

Pilot Feasibility and Preliminary Reliability of a Multi-Domain Fatigue-Risk Assessment Protocol for Shift Workers in a Malaysian Palm Oil Mill

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ABSTRACT

Occupational fatigue is a work-system risk that may compromise worker safety, health, and operational performance. Before implementing a fatigue-risk intervention, the practicality and preliminary measurement performance of the proposed assessment protocol should be established. This pilot study assessed the feasibility and preliminary internal consistency reliability of a multi-domain fatigue-risk assessment protocol among shift workers in a Malaysian palm oil mill. A quantitative cross-sectional pilot study was conducted among 26 randomly selected shift workers. Participants completed a paper-based, six-section assessment protocol covering sociodemographic and occupational characteristics, burnout, psychological distress, perceived mental effort, personal wellbeing, and individual work performance. Feasibility outcomes included completion among enrolled participants, missing analytic item responses, completion time, and administration practicality. Descriptive statistics and Cronbach's alpha coefficients were calculated for applicable multi-item scales and domains. All enrolled participants completed the assessment, and no missing analytic item responses were observed. The average completion time was approximately 27 minutes. Participants had a mean age of 33.4 years ($SD = 9.7$), while the mean reported daily working duration was 10.2 hours ($SD = 2.3$). The personal burnout and work-related burnout domains of the Copenhagen Burnout Inventory showed Cronbach's alpha values of 0.802 and 0.760, respectively. The Personal Wellbeing Index demonstrated acceptable preliminary internal consistency ($\alpha = 0.751$), while the Individual Work Performance Questionnaire domains ranged from 0.722 to 0.894. A reverse-scored burnout item and selected wellbeing items required further review. The findings support the feasibility of the paper-based protocol and identify measurement and procedural refinements required before the main intervention study. This pilot was not designed to estimate fatigue prevalence, establish construct validity, or evaluate intervention effectiveness.

Keywords: Occupational fatigue; fatigue risk management; pilot study; shift workers

INTRODUCTION

Occupational fatigue is increasingly recognised as a workplace concern because it can affect how safely and effectively workers perform their duties. When workers are fatigued, they may experience reduced alertness, concentration, communication, decision-making ability and work performance. In safety-sensitive industries, these effects may contribute to errors, near misses, injuries and reduced operational efficiency. Fatigue is rarely caused by one factor alone. It can result from long working hours, night or rotating shifts, limited recovery time, physically

demanding tasks, high mental workload, repetitive work, environmental stressors, inadequate sleep and personal responsibilities outside work (Dawson & McCulloch 2005; Cunningham et al. 2022). For this reason, occupational fatigue should not be treated only as an individual health issue but also as a workplace risk that requires systematic assessment and appropriate control measures.

Traditional fatigue management approaches have often focused on prescriptive limits for working hours, shift duration or minimum break periods. Although these controls remain important, they may not adequately address the multiple pathways through which fatigue affects worker performance and safety. Fatigue risk management systems

emphasise a broader safety-management approach that considers work scheduling, sleep opportunity, actual recovery, fatigue symptoms, fatigue-related errors and incident reporting. This approach recognises that workers may experience fatigue despite compliance with working-hour rules and that organisations require multiple layers of defence to reduce fatigue-related risk (Dawson & McCulloch 2005; Wong et al. 2019).

. Palm oil mill operations provide a particularly relevant setting for fatigue risk management because production commonly involves continuous processing, shift-based schedules, and safety-sensitive activities. Workers may perform production, maintenance, boiler, machinery, loading, monitoring, and supervisory duties under changing operational demands. Depending on their task allocation, they may also be exposed to prolonged standing, repetitive work, manual material handling, high process temperatures, noise, hazardous machinery, time pressure, and fluctuating production workloads. Research in Malaysian palm oil mills has identified heat-related symptoms and physiological changes among workers in high-temperature workstations, suggesting that environmental and operational exposures may affect worker health and functional capacity (Vallennie et al. 2024). When these exposures interact with extended working periods, shift schedules, and insufficient recovery, may become a significant threat to both worker wellbeing and process safety.

