

**DEVELOPMENT OF KNOWLEDGE,
AWARENESS, AND PRACTICE
QUESTIONNAIRE ON SAFETY AND
EMERGENCY RESPONSE AND ASSESSING
FACTORS ASSOCIATED WITH DIVING
RELATED ILLNESS AND INJURY AMONG
RECREATIONAL SCUBA DIVERS IN MALAYSIA**

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UNIVERSITI SAINS MALAYSIA

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by

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for the degree of
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LIST OF SYMBOLS

%	Percentage
N:q	The ratio of participants to measured variables
n	Number of samples
>	More than
\geq	greater than or equal to
Δ	precision of estimation
$Z\alpha$	The Z-score associated with the level of significance α
p	Proportion
σ	Standard deviation
d	Detectable difference
P0	The proportion of participants with exposure to factors without the outcome
P1	The proportion of participants with exposure to factors with the outcome
M	The ratio of independent variables
α	alpha
b	Difficulty
a	Discrimination
χ^2	Chi-square

LIST OF ABBREVIATIONS

2PL-IRT	Two-Parameter Logistic Item Response Theory
AdjOR	Adjusted Odd Ratio
AIC	Akaike Information Criterion
AUC	Area Under Curve
AVE	Average Variance Extracted
BIC	Bayesian Information Criterion
BMI	Body Mass Index
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CI	Confidence Interval
DAN	Divers Alert Network
DCI	Decompression Illness
DCS	Decompression Sickness
DF	Degree of Freedom
DMO	Diving Medical Officer
DON	Dysbaric Osteonecrosis
EAP	Emergency Action Plan
ED	Emergency Department
EFA	Exploratory Factor Analysis
EMS	Emergency Medical Services
FL	Factor Loading
IBM	International Business Machines
I-CVI	Item-Level Content Validity Index
I-FVI	Item-Level Face Validity Index

IQR	Interquartile Range
IRT	Item Response Theory
ISO	International Organization for Standardization
JEPeM	Human Research Ethics Committee
KAP	Knowledge, Awareness, And Practice
KMO	Kaiser-Meyer-Olkin
MCO	Movement Control Orders
MI	Modification Indices
MLR	Multiple Logistic Regression
MLR	Maximum Likelihood Robust
MPA	Marine Protected Areas
MSDA	Malaysia Scuba Diving Association
NAT	Norm Activation Theory
NAUI	National Association of Underwater Instructors
OR	Odds Ratio
OSH	Occupational Safety and Health
PADI	Professional Association of Dive Instructors
PAF	Principal Axis Factoring
PFO	Patent Foramen Ovale
RMSEA	Root Mean Square Error of Approximation
RMSR	Root Mean Square Residual
ROC	Receiver Operating Characteristic
SAGE	Scientific Advisory Group for Emergencies
Scuba	Self-Contained Underwater Breathing Apparatus
S-CVI	Scale-Level Content Validity Index
S-CVI/Ave	Scale-Level Content Validity Index Using the Averaging
S-CVI/UA	Scale-Level Content Validity Index Using the Universal Agreement

SD	Standard Deviation
SDG	Sustainable Development Goals
SLR	Simple Logistic Regression
SPSS	Statistical Package for the Social Sciences
SRMR	Standardized Root Mean Square Residual
SSI	Scuba Schools International
TDF	Theoretical Domains Framework
TLI	Tucker Lewis Index
UN	United Nations
USA	United States of America
USM	Universiti Sains Malaysia

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Appendix N	Achievement

**PEMBENTUKAN SOALAN KAJI SELIDIK TENTANG
PENGETAHUAN, KESEDARAN DAN AMALAN TERHADAP
KESELAMATAN DAN TINDAK BALAS KECEMASAN SERTA
PENILAIAN FAKTOR-FAKTOR YANG BERKAITAN DENGAN
PENYAKIT DAN KECEDERAAN BERHUBUNG DENGAN SELAMAN
DALAM KALANGAN PENYELAM SKUBA REKREASI DI MALAYSIA**

ABSTRAK

Latar belakang: Aktiviti selaman skuba bagi tujuan rekreasi, merupakan salah satu sukan yang mencabar, membawa risiko dalaman seperti persekitaran bertekanan tinggi dan perubahan keapungan, yang boleh memberi impak kepada kebajikan fizikal dan psikologi penyelam. Walaupun aktiviti selaman ini mengujakan, keselamatan bergantung pada pengetahuan, kesedaran, dan amalan keselamatan yang kukuh. Penilaian KAP penyelam adalah penting, menekankan keperluan penambahbaikan yang berterusan.

Objektif: Kajian ini bertujuan menghasilkan dan mengesahkan kaji selidik baru untuk menilai pengetahuan, kesedaran, dan amalan keselamatan serta tindak balas kecemasan dalam kalangan penyelam skuba di Malaysia, dan mengkaji faktor-faktor yang mempengaruhi tahap pengetahuan, kesedaran, dan amalan keselamatan serta tindak balas kecemasan. Selain itu, kajian bertujuan menyelidik prevalens kecederaan dan penyakit berkaitan menyelam bersama faktor-faktor yang mempengaruhinya.

