improving operational performance during field assignments.²⁵

Quantitative findings

Descriptive analysis

A total of 100 Indonesian military personnel participated in the quantitative phase of the study, all possessing prior operational experience in humanitarian missions, disaster response, COVID-19 management activities, or regional security assignments that provided relevant perspectives on implementing warm-up and cool-down routines during field operations. The empirical analysis evaluates the measurement model (Tables 1–5) by assessing outer loadings, internal consistency reliability, convergent validity via Average Variance Extracted (AVE), and discriminant validity using the Heterotrait-Monotrait Ratio of Correlations (HTMT) and the Fornell-Larcker criterion. Subsequently, the

Table 1. Warm-up and cool-down (X)-variable

Variable X	Indicator	Outer loading
Warm-up and cool-down	X1-Warm-up duration	0.885
	X2-Cool-down duration	0.887
	X3-Dynamic stretching	0.924
	X4-Static muscle stretching and Frequency of implementation	0.864
	X5-Breathing regulation and Compliance with exercise procedures	0.675

Table 2. Muscle injury prevention (Y)-variable

Variable Y	Indicator	Outer loading
Muscle injury prevention	Y1-Reduction of muscle cramps and Reduction of muscle pain	0.855
	Y2-Reduction of physical fatigue, Reduction of muscle tension, and Improvement of body flexibility	0.858
	Y3-Improvement of physical endurance and Reduction of injury risk during operations	0.766
	Y4-Faster body recovery and Compliance with exercise procedures	0.710

Table 3. Construct validity and reliability

	Cronbach's alpha	Composite reliability (rho-a)	Composite reliability (rho-c)	Average variance extracted
X-warm-up & cool-down	0.904	0.951	0.929	0.725
Y-muscle injury prevention	0.825	0.946	0.876	0.639

Table 4. Heterotrait-monotrait ratio of correlations (HTMT)

	X-warm-up & cool-down	Y-muscle injury prevention
X-warm-up and cool-down		
Y-muscle injury prevention	0.477	

Table 5. Fornell Larcker criterion

	X-warm-up and cool-down	Y-muscle injury prevention
X-warm-up and cool-down	0.852	
Y-muscle injury prevention	0.490	0.800

Table 6. Hypothesis testing

	Original sample	Sample mean	Standard deviation	T statistics	P-values
X-warm-up and cool-down to Y-muscle injury prevention	0.490	0.511	0.060	8.184	0.000

Table 7. F-square

	X-warm-up and cool-down	Y-muscle injury prevention
X-warm-up and cool-down		0.315
Y-muscle injury prevention		

structural model assessment (Tables 6–7) examines direct relationship strengths through path coefficients, statistical significance via hypothesis testing, and effect sizes using F^2 (F -squared), while overall model fit and predictive capability (Tables 8–10) are determined using the coefficient of determination (R^2), Standardized Root Mean Square Residual (SRMR), and Cross-Validated Predictive Ability Test (CVPAT).

Outer model

The outer loading results (Figure 2) indicate that all indicators used in this study met the convergent validity criteria because they had outer loading values above 0.60. In variable Warm-up and Cool-down (X), the highest outer loading value was found in indicator dynamic stretching (X3) with a value of 0.924, indicating that dynamic stretching was the most dominant indicator in representing warm-up and cool-down activities among Indonesian military personnel. This was followed by indicator cool-down duration (X2) with a value of 0.887 and warm-up duration (X1) with a value of 0.885, both demonstrating very strong contributions to the construct. Meanwhile, indicator Breathing regulation and compliance with exercise procedures (X5) had the lowest value of 0.675, but it still met the validity requirement because it was above the minimum threshold of 0.60.

In variable muscle injury prevention (Y), indicator reduction of physical fatigue, reduction of muscle tension, and improvement of body flexibility (Y2) obtained the highest outer loading value of 0.858, indicating that these factors were the strongest representation of muscle injury prevention. Indicator reduction of muscle cramps and reduction of muscle pain (Y1) also showed a strong contribution with a value of 0.855. Furthermore, indicator improvement of physical endurance and reduction of injury risk during operations (Y3) obtained a value of 0.766, while indicator faster body recovery and compliance with exercise procedures (Y4) had the lowest value of 0.710, but it remained valid because it exceeded the minimum threshold of 0.60. Overall, these findings demonstrate that all indicators were valid and appropriate for measuring

Table 8. R-square

	R-square	R-square adjusted
Y-muscle injury prevention	0.240	0.232

Table 9. Standardized root mean square residual (SRMR)

Standardized root mean square residual	Saturated model	Estimated model
SRMR	0.107	0.107

Table 10. Cross-validated predictive ability test (CVPAT)-structural equation modelling partial least squares (SEM PLS) vs. indicator average