Previous occupational fatigue studies among shift workers have frequently concentrated on individual components of fatigue risk, including working hours, shift schedules, sleepiness, subjective fatigue symptoms, mental workload, psychomotor performance, or associations between job demands and fatigue. These approaches are useful for identifying acute fatigue and schedule-related risks. However, when applied independently, they may provide limited insight into the broader pathways through which fatigue develops and affects workers. A single indicator may not distinguish whether fatigue-related vulnerability is associated with cumulative exhaustion, psychological distress, perceived task demands, reduced personal wellbeing, or deterioration in work performance. Contemporary fatigue risk management approaches therefore support the use of multiple complementary indicators rather than reliance on working-hour limits or a single fatigue measure alone (Dawson & McCulloch 2005; Wong et al. 2019; Cunningham et al. 2022).

The present study applies this multidimensional approach through a workplace-administered protocol comprising five distinct but complementary domains. The Copenhagen Burnout Inventory (CBI) assesses personal and work-related exhaustion, whereas the General Health Questionnaire-12 (GHQ-12) evaluates psychological

distress. The Subjective Mental Effort Questionnaire (SMEQ) measures perceived mental effort, while the Personal Wellbeing Index–Adult (PWI-A) assesses satisfaction across broader life domains. The Individual Work Performance Questionnaire (IWPQ) assesses potential functional consequences across task performance, contextual performance and counterproductive work behaviour. These instruments are not interchangeable measures of fatigue and are therefore not combined into a single overall score. Instead, each domain provides complementary information on potential work demands, worker responses, personal circumstances and performance-related consequences associated with fatigue risk.

Integrating these domains within one protocol provides added value compared with assessments limited to fatigue symptoms, working hours, or shift schedules. Workers exposed to similar schedules or reporting comparable levels of mental effort may differ in their degree of burnout, psychological distress, personal wellbeing, and work performance. A multidimensional assessment can therefore provide a more differentiated understanding associated with fatigue risk and help identify the areas in which preventive action may be required. Depending on the risk profile identified, relevant measures may include work-rest adjustments, workload or task redesign, psychological support, fatigue awareness training, improved supervisor communication, and broader work-system improvements. The protocol consequently provides a structured basis for progressing from the general identification of fatigue risk to the development of context-specific intervention strategies.

The present study was designed as a preparatory pilot investigation rather than a hypothesis-driven epidemiological study. Its primary purpose was to determine whether the proposed recruitment, participant briefing, questionnaire administration, data-management and scoring procedures could be implemented feasibly within an operational palm oil mill. It also sought to generate preliminary information on the measurement performance of the selected multi-item domains. The study was therefore not intended to estimate the prevalence of fatigue-related conditions, examine associations between occupational factors and fatigue-related outcomes, compare worker subgroups or provide definitive psychometric validation. Accordingly, formal hypothesis testing and power-based sample-size estimation were not considered appropriate for this pilot phase. Instead, the pilot sample was used to identify procedural challenges, respondent burden, missing-data patterns, item-level concerns and preliminary internal-consistency issues requiring refinement before the subsequent larger fatigue-risk intervention study.

The novelty of this pilot study lies not in the development of new measurement instruments, but in the structured integration of validated measures covering different dimensions and potential consequences of fatigue-related risk within a single pre-intervention assessment protocol. It also evaluates whether this combined protocol can be administered practically under actual industrial working conditions. Published evidence on the feasibility and preliminary measurement performance of an integrated fatigue-risk assessment protocol among shift workers in Malaysian palm oil mill operations remains limited. Accordingly, this pilot study evaluates participant completion, item-level missing data, completion time, administration procedures, respondent burden, and the preliminary internal consistency of the selected multi-item instruments. The findings are intended to guide the refinement of the protocol before its implementation in a larger fatigue-risk assessment and intervention study.

METHODOLOGY

STUDY DESIGN AND SETTING

This pilot study used a quantitative cross-sectional design to assess the feasibility and preliminary reliability of a multi-domain fatigue-risk assessment protocol intended for use among shift workers in Malaysian palm oil mills. The pilot was conducted at a participating palm oil mill in Kelantan, Malaysia. The mill's identity is not disclosed to protect corporate confidentiality.