Metodologi: Kajian ini bermula pada November 2022 sehingga Disember 2023, terdiri daripada dua fasa. Fasa pertama melibatkan 555 penyelam skuba bertujuan untuk menghasilkan dan mengesahkan kaji selidik dengan menggunakan tinjauan penulisan, pendapat pakar, soal selidik yang telah sedia ada, dan rangka teori yang sedia ada. Pengesahan kaji selidik melibatkan “item response theory” (IRT) untuk bahagian pengetahuan, manakala analisis faktor eksploratori/konfirmatori (EFA/CFA) untuk menganalisis bahagian kesedaran dan amalan. Pada fasa kedua, kajian keratan rentas telah dilakukan ke atas 407 penyelam skuba dari sepuluh pusat menyelam di Pulau Tioman dan Pulau Perhentian, menggunakan kaji selidik yang baharu.

Keputusan: Kaji selidik mempunyai 42 item yang disahkan secara statistik, menunjukkan konsistensi dalaman yang baik (Cronbach’s alpha: 0.77–0.80). Walau bagaimanapun, kebolehpercayaan komposit adalah di bawah paras yang diperlukan (Raykov’s rho: 0.55–0.71). Penunjuk kesesuaian model untuk pengetahuan adalah sah dengan menggunakan analisis *modified parallel* dengan keputusan RMSEA adalah 0.02 (95% CI = 0.005, 0.03). Manakala penunjuk kesesuaian model untuk kesedaran dan amalan adalah memuaskan (SRMR = 0.04; RMSEA = 0.03–0.04; CFI = 0.98; TLI = 0.96–0.97). Pada fasa kedua, prevalens kecederaan/penyakit berkaitan menyelam adalah 26.1%, terutamanya “barotrauma” (17.9%). Manakala kecelakaan berkaitan aktiviti selaman skuba pula dilaporkan sebanyak 51.4%, terutamanya disebabkan masalah keseimbangan (40.8%). Penilaian KAP menunjukkan bahawa 91.8% mempunyai pengetahuan yang baik (skor purata: 17.8 (SD=2.08), 93.1% mempunyai kesedaran yang baik (skor purata: 4.37, SD=0.41), dan 85% mempraktikkan amalan yang baik (skor purata: 4.11, SD=0.44). Faktor-faktor yang

mempengaruhi pengetahuan yang baik termasuk tahap pendidikan (*adjOR*: 3.13; 95% CI: 1.03–9.46; $p=0.044$) dan kedalaman menyelam (*adjOR*: 0.40; 95% CI: 0.18–0.90; $p=0.027$). Kekerapan menyelam adalah faktor penting bagi kesedaran yang baik (*adjOR*: 0.20; 95% CI: 0.05–0.89; $p=0.034$). Kecederaan dan penyakit berkaitan menyelam dikaitkan dengan peningkatan ketinggian individu (*adjOR*: 1.37; 95% CI: 1.00–1.88; $p=0.050$), berat badan (*adjOR*: 0.68; 95% CI: 0.46–0.99; $p=0.045$), BMI (*adjOR*: 3.14; 95% CI: 1.06–9.30; $p=0.039$), dan tahap pensijilan menyelam (*adjOR*: 3.78; 95% CI: 1.68–8.49; $p=0.001$). Manakala, kecelakaan juga dikaitkan dengan peningkatan berat badan (*adjOR*: 1.03; 95% CI: 1.01–1.05; $p=0.008$) dan tahap pensijilan menyelam (*adjOR*: 6.08; 95% CI: 2.20–16.84; $p=0.001$).

Kesimpulan: Kaji selidik yang baharu dihasilkan adalah sah dan boleh dipercayai untuk menilai KAP penyelam skuba dalam keselamatan dan tindak balas kecemasan. Penyelam skuba menunjukkan tahap pengetahuan, kesedaran, dan amalan terhadap keselamatan dan tindak balas kecemasan yang baik, menunjukkan komitmen penyelam terhadap keselamatan. Prevalens kecederaan dan penyakit berkaitan selaman skuba adalah rendah berbanding kajian sebelumnya manakala kejadian kecelakaan adalah lebih tinggi berbanding kajian lalu. Intervensi bersasar dapat meningkatkan strategi pencegahan dan intervensi, memberi manfaat kepada penyelam skuba secara lebih efisien.

Kata kunci: kaji selidik, penyelam skuba, pengetahuan, kesedaran, amalan, keselamatan, tindak balas kecemasan, penyakit/kecederaan berkaitan selaman skuba, kecelakaan.

**DEVELOPMENT OF KNOWLEDGE, AWARENESS, AND PRACTICE
QUESTIONNAIRE ON SAFETY AND EMERGENCY RESPONSE AND
ASSESSING FACTORS ASSOCIATED WITH DIVING RELATED ILLNESS
AND INJURY AMONG RECREATIONAL SCUBA DIVERS IN MALAYSIA**

ABSTRACT

Background: Recreational scuba diving, an adventurous sport, poses inherent risks like high-pressure environments and buoyancy changes, impacting divers' well-being. While the undersea journey is captivating, safety hinges on strong foundations in knowledge, awareness, and safety practices. Assessing divers' KAP is crucial, highlighting the need for ongoing improvements.

Objectives: To develop and validate a new questionnaire assessing the knowledge, awareness, and practice of safety and emergency response among scuba divers in Malaysia, and to determine factors associated with good KAP. Additionally, the study aims to investigate the prevalence of diving-related injury and illness, along with its associated factors.

Methodology: This study, spanning from November 2022 to December 2023, had two phases. Phase one involved 555 scuba divers, aimed to develop and validate a questionnaire using literature review, expert opinions, existing questionnaires, and a theoretical framework. Validation involved item response theory (IRT) for knowledge and exploratory/confirmatory factor analysis (EFA/CFA) for awareness and practice. In phase two, a cross-sectional study surveyed 407 divers from ten centers in Tioman and Perhentian Islands, employing the new questionnaire.