	PLS loss	Indicator average (IA) loss	Average loss difference	t value	P-value
Y-muscle injury prevention	0.240	0.270	-0.030	2.017	0.046

the relationship between warm-up and cool-down activities and muscle injury prevention among Indonesian military personnel during humanitarian operations.²⁶

The structural model results indicate that the Warm-up and Cool-down variable has a positive effect on Muscle Injury Prevention among Indonesian military personnel during humanitarian operations, with a path coefficient value of 0.490. This value demonstrates that proper implementation of warm-up and cool-down activities contributes moderately to reducing the risk of muscle injuries during field operations. In addition, the R-square value of 0.240 indicates that the Warm-up and Cool-down variable explains 24.0% of the variance in Muscle Injury Prevention, while the remaining 76.0% is influenced by other factors outside the research model, such as physical fitness level, operational intensity, environmental conditions, nutritional intake, and recovery management. These findings suggest that warm-up and cool-down activities play an important role in improving physical readiness, reducing fatigue and muscle tension, and supporting operational performance and motivation among Indonesian military personnel during humanitarian missions.²⁷

As shown in Table 3, the construct validity and reliability results indicate that all variables met the recommended criteria for reliability and convergent validity. The X-warm-up and cool-down variable obtained a Cronbach's alpha value

of 0.904, composite reliability (rho-a) of 0.951, composite reliability (rho-c) of 0.929, and AVE value of 0.725. Meanwhile, the Y-Muscle Injury Prevention variable showed a Cronbach's alpha value of 0.825, composite reliability (rho-a) of 0.946, composite reliability (rho-c) of 0.876, and AVE value of 0.639. These values exceeded the recommended thresholds of Cronbach's alpha and composite reliability >0.70 and AVE >0.50, indicating that all constructs were reliable, internally consistent, and capable of explaining the variance of their indicators adequately.²⁸

These findings indicate that all measurement items consistently represented their respective constructs and demonstrated strong internal consistency. Therefore, the measurement model was considered reliable and suitable for further structural model evaluation.

As shown in Table 4, the HTMT value between X-warm-up and cool-down and Y-muscle injury prevention was 0.477. This value was below the recommended threshold of 0.90, indicating that the two constructs possessed good discriminant validity and were empirically distinct from one another. The findings demonstrate that the indicators used in each variable measured different conceptual constructs and did not overlap substantially.²⁷ As shown in Table 5, the discriminant validity assessment using the Fornell-Larcker Criterion demonstrated satisfactory results. The square root of AVE for X-warm-up and cool-down was 0.852, while for Y-muscle injury prevention

it was 0.800. These values were higher than the correlation value between the two constructs (0.490), indicating that each construct had stronger relationships with its own indicators than with other constructs in the model. Therefore, the discriminant validity requirement based on the Fornell-Larcker Criterion was successfully achieved.

The satisfactory discriminant validity results indicate that the constructs measured different conceptual domains and minimized the risk of multicollinearity between latent variables. This supports the robustness of the proposed measurement framework.

Inner model

As shown in **Table 6**, the hypothesis testing results indicate that the X-Warm-up and Cool-down variable had a positive effect on Y-Muscle Injury Prevention, with an original sample (O) value of 0.490. This value indicates that better implementation of warm-up and cool-down activities contributed to higher muscle injury prevention among Indonesian military personnel during humanitarian operations. In addition, the T-statistics value of 8.184 was greater than 1.96, and the P-values value of 0.000 was lower than 0.05, indicating that the hypothesis was statistically significant and accepted. These findings demonstrate that warm-up and cool-down activities had a significant effect on muscle injury prevention among Indonesian military personnel during humanitarian missions.²⁸ The significant relationship suggests that structured warm-up and cool-down activities may play an important preventive role in maintaining physical readiness and reducing operational injury risk among military personnel.

As shown in **Table 7**, the F-square value for the effect of X-warm-up and cool-down on Y-muscle injury prevention was 0.315. This value indicates that the warm-up and cool-down variable had a moderate to strong effect on muscle injury prevention based on Cohen's effect size criteria, namely 0.02 (small), 0.15 (moderate), and 0.35 (large). Therefore, the findings suggest that the implementation of warm-up and cool-down activities provided a substantial contribution to preventing muscle injuries

among Indonesian military personnel during humanitarian operations.²⁹

Model of fit

As shown in **Table 8**, the R-square value for Y-Muscle Injury Prevention was 0.240, while the adjusted R-square value was 0.232. These results indicate that the X-Warm-up and Cool-down variable was able to explain 24.0% of the variance in Muscle Injury Prevention, whereas the remaining 76.0% was influenced by other variables outside the research model. The adjusted R-square value, which was relatively close to the R-square value, also indicates that the model had acceptable predictive accuracy and consistency in explaining the dependent variable.³⁰