Data collection was conducted in the mill administrative office which provided a quiet and controlled setting for questionnaire completion without disrupting routine production activities. The pilot, carried out prior to the main fatigue-risk intervention project, aimed to test the feasibility of recruitment methods, participant briefings, questionnaire administration and data management, and the initial performance of the instruments selected.

PARTICIPANTS AND SAMPLING

The study population consisted of shift workers employed at the participating palm oil mill. Workers were eligible if they were aged between 18 and 60 years, employed full-time in production, maintenance, or boiler-related work, had at least six months of work experience at the mill, and were involved in shift work. Workers who did not provide consent, were unable to read and understand the questionnaire, or were not engaged in shift work were excluded.

The pilot sample size was determined pragmatically in accordance with the preparatory and feasibility-oriented purpose of the study. Consideration was given to the number of eligible workers who could participate without disrupting routine mill operations and to the need to evaluate the complete assessment procedure under actual workplace conditions. An a priori power-based sample-size calculation was not undertaken because the study was not designed to test a formal hypothesis, estimate an intervention effect, compare occupational groups, examine associations between variables or develop a predictive model. Instead, the sample was intended to provide sufficient practical information to identify major recruitment and administrative difficulties, questionnaire-completion problems, respondent burden, missing-data patterns, scoring issues and preliminary item-level or internal-consistency concerns. Reliability estimates obtained from this small pilot sample were therefore interpreted as provisional indicators for instrument refinement rather than as definitive psychometric evidence.

An employee list was obtained from the participating mill to identify workers who met the eligibility criteria. Each eligible worker was assigned an identification number. A computer-generated random number procedure was then used to select 26 participants from the eligible-worker list. Selection was performed without replacement; therefore, a worker selected once could not be selected again.

The selected workers were approached individually and provided with information regarding the study objectives, procedures, confidentiality safeguards and voluntary nature of participation. Written informed consent was obtained before questionnaire administration. When a selected worker declined participation, was unavailable during the data-collection period or did not satisfy the final eligibility assessment, a replacement participant was randomly selected from the remaining eligible workers using the same procedure. This process was intended to maintain the random-selection approach and provide each eligible worker with an equal opportunity to participate in the pilot study.

DATA COLLECTION PROCEDURE

Data were collected in small groups of approximately four to five participants per session. At the beginning of each session, the researcher delivered a standardised briefing outlining the study purpose, participant rights, confidentiality arrangements, and instructions for completing the questionnaire.

Participants were encouraged to request clarification for items that they did not understand. Clarifications were

provided consistently and without suggesting preferred responses. Supervisors and managerial personnel were not present during questionnaire administration to minimise perceived pressure and reduce the potential influence of workplace authority on participant responses.

Paper-based questionnaires were used because internet access at the study location was limited and inconsistent. The average completion time was recorded to assess respondent burden and to guide scheduling for the main study. Questionnaire completeness and the presence of missing responses were checked during data screening after collection.

STUDY INSTRUMENTS

The assessment protocol comprised six sections designed to capture complementary factors relevant to fatigue-related risk among shift workers.

Part A: Sociodemographic and Occupational Characteristics: This section collected information on participants' age, sex, ethnicity, marital status, education level, job category, employment duration, work schedule, daily working hours, selected health-related factors and workplace exposures. These variables were included to describe the workforce profile and work conditions that may influence fatigue-related risk.

Part B: Copenhagen Burnout Inventory

Burnout and exhaustion-related symptoms were assessed using the Malay version of the Copenhagen Burnout Inventory (CBI). The CBI was originally developed to assess personal, work-related, and client-related burnout (Kristensen et al. 2005). In the present study, the personal burnout and work related-burnout domains were used because they were relevant to the study population. The Malay version of the CBI has previously demonstrated acceptable validity evidence and reliability in Malaysia (Chin et al. 2018). Items were scored according to the standard CBI scoring procedure, with higher scores indicating greater burnout-related symptoms.

Part C: General Health Questionnaire-12

Psychological distress was assessed using the Malay version of the 12-item General Health Questionnaire (GHQ-12). The GHQ-12 is a widely used screening instrument for psychological distress and general mental health status (Goldberg 1972). The Malay version has demonstrated acceptable reliability and validity among Malaysian respondents (Quek et al. 2001; Yusoff et al. 2010). For the present study, the GHQ-12 scoring method,

reverse-coded items, possible score range, and interpretation of higher scores were based on the validated Malay GHQ-12 scoring procedure used in the main study.