Result: A validated 42-item questionnaire, demonstrating good internal consistency (Cronbach's alpha: 0.77–0.80). Composite reliability, however, fell slightly below the threshold (Raykov's rho: 0.55–0.71). The model fitness for the knowledge component was confirmed through modified parallel analysis, revealing an RMSEA of 0.02 (95% CI = 0.005, 0.03). Meanwhile, for awareness and practice, the fitness indices were deemed satisfactory: SRMR = 0.04, RMSEA = 0.03–0.04, CFI = 0.98, TLI = 0.96–0.97. In phase two, diving-related injury/illness prevalence was 26.1%, predominantly barotrauma (17.9%). Mishaps were reported at 51.4%, mainly due to equalization problems (40.8%). KAP assessment revealed that 91.8% had good knowledge (mean score: 17.8 (SD=2.08), 93.1% had good awareness (mean score: 4.37, SD=0.41), and 85% exhibited good practice (mean score: 4.11, SD=0.44). Factors associated with good knowledge included education level (adjOR: 3.13; 95% CI: 1.03,9.46; p=0.044) and diving depth (adjOR: 0.40; 95% CI: 0.18,0.90; p=0.027). Dive frequency was a significant factor for good awareness (adjOR: 0.20; 95% CI: 0.05,0.89; p=0.034). Diving-related injury and illness were associated with increasing height (adjOR: 1.37; 95% CI: 1.00,1.88; p=0.050), weight (adjOR: 0.68; 95% CI: 0.46,0.99; p=0.045), elevated BMI (adjOR: 3.14; 95% CI: 1.06,9.30; p=0.039), and certification level (adjOR: 3.78; 95% CI: 1.68,8.49; p=0.001). Mishaps were associated with increased weight (adjOR: 1.03; 95% CI: 1.01,1.05; p=0.008) and certification level (adjOR: 6.08; 95% CI: 2.20,16.84; p=0.001).

Conclusion: The newly developed questionnaire has been proven to be valid and reliable for assessing scuba divers' KAP in safety and emergency response. Scuba divers possess good knowledge, awareness, and practice in safety and emergency

response, underscoring their commitment to safety. Dive-related injuries/illnesses among scuba divers were slightly lower than in the previous study, whereas the prevalence of mishaps was higher compared to earlier studies. Targeted group interventions have the potential to improve prevention and intervention strategies, providing efficient benefits to scuba divers.

Keywords: Scuba diving, knowledge, awareness, practice, safety, emergency response, diving related injury, mishaps

CHAPTER 1

INTRODUCTION

1.1 Scuba Diving Industry

The recreational scuba (Self-contained Underwater Breathing Apparatus) diving industry is a rapidly growing marine industry globally, including in Malaysia. The Professional Association of Dive Instructors (PADI) has issued more than 28 million diver certifications since 1967, and there are more than 128,000 PADI professional members around the globe (PADI, 2021). The number of locations promoting their marine resources to become scuba diving destinations and hotspots demonstrates that scuba diving tourism is an economically significant industry. There are 6,600 PADI Dive Centers and Resorts worldwide (PADI, 2021).

Scuba diving constitutes a significant and economically valuable component of marine tourism, as evidenced by annual estimates exceeding \$4.5 billion in Southeast Asia (Brauwer *et al.*, 2017). In the specific context of Malaysia, the economic revenue derived from recreational scuba diving in the Semporna region alone is substantial, with projected figures reaching USD55.3 million for local enterprises. This contribution accounts for approximately 0.02% of Malaysia's total Gross Domestic Product during the period spanning 2016 to 2018 (Zimmerhackel *et al.*, 2018)

1.2. Safety and Health in Scuba Diving Industry

Safety has become paramount to meet the growing market demand and expand scuba diving into new markets while minimizing risks and ensuring a secure and enjoyable experience (Dimmock and Musa, 2015). The scuba diving industry

strongly emphasizes both safety and health to ensure the well-being of divers and the preservation of underwater ecosystems. While scuba diving is commonly perceived as a safe recreational activity, it remains essential to underscore safety concerns to ensure divers' well-being and reduce potential health complications.

Recreational scuba diving operations are susceptible to numerous hazards, resulting in liability, incidents, accidents, personal injuries, or even fatalities. These risks encompass human lives, infrastructure, vessels, vehicles, the environment, and services, necessitating comprehensive risk assessment in different dive locations and diving activities (Lucrezi *et al.*, 2018).

Even with well-established safety measures, residual risks persist in scuba diving, increasing the potential for accidents when safety precautions are overlooked. Safety measures in scuba diving encompass essential aspects such as proper training and certification, diligent equipment maintenance, thorough dive planning, and awareness of environmental conditions. Ensuring safe scuba diving involves obtaining adequate training and certification from well-recognized organizations like PADI and NAUI (National Association of Underwater Instructors). These organizations have gradually established safety standards for recreational divers, particularly those passively exploring marine habitats, contributing to the sport's overall safety. The routine maintenance and thorough inspection of diving equipment, including tanks, regulators, and buoyancy control devices, are paramount in preventing equipment-related incidents (Buzzacott, 2012; Mitchell and Doolette, 2013).

Additionally, effective dive planning, which encompasses comprehension of dive tables, profiles, and the potential risks associated with nitrogen narcosis and

decompression illness, plays a pivotal role in ensuring diver safety (Vann *et al.*, 2011). Furthermore, divers must exhibit awareness of environmental factors such as underwater currents, visibility conditions, and potential hazards. Additional training and heightened caution may be necessary when divers explore unfamiliar or challenging environments.