As shown in **Table 9**, the Standardized Root Mean Square Residual value for both the saturated model and estimated model was 0.107. Although the value was slightly above the ideal threshold of 0.08, it was still considered acceptable for exploratory research and indicated that the model had an adequate level of fit. The results suggest that the structural model in this study has been good enough to describe the association between warm-up and cool-down activities and muscle injury prevention in Indonesian military personnel in humanitarian operations.³¹

Table 10 presents the result of the comparison of PLS-SEM and Indicator Average. The loss value of PLS is 0.240 and the loss value of IA is 0.270 with an average loss difference of -0.030. In addition, the t-value was 2.017 with a p-value of 0.046, which was below the significance level of 0.05. These findings indicate that the PLS-SEM model performed significantly better than the indicator average approach in predicting Muscle Injury Prevention. Therefore, the model developed in this study was considered effective and statistically reliable for explaining the influence of warm-up and cool-down activities on muscle injury prevention among Indonesian military personnel during humanitarian operations.³²

DISCUSSION

The major findings of this study showed that the implementation of warm-up and cool-down activities, had a positive and significant effect on muscle injury

prevention among Indonesian military personnel in humanitarian operations. The study showed that high intensity physical activities, difficult operational terrain, limited recovery time and physical fatigue were the main factors contributing to risk of muscle injuries among soldiers. Qualitative analysis indicated the importance of warm-up and cool-down activities in the improvement of physical fitness, body flexibility, operational readiness and motivation of soldiers during humanitarian missions.³³

The findings suggest warm-up and cool-down activities are important preventive physiotherapy strategies within military operational environments. Not only do they help prevent injuries, they also support physical readiness, operational stamina and recovery ability on challenging humanitarian missions. The study also found that dynamic stretching was the most dominant indicator to support the effectiveness of warm-up and cool-down activities. Moreover, the research model demonstrated an acceptable predictive power with R-square of 0.240 and superior predictive performance when compared to the indicator average method. The findings of this study prove that the structured warm-up and cool-down programs can be used as preventive physiotherapy strategies to improve physical readiness, reduce the risk of muscle injuries, and support operational performance of Indonesian military personnel during humanitarian operations.³⁴

The present study results support some previous international studies that regular and structured warm-up and cool-down programs may improve flexibility, decrease muscle tension and reduce the risk of injury in physically active people. For example, Takeuchi et al. (2024) revealed a substantial decrease in the prevalence of muscle injuries in athletes through stretching interventions. Fanchini et al. (2020) emphasized the importance of routine exercise based injury prevention programs among elite football players. Vaara et al. (2022) also stress the importance of physical readiness to ensure operational performance of military personnel. The present study contributes to the existing evidence by focusing on humanitarian operations conducted by

Indonesian military personnel. Different from sports environments, humanitarian operations involve unpredictable workloads, emergency situations, harsh terrain, and limited recovery time. These operational characteristics may explain why warm-up and cool-down activities are even more critical for maintaining the operational readiness of personnel from the Indonesian National Armed Forces. Differences in the findings of different studies may be due to the differences in the characteristics of respondents, the operational environment, the level of physical activity intensity, and the method of assessing and measuring the occurrence of injury.

This study has important implications for the development of preventive physiotherapy strategies and physical training systems in the Indonesian military during humanitarian operations. The findings show that structured warm-up and cool-down activities can improve physical readiness, maintain body flexibility, reduce physical fatigue, and minimize the risk of muscle injury among soldiers involved in high intensity field activities. These results indicate that warm-up and cool-down activities should not be seen as complementary exercises before and after physical activities but as essential components in maintaining physical stability and operational performance during humanitarian missions.³⁵

The study also highlights the importance of consistently implementing warm-up and cool-down activities in every humanitarian operation, especially in disaster response, victim evacuation, logistics distribution, and other humanitarian missions. Consistent implementation is necessary because humanitarian operations are often conducted in difficult terrains, under high operational pressure, and with limited recovery time. When these activities are carried out routinely and according to proper procedures, soldiers' physical readiness can be better maintained, thereby reducing the risk of muscle disorders, physical fatigue, and decreased operational performance during field missions.³⁶

In addition, the results have strategic implications for the Ministry of Defense

and the Indonesian National Armed Forces to optimize the military health policies and operational fitness programs. The results indicate the need to improve the physical training systems that focus not only on improving physical performance but also on injury prevention and physical recovery. Therefore, warm-up and cool-down activities should be more systematically integrated into the military fitness programs, operational field procedures, rehabilitation systems, and occupational health management for military personnel.