Part D: Subjective Mental Effort Questionnaire

Perceived mental effort during work was assessed using the Subjective Mental Effort Questionnaire (SMEQ). The SMEQ is a single-scale measure developed to assess the amount of mental effort required to perform a task (Zijlstra & Van Doorn 1985; Zijlstra 1993). It has been translated and evaluated in the Malay language for use in the Malaysian population (Shahirah et al. 2023). As the SMEQ is a single-item measure, internal consistency reliability was not calculated.

Part E: Personal Wellbeing Index-Adult

Subjective wellbeing was assessed using the Personal Wellbeing Index-Adult (PWI-A). The PWI-A evaluates satisfaction across several life domains and provides an overall indicator of subjective wellbeing (International Wellbeing Group 2013). Scores were calculated according to the manual for the specific PWI-A version used in this study, with higher scores indicating better perceived wellbeing.

Part F: Individual Work Performance Questionnaire

Individual work performance was assessed using the Individual Work Performance Questionnaire (IWPQ). The IWPQ was developed as a generic measure of work performance and includes three domains: task performance, contextual performance, and counterproductive work behaviour (Koopmans et al. 2014; Koopmans 2015). The questionnaire was analysed according to the verified domain structure and scoring guidance for the version used in this study. The exact IWPQ version and item allocation were reviewed before the main-study implementation to ensure that only valid domain scores were retained.

FEASIBILITY OUTCOMES

The primary feasibility outcomes were participant completion among enrolled workers, item-level missing data, questionnaire completion time, practical issues during administration, and the need for clarification or item revision. Completion was defined as submission of a completed questionnaire by a participant who commenced the survey. Item-level missingness was assessed for each section of the assessment protocol.

DATA ANALYSIS

Data were coded and analysed using IBM SPSS Statistics version 29. The analytical strategy was aligned with the preparatory and feasibility-oriented purpose of the pilot study. Formal null hypotheses were not specified because the study was not designed to detect statistically significant associations, estimate intervention effects, compare occupational groups or develop predictive models. Consequently, inferential hypothesis testing, correlation analyses, group comparisons and regression modelling were not performed. An a priori power-based sample-size calculation was also not undertaken because statistical hypothesis testing was outside the intended scope of the study.

Descriptive statistics were used to characterise the pilot participants and summarise the feasibility outcomes. Categorical variables were reported as frequencies and percentages. Continuous variables were presented as means and standard deviations when their distributions were approximately normal, or as medians and interquartile ranges when the data were skewed.

Preliminary internal consistency was assessed separately for each applicable multi-item instrument or subscale using Cronbach's alpha. Alpha coefficients of 0.70 or above were regarded as acceptable for preliminary use. Corrected item-total correlations and Cronbach's alpha coefficients following item deletion were also examined to identify items requiring further assessment. However, items with weak item-total correlations were not removed solely on statistical grounds. Decisions regarding item retention, revision or removal also considered the original instrument wording, translation accuracy, reverse-scoring requirements, conceptual relevance and participant feedback.

A single overall Cronbach's alpha coefficient was not calculated for the complete assessment protocol because it comprised several instruments measuring conceptually distinct domains. Internal consistency was also not assessed for the Subjective Mental Effort Questionnaire because it is a single-item measure. The reliability coefficients and item-level diagnostics were interpreted cautiously as provisional indicators of measurement performance because the small pilot sample was intended to support instrument refinement rather than provide definitive reliability or validity evidence. Exploratory and confirmatory factor analyses were not conducted because the pilot sample was neither designed nor sufficiently large for structural validation.

ETHICAL CONSIDERATIONS

Ethical approval was obtained from the Secretariat Ethics Committee UKM (Human), Universiti Kebangsaan Malaysia, before data collection commenced (PPI/111/8/JEP-2025-757). A non-disclosure agreement was also established between the participating organisation and the research team to protect company information and maintain organisational confidentiality.