These safety requirements have evolved in tandem with the commercialization of the scuba diving industry. Safety organizations, such as the Divers Alert Network (DAN), are dedicated to research, campaigning, emergency medical assistance, education, prevention, mitigation, accessories, and insurance for diving operations and scuba divers (DAN, 2020). This endeavor holds the potential to uncover new knowledge and insights that can contribute to developing policies and safety standards, ultimately reducing incidents associated with recreational diving.

In Malaysia, Tourism Malaysia collaborates closely with the Malaysia Scuba Diving Association (MSDA) to elevate Malaysia into a world-class diving destination. This collaboration fosters international recognition for diving in Malaysia and shapes the future of the country's diving sector. It ensures alignment with internationally recognized Dive Safety Standards as stipulated by The International Organization for Standardization (ISO) Standards of Recreational Diving Services (Tourism Malaysia, 2020).

The health of divers is equally essential and encompasses factors like physical fitness and medical considerations. To ensure diver health, being in good physical condition and undergoing medical evaluations when necessary is crucial. Divers with pre-existing medical conditions should undergo thorough assessments before engaging in diving activities (Denoble *et al.*, 2008). Having a comprehensive

understanding and knowledge of the risks associated with diving-related injuries and illnesses, as well as their symptoms and signs, is paramount to ensure prompt and appropriate treatment. Effective treatment and proper management of diving-related injuries constitute essential aspects of a diver's health. Divers also need a good knowledge of marine life hazards, including stinging and biting organisms. Prevention and treatment of envenomation are integral to diver safety (Lucrezi *et al.*, 2018).

It's crucial for the diving community, including divers, instructors, and dive operators, to prioritize both safety and health to ensure enjoyable and risk-minimized diving experiences. By prioritizing safety and health, divers can enjoy their underwater adventures while minimizing risks, thus contributing to the sustainable exploration and preservation of marine environments.

1.3 Prevalence of Diving Related Illness/Injuries and Mishaps

The prevalence of dive-related injuries and illnesses is a significant concern in diving industries, whether recreational or occupational. Several studies have examined the incidence and types of diving-related injuries and illnesses. In the USA, according to DAN, it was reported that the incidence of all self-reported diving-related injuries was 3.02 per 100 dives. DAN researchers suggest that recreational scuba diving fatalities in the United States and Canada vary between 80 and 100 per year (Ranapurwala *et al.*, 2014). According to the report by DAN, in 2014, the number of diving-related injuries was 2046 cases, which has increased over the years (DAN, 2019). Of the injuries and illnesses related to diving, the majority were otolaryngologic, with approximately two-thirds being otologic in nature. Moreover, other frequently reported injuries included decompression illness, near

drowning, panic attacks, and other injuries such as wounds and musculoskeletal issues (DAN, 2019; Mallen and Roberts, 2020)

Meanwhile, 20 diving accident cases in Malaysia are reported annually, and the percentage of accidents among divers is increasing (Rozali *et al.*, 2008). According to MSDA, in Malaysia, the incidence of diving accidents is on the rise, mirroring the increase in the number of individuals engaged in scuba diving. It was reported that, between January 2019 and July 2019, seven fatal cases among divers were documented in Malaysia (MSDA, 2020). Nevertheless, published data remains scarce regarding the prevalence of dive-related injuries and illnesses in Malaysia in recent years.

In the most recent incident related to recreational scuba diving, four divers went missing during a diving exercise in Pulau Tokong Sanggol, Mersing, Johor. They failed to return to the boat, with three eventually being found safe by an Indonesian fisherman. At the same time, one diver tragically lost their life after being swept away into Indonesian waters (Ahmad, 2022). Similarly, in another recent fatality involving recreational scuba diving, a certified scuba diver passed away while diving in Tokong Timur, Pulau Tenggol. She was found unconscious after surfacing just 15 minutes into her planned 45-minute dive, and the cause of the accident is still under investigation (Ilham, 2022). These incidents are noteworthy as they involved certified and experienced scuba divers led by experienced dive instructors, highlighting the unpredictable nature of accidents in the activity.

Mishaps were unplanned events that occurred due to human error, equipment failures, and environmental factors. These events were the precursor of injuries and accidents that may contribute to illnesses and fatalities (Ranapurwala *et al.*, 2017).

Mishaps have the potential to be preventable through continuous learning and the consistent practice of safety measures. Responsibility for safety falls not solely on the dive center but also on the divers, who must take a proactive role in prioritizing safety. For example, the utilization of pre-dive checklists is not solely the responsibility of the dive center to oversee; divers should conduct these checks meticulously and effectively.

It was reported that about 36% of the divers experienced at least one mishap, ranging from 1 to 11 mishaps per diver. The most common mishaps experienced by the divers include rapid ascent, lost buddy, change in buoyancy, equalization problems, and mask problems (Ranapurwala *et al.*, 2017).

1.4 Factors Associated with Mishaps and Dive-Related Injuries/illness

Despite the robust educational and training programs implemented by certification agencies during the certification process, the persistence of preventable accidents in recreational diving is evident. This observation underscores the notion that such training primarily emphasizes skill acquisition and material aspects. However, it is increasingly recognized that knowledge alone may not offer a comprehensive solution. A heightened focus on safety awareness and the consistent implementation of safety practices is imperative in mitigating such incidents and accidents.