From an academic perspective, this research adds to the development of military physiotherapy, military sports science and occupational health, specifically in the field of humanitarian and disaster response operations. The findings strengthen the argument that preventive physiotherapy approaches play an important role in supporting modern military operational readiness, especially in Military Operations Other Than War. Furthermore, this research may serve as a foundation for future studies related to military fitness, physical fatigue management, operational injury rehabilitation, and evidence-based military physiotherapy strategies for improving soldiers' health and operational performance.

The findings of this study have several practical implications for the Indonesian National Armed Forces. First, structured warm-up and cool-down procedures should be systematically integrated into military physical fitness programs and pre deployment preparation activities, both in operational settings and office environments. Second, military physical training instructors should emphasize the importance of dynamic stretching, breathing regulation, and post-activity recovery procedures following physical exercises and routine workplace activities as part of injury prevention strategies. Third, the implementation of standardized warm-up and cool-down procedures may contribute to maintaining operational readiness in daily duties, reducing injury related physical limitations among personnel, minimizing the need for rehabilitation services within Ministry of Defense and TNI hospitals, and enhancing

the effectiveness of various humanitarian operations.

This study contributes to strengthening the national defense posture through enhancing the physical and mental readiness of Indonesian National Armed Forces personnel as the primary component of national defense. The findings demonstrate that the regular implementation of warm-up and cool-down activities plays an important role in supporting muscle injury prevention, reducing physical fatigue, improving body flexibility, accelerating recovery processes, and maintaining personnel motivation and morale during operational duties. These aspects are particularly important because combat readiness and operational preparedness are determined not only by the availability of major defense equipment and weapon systems, but also by the quality of human resources who are healthy, physically fit, and capable of performing their duties continuously in various operational environments, including humanitarian operations, disaster response missions, security operations in conflict-prone areas, and international peacekeeping missions. This may reduce the rate of injury and health disruptions, and improve unit operational readiness. This also reduces the load on rehabilitation and health care services and enhances mission effectiveness. The study therefore supports the development of defense health policies, military physical fitness programmes and preventive physiotherapy as part of building a professional, resilient, adaptive and responsive national defense posture that can respond to diverse threats and emergency situations.

There are some limitations in this research. The first limitation is about the sample which was only comprised of 100 Indonesian National Armed Forces personnel who have been involved in humanitarian operations and this may limit the generalizability of the results. A second limitation is that this study only looked at warm-up and cool-down activities and did not consider other potential factors that might influence the prevention of muscle injury like nutrition, quality of sleep, hydration, stress, workload and medical history. Thirdly, the employment

of self-administered questionnaires might have resulted in response bias and the qualitative perspective of the study may not have fully depicted the intricate nature of the experiences of personnel. Additionally, the relatively low R-square value (0.240), the purposive sampling technique and the cross-sectional design suggest that there are other contributing factors and causal inference cannot be made. Future research should employ larger and more diverse samples, health and operational variables, and longitudinal designs to enhance the robustness and generalizability of the findings.

CONCLUSION

The present study shows that warm-up and cool-down activities are helpful in preventing muscle injuries and improving physical readiness among the personnel of the Indonesian National Armed Forces in supporting national defense duties. Regular implementation of these activities helps to improve physical condition, maintain body flexibility, reduce fatigue and muscle tension, accelerate the recovery processes, and minimize the risk of injuries during field assignments. Thus, warm-up and cool-down activities are important elements in maintaining physical performance and operational readiness, especially during humanitarian missions that require high levels of mobility and endurance.

Operational intensity, difficult terrain, limited time for recovery, and heavy physical workloads were identified as the main factors that increase the odds of muscle injury among military personnel. Therefore, a systematic approach to warm-up and cool-down activities needs to be routinely and continuously implemented as a preventive physiotherapy strategy to maintain physical fitness, enhance resilience, and support mental readiness to face varying operational demands.

The results, besides the practical implication for military members, provide scientific justification for the establishment of physical training programs, injury prevention systems, and health maintenance policies of the Indonesian National Armed Forces. In summary, this study highlights the strategic value of structured, regular, and continuous warm-

up and cool-down programs in enhancing operational readiness, contributing to defense health management, and enhancing the operational effectiveness of military operations and humanitarian missions. Ultimately, the physical condition of military personnel is the basis for force readiness, operational capability, and sustainability of the posture of national defense of Indonesia, both in domestic humanitarian operations and in international deployments.

ETHICAL CLEARANCE

This study has been approved by the Institutional Review Board of Universitas Pertahanan Indonesia, Jakarta, Indonesia with registration number 22/EC/II/2026 dated March 11, 2026.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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AUTHORS CONTRIBUTIONS

R, JAN, and GES designed the study, collected and processed the data, and drafted the initial manuscript. HR and FH contributed to study design and manuscript revision.

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