RESULTS AND DISCUSSION

PILOT FEASIBILITY AND DATA COMPLETENESS

This pilot study provides preliminary evidence that the proposed multi-domain fatigue-risk assessment protocol can be administered under actual operating conditions in a Malaysian palm oil mill. All 26 enrolled workers completed the assessment, no missing analytic item responses were identified, and the mean completion time was approximately 27 minutes. These findings indicate that a paper-based protocol, administered in small groups using a standardised briefing and a protected setting without supervisors, was operationally manageable at the study site.

However, questionnaire completion among enrolled participants should not be interpreted as definitive evidence of acceptability or population-level participation. Formal acceptability ratings were not obtained, and the numbers of workers approached, screened, eligible, unavailable or declining participation were not recorded. Recruitment and response rates could therefore not be calculated. The findings should consequently be interpreted as evidence of procedural feasibility within the enrolled sample rather than evidence that the protocol would achieve equivalent reach, completion or acceptability when implemented on a larger scale.

This distinction is particularly important in workplace research because successful questionnaire completion may have been facilitated by on-site administration, management-supported scheduling, the small number of participants and the direct presence of the researcher. The main study should retain the practical features that supported questionnaire completion while introducing a prospective recruitment log, individual completion-time records and predefined feasibility criteria. The principal feasibility findings and their operational implications are summarised in Table 1.

TABLE 1. Pilot assessment protocol feasibility outcomes

Outcome	Pilot finding and operational implication
Missing analytic item responses	No missing analytic item responses were identified. A17 was an unused blank field in the exported dataset and will be removed from the main-study data dictionary.
Average completion time	Approximately 27 minutes; suitable for scheduled group administration but the main study will record individual timestamps
Administration process	Paper-based questionnaires administered in groups of 4–5 workers using a standardised briefing, with no supervisors present; appropriate for limited internet connectivity and confidential self-reporting.
Recruitment records	Denominators for workers approached, eligible, unavailable and declining participation were not retained. A prospective screening and recruitment log should be introduced in the main study.

SOCIODEMOGRAPHIC AND OCCUPATIONAL CHARACTERISTICS

The sociodemographic and occupational characteristics of the pilot participants are shown in Table 2. The mean participant age was 33.4 years ($SD = 9.7$). Most participants were Malay (92.3%), while 46.2% were married and 42.3% were single. More than half had completed secondary education (57.7%).

The sample included workers from operator-related roles (38.5%), plant or technical roles (34.6%) and supervisory roles (26.9%). This distribution is relevant because workers across these categories may experience different fatigue-related demands. Operator and technical roles may involve direct interaction with machinery, process equipment, repetitive tasks, and manual handling, while supervisory personnel may experience demands related to coordination, monitoring, communication, and decision-making. However, the pilot sample was not designed to compare fatigue-related outcomes between job categories.

The mean reported daily working duration was 10.2 hours ($SD = 2.3$). This finding describes the working-time context in which the protocol was tested but should not be

interpreted as evidence that extended working hours caused the observed fatigue-related outcomes. Nevertheless, working hours alone do not determine whether a worker is fatigued. Fatigue-related risk should be interpreted within the wider context of work demands, sleep, recovery practices, and organisational fatigue controls (Dawson & McCulloch 2005; Wong et al. 2019).

The present operational profile is also relevant from an engineering-management perspective. Previous manufacturing research has shown that worker characteristics and shift rotation may interact with work-stress factors that influence productivity and employee wellbeing (Bugvi et al. 2022). Similarly, engineering-based workplace assessments can provide a practical foundation for identifying task-related risks and developing targeted ergonomic, administrative, and behavioural interventions (Amran et al. 2026; Thiruchelvam et al. 2021). However, the current pilot study was not designed to test associations between working hours, job category, stress or fatigue-related outcomes.

Overall, these findings describe the operational setting in which the fatigue-risk assessment protocol was tested. They should not be interpreted as prevalence estimates or as representative of all palm oil mill workers in Malaysia.