Buzzacott (2010) depicted the contributing factors for diving-related injuries in Figure 1.1, classifying these factors into environmental, diver-related, and dive activity-related categories. Importantly, all these factors were not isolated but rather exhibited interdependencies and interrelatedness among them.

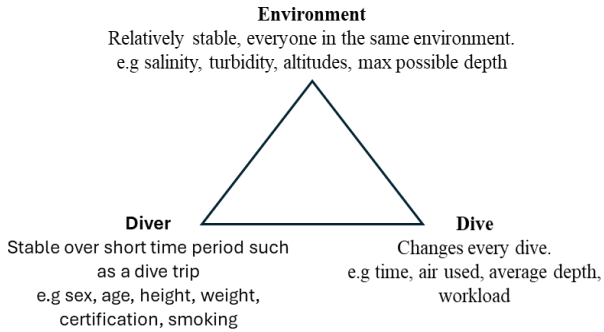


Figure 1.1: Diving Injury Triangle

Diver-related factors emerge as the primary contributors to diving-related injuries and illnesses. These encompass the diver's health, behavior, and experience, all of which wield considerable influence over their safety during a dive. Health issues, including underlying medical conditions, have been identified as potential precursors to diving-related incidents (Denoble *et al.*, 2008). For example, divers with cardiovascular risk factors are implicated in a significant proportion of deaths and injuries among US recreational divers (Buzzacott *et al.*, 2018), while individuals with diabetes mellitus require additional attention, as changes in insulin requirements and resistance, along with the hyperbaric environment, can impact blood glucose levels during diving (Koufakis *et al.*, 2019).

In addition, behavioral factors are equally significant and encompass compliance with safety procedures and the appropriate use of equipment (Buzzacott *et al.*, 2015). This category may involve inadequate knowledge of safety procedures and insufficient training, leading to issues such as poor buoyancy control, rapid ascents, and gas exhaustion. Alarming, a notable portion of recreational divers reported violations of safety procedures, which have been associated with diving-related

injuries and fatalities. Moreover, divers tend to underestimate the perception of safety, the value of some safety-related accessories and practices, and the lack of or insufficient awareness of the importance of an emergency response plan (Baek *et al.*, 2021; Kang *et al.*, 2011; Lucrezi *et al.*, 2018). The level of experience and training is also pivotal, as inexperienced divers may exhibit a higher susceptibility to accidents. Divers accumulate valuable knowledge and experience as they gain more diving exposure, allowing them to adapt and respond effectively to various situations encountered during their dives (Mitchell and Doolette, 2013)

Environmental factors encompass underwater conditions that may pose risks to divers. These factors encompass water temperature, visibility, underwater currents, tides, aquatic life, and the characteristics of the underwater terrain. For example, water temperature can influence divers' vulnerability to conditions like hypothermia (Pendergast *et al.*, 2015). Both visibility and underwater currents are critical in affecting navigation and ensuring safety during dives (Mitchell and Doolette, 2013). Furthermore, the presence of marine life, including potentially harmful or venomous organisms, can pose injury risks if divers encounter them (Mallen and Roberts, 2020). Nonetheless, with a foundation of solid knowledge, heightened awareness, and good practice, these potential risks and hazards become manageable and preventable, and their impact can be significantly reduced.

Turning to dive activity-related factors, these encompass specific elements of a dive, including its nature, depth, duration, and the equipment employed. The type of dive, whether recreational, technical, or commercial, can introduce differing levels of risk. Each of these dive types presents a distinct set of challenges, risks, and safety considerations (Marroni *et al.*, 2014). For example, dysbaric osteonecrosis (DON) is

more common in technical divers due to the presence of risk factors such as deep diving, repetitive diving, and extended bottom times, while recreational divers may experience more intense stress responses compared to military divers, as indicated by higher levels of cortisol release (Coleman and Davis, 2020; Zec *et al.*, 2022).

The depth and duration of a dive also play pivotal roles in shaping the level of physiological stress and the potential for adverse events. Deep or extended dives are particularly notable, as they may subject divers to higher pressures, thereby increasing the risk of decompression sickness and other physiological concerns (Patrician *et al.*, 2021). The depth and duration of a dive necessitate more cautious planning and adherence to safety protocols.

Another aspect of dive activity-related factors is the condition and proper utilization of equipment. Equipment malfunctions or improper usage can significantly contribute to diving incidents. The correct functioning and maintenance of diving gear, such as regulators, tanks, and buoyancy control devices, are crucial to diver safety. Diving gear plays a vital role in ensuring diver safety. Proper functioning and maintenance of this equipment are essential to prevent failures that could lead to emergencies. Failure in equipment can result in emergencies that divers must respond to effectively (Baldassarre *et al.*, 2017; Merinar and Dick, 2019)

On the other hand, it's essential to recognize that these three main factors; environmental, diver-related, and dive activity-related, are intricately interrelated. Typically, diving incidents do not occur due to a single contributing factor in isolation. Instead, the interplay and convergence of these factors significantly influence a dive's outcome. This underscores the importance of a comprehensive

understanding of diving safety, as it necessitates a holistic approach that considers the dynamic relationships among these elements.

1.5 Sustainable Development Goal (SDG) 14: Life Below Water

The Sustainable Development Goals (SDGs) are a set of global goals established by the United Nations to address various social, economic, and environmental challenges. Scuba diving activities can have both positive and negative impacts on marine ecosystems and contribute to the achievement of Sustainable Development Goal 14 (SDG 14) - Life Below Water. SDG 14 aims to ensure the conservation and sustainable use of oceans, seas, and marine resources for sustainable development (UN, 2015). Divers and the diving industry play a critical role in this mission by being stewards of the underwater environment and advocating for its protection.