TABLE 2. Sociodemographic and occupational characteristics of pilot participants

Variables	n (%)	Mean $\pm$ SD
Age (years)		33.4 $\pm$ 9.7
20-29	11 (42.3)	
30-39	9 (34.6)	
≥ 40 years	6 (23.1)	
Ethnicity		
Malay	24 (92.3)	
Other	2 (7.7)	
Marital status		
Married	12 (46.2)	
Single	11 (42.3)	

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Widowed	3 (11.5)	
Education Level		
Primary education	4 (15.4)	
Secondary education	15 (57.7)	
Certificate	4 (15.4)	
Diploma	3 (11.5)	
Job Category		
Operator	10 (38.5)	
Plant or Technical	9 (34.6)	
Supervisor	7 (26.9)	
Daily Working Hours		10.2 ± 2.3
N = 26		

PRELIMINARY DESCRIPTIVE FINDINGS

Table 3 presents selected descriptive findings from instruments for which the preliminary scoring procedures had been verified. The mean personal-burnout score was 32.2 (SD = 16.0), whereas the mean work-related-burnout score was 23.2 (SD = 16.4). The higher mean personal-burnout score should not be interpreted as evidence that non-work-related factors were more influential than workplace factors. Personal burnout reflects general physical and psychological exhaustion, whereas work-related burnout reflects the extent to which respondents attribute their exhaustion to work (Kristensen et al. 2005). The two domains therefore represent related but distinct aspects of burnout.

The mean SMEQ score was 79.2 (SD = 21.7), indicating variation in the perceived mental effort reported by participants. This variation may reflect differences in job roles, task complexity, production demands, work experience or the timing of questionnaire completion. However, the SMEQ scores should not be classified using a universal threshold for high mental workload because perceived mental effort is task-specific and influenced by the work context.

The mean Personal Wellbeing Index score was 70.3 (SD = 11.2). This finding provides preliminary information on perceived wellbeing in the pilot sample but should not be classified as low or high without comparison with an appropriate reference population assessed using the same PWI-S version. Furthermore, the PWI-A measures satisfaction across several life domains and should not be interpreted as a direct measure of occupational wellbeing alone (International Wellbeing Group 2013).

Overall, the descriptive findings are presented to characterise the pilot sample, demonstrate score variability, verify scoring procedures and support protocol refinement. They should not be interpreted as estimates of fatigue prevalence, evidence of high workload or poor wellbeing, or differences between occupational groups.

TABLE 3. Preliminary descriptive findings for selected fatigue-related domains

Measures	Score range	Mean ± SD	Median (IQR)
CBI personal burnout	0-100	32.2 ± 16.0	29.2 (20.8–45.8)
CBI-work related burnout	0-100	23.2 ± 16.4	21.4 (10.7–32.1)
SMEQ	0-150	79.2 ± 21.7	80.0 (70.0–90.0)
PWI-A	0-100	70.3 ± 11.2	72.2 (61.1–77.1)

CBI = Copenhagen Burnout Inventory; SMEQ = Subjective Mental Effort Questionnaire; PWI-A = Personal Wellbeing Index–Adult.

COMPARISON WITH INTERNATIONAL FEASIBILITY STUDIES

The present findings contribute to growing international evidence demonstrating that the feasibility of occupational fatigue assessment depends strongly on the data-collection method and operational context. Seong et al. (2022), for example, evaluated an integrated ecological momentary

assessment and smartwatch system among Korean construction workers. Although the system enabled the real-time collection of subjective and physiological information, participants reported that repeated responses could be burdensome. Difficulties were also identified in relation to device use, battery charging, overnight wear, data security and technology use among older workers.

In contrast, the present one-session paper-based protocol did not depend on internet connectivity, mobile devices, battery life or repeated daily responses. These characteristics may partly explain the absence of missing item responses. Nevertheless, the two approaches serve different purposes. The present protocol provides a broader psychosocial and work-performance profile at a defined assessment point, whereas wearable and ecological momentary assessment approaches provide temporally sensitive information on within-shift changes. The paper-based protocol should therefore be regarded as a pragmatic baseline and outcome-assessment method rather than a substitute for real-time fatigue monitoring.

Retention represents another important feasibility consideration. In a pilot trial of an app-based sleep-health intervention among paramedic shift workers, Shriane et al. (2024) reported engagement and retention difficulties, including substantial loss to follow-up. This finding illustrates that successful completion of a baseline assessment does not necessarily ensure sustained participation in a longitudinal intervention. The subsequent palm oil mill study should therefore distinguish between baseline questionnaire completion, intervention attendance, adherence to intervention components, post-intervention assessment completion and longer-term retention. Each outcome should be prospectively monitored.