Effective diving safety practices not only safeguard divers but also protect marine ecosystems. Responsible diving entails strict adherence to guidelines aimed at preserving fragile coral reefs. This includes maintaining excellent buoyancy control to prevent inadvertent damage to the reefs through contact with dive equipment. Scuba diving itself does not pose a threat to the environment or marine animals, but poor buoyancy control and lack of awareness can contribute to damage in the benthic zone, thus affecting the sustainability of marine biodiversity in the future (Toyoshima and Nadaoka, 2015). Divers should also refrain from contact or disturbance of marine life and remain vigilant to environmental hazards. Such responsible practices are pivotal in minimizing the ecological impact of dive tourism on these sensitive habitats. The diving community actively contributes to SDG 14 by promoting good diving practices.

The sustainable development of scuba diving tourism systems has been studied in the context of marine protected areas (MPAs). The perceptions of the scuba diving industry in MPAs play a crucial role in ensuring sustainable approaches and quality standards by following the safety procedure, which benefits the health and safety of the divers and the marine ecosystem (Lucrezi *et al.*, 2017).

Optimizing scuba diving activities in marine protected areas based on benthic vulnerability assessments can contribute to the sustainable management and conservation of marine coastal ecosystems. Considering the vulnerability of benthic habitats, diving activities can be strategically planned and managed to mitigate adverse impacts (Betti *et al.*, 2023). This can be achieved through effective guidance and monitoring by dive guides and consistent reminders from dive buddies during the dive. Diving in small groups with a diving instructor and receiving a complete briefing before diving can significantly reduce the damage caused to marine benthic species. All these practices are aimed at preserving these delicate ecosystems.

1.6 Problem Statement

1. Safety

- i. Although certifying and safety agencies are in possession, scuba diving is based on self-responsibility, and therefore, risk awareness and practice are determining factors for triggering dive accidents. Occasionally, scuba divers will engage in unsafe activity, demonstrate a lack of interest in safety procedures and equipment, and fail to report accidents and incidents when they occur.
- ii. Due to the non-mandatory reporting of diving-related accidents and incidents, the importance of safety has often been underestimated among

recreational divers. Scuba divers, regrettably, tend to show limited interest in adhering to safety protocols and frequently neglect the reporting of accidents and incidents, a crucial step towards enhancing safety standards and service improvement.

iii. The escalation of dive-related incidents can be attributed to inadequate enforcement of safety practices in daily diving schedules, the repetitive diving profile, and the oversight of workplace and essential equipment inspections.

2. Emergency response

i. Most scuba divers underestimate a personal emergency action/assistance plan. Risk of accident and injury associated with poorly trained staff, especially in the emergency response and inefficient emergency assistance plans.

ii. The awareness of a scuba diver regarding the necessity of immediate on-site treatment serves as a protective barrier against injury and illness. In emergencies, such awareness safeguards the patient and prevents the escalation of pain, incapacity, and long-term complications from the injury/illness.

iii. Scuba dive crews, including Divemaster/instructors, boatmen, and even the scuba divers themselves, share the responsibility and play specific roles in emergency situations, ensuring that appropriate first responder actions are taken. Therefore, it is crucial to ensure their awareness of responsibilities and foster good practices in emergency response.

3. Local study

- i. Limited published research focuses exclusively on scuba divers' knowledge, awareness, and practice toward safety and emergency response in Malaysia.
- ii. Specific study tools assessing KAP on safety and emergency response among scuba divers are still lacking.
- iii. Research regarding divers' perception of the risks they may encounter, their knowledge of safety measures, and their awareness of emergency treatment remains insufficient and warrants further investigation.
- iv. The scarcity of recent data on dive-related injuries and illnesses in the recent decade has prompted the need for new research and publications in this field.

1.7 Rationales

- i. The scarcity of recent data on dive-related injuries and illnesses in the recent decade has prompted the need for new research and publications in this field.
- ii. This research also can help identify the root cause of the accident. Rather than focusing on the final act of doing something wrong, it is critical to uncover each root cause of an accident. As a result, the prevention plan and action can be highlighted early. This initiative can help in reducing the occurrence of incidents and injuries.

- iii. Therefore, assessing the level of knowledge, awareness, and practice among scuba divers regarding the safety and emergency response in the scuba diving industry is beneficial.
- iv. Using a validated questionnaire is crucial for accurately assessing safety and emergency response knowledge, awareness, and practice (KAP). Developing and validating the questionnaire is essential to ensure its accuracy and reliability, contributing to effective interventions and informed decision-making within the industry.

1.8 Research Questions

1. Phase 1:

Is the newly developed questionnaire on knowledge, awareness, and practice on safety and emergency response among scuba divers a valid tool?

2. Phase 2:

- i. What is the prevalence of mishaps and diving-related injury/illness in Malaysia?
- ii. What is the level of knowledge, awareness, and practice on safety and emergency response among scuba divers in Malaysia?
- iii. What factors are associated with the level of knowledge, awareness, and practice on safety and emergency response among scuba divers in Malaysia?

- iv. Is there any association between the presence of mishaps and diving-related illness/injuries with sociodemographic, diving profile, and KAP level among scuba divers in Malaysia?

1.9 Study Objectives

1.9.1 General Objective.

To develop and validate a new questionnaire on safety and emergency response among scuba divers, determine scuba divers' level of (KAP) using the newly validated questionnaire, the prevalence of dive-related injuries/illnesses, mishaps, and their' s associated factors among scuba divers in Malaysia.