Comparable lessons were reported in a process evaluation involving mining shift workers. Monnaatsie et al. (2023) found that a text-messaging health-promotion programme was feasible and achieved relatively high adherence among enrolled participants. Nevertheless, recruitment, organisational support and management involvement remained important determinants of programme reach, while work-related fatigue was identified as a barrier to participation.

These findings have direct relevance to the present study. Management cooperation will be required to protect the time allocated for assessment and intervention activities. However, supervisors should remain absent during individual questionnaire completion to minimise perceived pressure and protect confidentiality. Recruitment materials should also clearly state that participation is voluntary and that individual responses will not be used for employment evaluation.

IMPLICATIONS OF THE MULTI-DOMAIN FINDINGS

The observed variation in burnout, perceived mental effort, wellbeing, and work performance domains supports retaining a multi-domain assessment structure. It does not, however, establish relationships among these constructs or demonstrate that any domain represents fatigue prevalence. The instruments measure conceptually distinct

components that may function as contributing factors, worker responses, contextual resources, or potential consequences within a broader fatigue-risk pathway.

This distinction is important because recent occupational literature shows that fatigue cannot be explained adequately by work duration alone. A scoping review of public-safety workers identified interconnected outcomes involving working hours, sleep, fatigue, psychological stress, work performance, injury, and chronic health effects (Allison et al. 2022). Similarly, research among oil and gas workers found that the association between mental workload and occupational fatigue may operate through sleep quality rather than through a simple direct pathway (Kusmawan et al. 2024). Recent evidence has also demonstrated complex relationships between occupational fatigue and personal wellbeing (Wu et al. 2024). Collectively, these findings support an assessment strategy that considers work demands, recovery, psychological functioning, personal wellbeing, and performance rather than if one fatigue score can explain the entire risk process.

The mean reported working duration of 10.2 hours per day is operationally relevant because extended working periods may reduce the time available for sleep, commuting, family responsibilities and recovery. However, the present study cannot determine whether longer working hours caused the observed burnout, mental-effort, wellbeing or work performance scores. The pilot was neither powered nor designed to examine such relationships. In the main study, working hours should be assessed together with shift timing, shift rotation, consecutive shifts, overtime, rest intervals, commuting time, sleep opportunity, task demands and environmental exposures. Collecting these variables would provide a more defensible basis for identifying the aspects of work organisation that may require modification.

The preliminary domain scores should not be interpreted using universal classifications such as low, moderate or high unless validated thresholds and suitable reference populations are available for the exact instrument versions used. Comparisons with other occupational groups should also be made cautiously because differences may reflect variations in industry, occupation, culture, instrument version, scoring method, work schedule or data-collection timing rather than genuine differences in fatigue-related vulnerability.

PRELIMINARY INTERNAL CONSISTENCY RELIABILITY

Internal consistency reliability was assessed separately for each multi-item scale or subscale because the protocol included instruments that measured different constructs. A combined Cronbach's alpha value for the complete questionnaire was therefore not calculated or interpreted.

The CBI personal-burnout subscale demonstrated good preliminary internal consistency reliability ($\alpha = 0.802$), while the work-related-burnout subscale demonstrated acceptable reliability ($\alpha = 0.760$). The PWI-A also showed acceptable preliminary internal consistency ($\alpha = 0.751$). The IWPQ domains demonstrated acceptable to good reliability, with alpha values ranging from 0.722 to 0.894.

These results provide preliminary support for consistency among items within the respective domains. However, Cronbach's alpha does not independently establish content validity, construct validity, or unidimensionality. Its interpretation should also consider the number of items and conceptual similarity among them (Tavakol & Dennick 2011). Therefore, the findings should be viewed as part of an instrument-refinement process rather than as final validation evidence.

The reverse-scored B13 item in the CBI work-related-burnout subscale demonstrated a weak corrected item-total correlation ($r = 0.069$). Removing this item increased Cronbach's alpha from 0.760 to 0.872. Nevertheless, the item was not removed automatically. The wording, Malay

translation, reverse-scoring procedure, participant interpretation, and conceptual relevance should first be checked against the original CBI. A statistically weak item may still be retained if it is important for ensuring adequate conceptual coverage of the construct.