1.9.2 Specific Objectives

1. Phase 1:

- i. To develop and validate a new questionnaire on knowledge, awareness, and practice on safety and emergency response among scuba divers in Malaysia using a pre-validated questionnaire.

2. Phase 2:

- i. To determine the prevalence of mishaps and diving-related injury/illness among scuba divers in Malaysia.
- ii. To determine the level of knowledge, awareness, and practice on safety and emergency response among scuba divers in Malaysia.

- iii. To determine factors associated with the good level of knowledge, awareness, and practices on safety and emergency response among scuba divers in Malaysia.
- iv. To determine the association between the presence of mishaps and diving-related illness/injuries with sociodemographic, diving profile, and level of KAP among scuba divers in Malaysia.

1.10 Research Hypothesis.

1. The newly developed questionnaire is valid and reliable to be used to assess KAP on safety and emergency response among scuba divers in Malaysia.
2. There is a significant association between sociodemographic and diving profiles and with the level of KAP among scuba divers in Malaysia.
3. There is a significant association between the presence of mishaps and diving-related illness/injuries with sociodemographic, diving profile, and level of KAP among scuba divers in Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 Prevalence of Dive-related Injury and Illness among Scuba Divers

Many studies employ various methods to assess the occurrence of injuries and illnesses, such as measuring prevalence, calculating incidence per population, and evaluating incidence per dive as well as per Emergency Department (ED) admission. Various sources of data were utilized in the literature, including self-claim (Lucrezi *et al.*, 2018), hospital admission records (Buzzacott *et al.*, 2018; Buzzacott, 2012; Rozali *et al.*, 2008), and cases reported or notified to relevant organizations (DAN, 2019).

For instance, according to a formal report by DAN, from 2014 to 2017, there were 8,468 reported diving-related injuries worldwide, with the overall self-reported rate of injuries being 3.02 per 100 dives. Among scuba divers, the most reported injuries and illnesses included barotrauma, decompression sickness, and marine envenomation (DAN, 2019). Conversely, middle European countries reported a prevalence of diving-related accidents and injuries, with 30% of scuba divers and 30% of dive centers indicating their involvement in dealing with such incidents and accidents. According to information provided by dive centers or divers themselves, the most frequently reported injuries included decompression illness and drowning (Lucrezi *et al.*, 2018). The incidence varied across regions, with rates ranging from 7 to 35 injuries per 10,000 divers in Australia, 9.9 to 16.5 per 10,000 Emergency Department presentations in the USA and Canada, and 3.02 per 100 dives among

DAN members worldwide (Buzzacott *et al.*, 2018; Buzzacott, 2012; Ranapurwala *et al.*, 2014).

On a global scale, DAN received reports of 228 deaths related to underwater diving in 2017, with an annual average of 80-90 fatalities yearly and the majority (71%) involving recreational divers. Most of these cases involved male divers (79%) aged 40 years and older (80%). The fatality rates associated with dive-related injuries and illnesses were 0.57 per 100,000 divers in Australia and 4 per 100,000 divers in Scotland, as reported by Tuan Abdullah *et al.* (2020) while according to Buzzacott *et al.* (2018), in the US and Canada, 49 deaths were reported per 1000 ED admission related to dive injuries.

As per DAN's report in 2019, a concerning trend of rising diving accidents was observed in three Southeast Asian countries, Malaysia, Indonesia, and Thailand, from 2009 to 2011 (DAN, 2019). Specifically, in Malaysia, the escalation in the percentage of diving accidents was directly linked to the increasing number of individuals engaging in scuba diving activities, as reported by the MSDA (2020). Recently published data on the occurrence of dive-related injuries and illnesses in Malaysia is scarce. Over a span of 10 years (2000-2010), Hospital Angkatan Tentera Lumut documented a total of 175 diving-related cases. Of these cases, 43% were associated with recreational divers, and most of these cases were treated for decompression sickness (Jamharee *et al.*, 2016).

Meanwhile, according to Rozali *et al.* (2008), a few years before that, on average, there were approximately 20 reported diving accidents each year, with 39% of these incidents linked to recreational diving. Interestingly, decompression illness emerged as the predominant cause, accounting for a remarkable 96.1% of all reported cases,

primarily occurring in commercial diving activities, notably underwater logging. However, it's important to note that the actual prevalence of these illnesses cannot be determined as the total number of scuba divers in Malaysia is unknown.

In terms of diving-related fatalities, within Southeast Asia, Malaysia ranked second after Thailand, Indonesia, and the Philippines. Malaysia reported fewer than five diving-related fatalities in 2017 (DAN, 2019). According to MSDA (2020), seven reported fatalities were associated with recreational scuba diving between January 2019 and July 2019.

The summary of the occurrence of dive-related illness and injuries is summarized in Table 2.1

Table 2.1: Summary of Dive-Related Injury/illness Occurrence

No	Author	Country	Finding	Notes
1.	Monnot <i>et al.</i> (2019)	France	<p>65% of scuba divers reported experiencing at least one symptom of diving-related injury. Most reported symptoms included ear pain, sinus pain, and toothaches.</p> <p>The most frequent injuries among divers were barotrauma (63% of injured divers), followed by decompression illness (DCI) affecting 28% of those with injuries.</p>	Data were based on self-reporting
2.	Hubbard <i>et al.</i> (2018)	New Zealand	Out of the 55 recorded injuries in the dive center database, 20 (36.4%) were classified as dive-related injuries. Among these, 45% were attributed to decompression illness (DCI), 20% to barotrauma, and the remaining cases were associated with panic attacks and other causes.	Data was obtained from the injury database in the dive center of study area
3.	Lucrezi <i>et al.</i> (2018)	Middle European Countries	<p>30% of scuba divers had experience of dive-related injury and illness.</p> <p>30% of the dive centers had dealt with scuba diving incidents and accidents, mostly decompression illness (60%), drowning (11%), equipment failure (11%), and boat accidents (9%)</p>	Data were based on self-reporting

Table 2.1: Continued

No	Author	Country	Finding	Notes
4.	Buzzacott <i>et al.</i> (2018)	USA	A total of 1394 ED presentations were scuba-related injuries per year, or 9.9 per 10,000 ED presentations. Mortality: 0.18 per 10,000 dives.	Data was obtained from hospital records. Incidences were calculated per total ED admission.
		Canada	An average of 3.8 cases of dive-related injury were reported each year. The incidence was 16.5 per 10,000 ED presentations.	
		Australia	The incidence of dive-related injuries was 7 to 75 injuries per 10,000 scuba divers.	Incidence was calculated per total scuba divers.
5.	Jamharee <i>et al.</i> (2016)	Malaysia	Out of the 175 reported cases of dive-related illness, 43% involved recreational divers.	Data was obtained from hospital records. The prevalence of the illnesses cannot be determined due to a lack of data regarding the total number of scuba divers.
6.	Ranapur wala <i>et al.</i> (2014)	DAN members worldwide	The overall rate of diving-related injury was 3.02 per 100 dives.	Data were based on self-reporting. Incidence was calculated per total dive.

Table 2.1: Continued

No	Author	Country	Finding	Notes
7.	Buzzacott (2012)	Australia	<p>The incidence of dive-related injuries was 7 to 35 injuries per 10,000 divers.</p> <p>The incidence of dive-related injuries was 5 to 152 injuries per 100,000 dives.</p> <p>Fatalities account for 0.013%.</p>	<p>Data were based on self-reporting. Incidences were calculated per total dives and total divers.</p>
8.	Rozali <i>et al.</i> (2008)	Malaysia	<p>An average of 20 dive-related cases were reported annually, and out of 179 cases related to dive-related illness, 39% involved recreational divers.</p>	<p>Data was obtained from hospital records.</p> <p>The prevalence of the illnesses cannot be determined due to a lack of data regarding the total number of scuba divers.</p>

2.2 Prevalence of Mishaps and Unsafe Conditions in Recreational Scuba Diving

Mishaps are unforeseen and unintended events that occur during diving and contribute to an increased likelihood of injuries resulting from human errors, equipment problems, and environmental hazards. Mishaps can be categorized into major, which have the potential to cause life-threatening injuries, such as rapid ascents or running out of air. On the other hand, minor mishaps are associated with less severe injuries, such as equalization problems or mask squeezes. Many researchers use the terms 'errors,' 'incidents,' and 'triggers' interchangeably to describe mishaps with similar meanings. DAN researchers have proposed that a significant proportion of diving fatalities were preceded by diving mishaps (Ranapurwala *et al.*, 2017).

According to Ranapurwala *et al.* (2017), in her prospective cohort study among scuba divers in Mexico and Cayman Island, it was reported that 36% of divers experienced either a major or minor mishap with a range of 1-11 mishaps per diver, and the overall rate of mishaps was 29.4 per 100 dives, which was very common. Rapid ascent and lost buddy contact were the most frequently observed mishaps. This figure represents a slight increase from an earlier cluster-randomized trial study, which found that 25% of recreational scuba divers had experienced at least one mishap, with an overall mishap incidence of 8.6 per 100 dives. The most frequently reported mishaps in this study were rapid ascents and changes in buoyancy (Ranapurwala *et al.*, 2015).

The summary of the prevalence of mishaps is illustrated in Table 2.2

Table 2.2: Summary of Dive-Related Mishaps Prevalence

No	Author	Country	Finding	Notes
1.	Ranapurwala <i>et al.</i> (2017)	Mexico and Cayman Island	36% of scuba divers had experienced mishaps, with a rate of 29.4 per 100 dives.	Prospective cohort study
2.	Ranapurwala <i>et al.</i> (2015)	USA, Mexico, and Cayman Island	25% of scuba divers experienced mishaps, with a rate of 8.6 per 100 dives.	Cluster-randomized trial study

2.3 Overview of the Existing Study Related to KAP on Safety and Emergency Response among Scuba Divers

The literature search about knowledge, awareness, and practice on safety and emergency response among scuba divers was widely done using search engines such as PubMed. Various searching strategies were applied, such as combining terms with the use of Boolean operators (AND, OR). The entire literature search published from 2000 to 2023 was included. The keywords used were scuba diving, diving injury, mishaps, knowledge, awareness, and practice.

The existing research in the field of scuba diving predominantly concentrates on the knowledge of safety and emergency response, as highlighted by studies such as those conducted by Kang and Song (2023), Cho *et al.* (2019), Park and Cho (2015), and Kang *et al.* (2011). The initial questionnaire was used initially by Kang *et al.* (2011) and subsequently improved and modified by Park and Cho (2015), Cho *et al.* (2019), and Kang and Song (2023).

Lucrezi *et al.* (2018) extended this perspective by assessing awareness of safety, particularly in terms of perception, among scuba divers. This study employed questionnaires administered to both dive centers and individual divers. In a subsequent study, Baek *et al.* (2021) identified that a mere 39% of scuba divers