The PWI-A items coded as E02, E05, and E08 also showed relatively weak corrected item-total correlations. Because the PWI-A assesses satisfaction across conceptually different life domains, weaker item correlations may reflect genuine differences in how respondents evaluate domains rather than a measurement problem. These items should therefore be reviewed using the original wording, participant feedback, and expert assessment before any revision or removal is considered.

The IWPQ task-performance, contextual-performance, and counterproductive work-behavior domains demonstrated acceptable to good reliability. This supports the use of domain-specific scores rather than one overall work-performance score because the IWPQ was developed as a multidimensional measure of individual work performance (Koopmans et al. 2014).

TABLE 4. Preliminary internal consistency reliability of multi-item instruments

Instrument or domain	Number of items	Cronbach's alpha	Corrected item-total correlation range
CBI personal burnout	6	0.802	0.350–0.836
CBI work related burnout	7	0.760	0.069–0.828
PWI-A	9	0.751	0.124–0.675
IWPQ task performance	5	0.798	0.445–0.781
IWPQ contextual performance	8	0.894	0.508–0.804
IWPQ counterproductive work behaviour	5	0.722	0.364–0.554

CBI = Copenhagen Burnout Inventory; IWPQ = Individual Work Performance Questionnaire; PWI-A = Personal Wellbeing Index–Adult.

DIRECT IMPLICATIONS FOR THE FATIGUE-RISK INTERVENTION PROGRAMME

The principal contribution of this pilot study is its translation of feasibility and preliminary measurement findings into specific design considerations for the subsequent intervention. From an engineering and human-factors perspective, fatigue-related risk may be shaped by interactions among worker characteristics, task demands, work organisation and the physical work environment. The subsequent intervention should therefore use the pilot findings to guide the development of practical controls, including fatigue awareness, work-rest planning, communication procedures, supervisor involvement, and task or workstation improvements where appropriate (Amran et al. 2026; Thiruchelvam et al. 2021).

First, the intervention programme should adopt a multilevel structure rather than relying exclusively on individual fatigue awareness education. International evidence indicates that multicomponent interventions addressing both worker behaviour and the work environment are more appropriate for shift-working populations.

The PerfectFit@Night programme, for example, combined individual components, including e-learning and sleep coaching, with environmental and organisational measures such as healthy rostering, recovery facilities and access to appropriate food. Reductions in fatigue, insomnia and need for recovery were reported, while organisational culture and appropriate work demands were identified as important implementation facilitators (van Elk et al. 2024).

Accordingly, the proposed palm oil mill intervention should contain four interconnected components. The first should address work scheduling and recovery through the

review of shift duration, overtime, consecutive shifts, break opportunities, rest intervals and sleep opportunity. The second should address task and environmental demands through workload review, task allocation, job rotation, staffing, workstation improvement, heat control, hydration access, noise management and mechanical assistance, where appropriate.

The third component should strengthen organisational support through supervisor training, fatigue-reporting procedures, non-punitive communication, early referral pathways and management review of fatigue-related hazards. The fourth should provide worker-level education on fatigue recognition, sleep and recovery practices, hydration, the strategic use of rest periods and the importance of reporting conditions that may compromise safe work performance.

Second, the assessment domains should guide intervention tailoring rather than being combined into a single overall score. Elevated mental effort scores may indicate a need to examine task complexity, staffing, work pace, information demands or opportunities for task rotation. Higher work-related burnout scores may indicate inadequate recovery, sustained workload, limited job control or insufficient organisational support. Psychological distress findings may support the development of confidential referral pathways and improvements in supervisor communication. Wellbeing findings may identify broader recovery or work-life concerns, although the PWI-A should not be interpreted as an occupational measure alone. Changes in the IWPQ domains may provide information on whether fatigue-related vulnerability is accompanied by difficulties in task execution, contextual contribution or counterproductive work behaviour.

This domain to intervention mapping should be specified prospectively in a programme logic model. The model should identify: (1) fatigue-related determinants, such as work schedules, environmental conditions and workload; (2) intervention components; (3) immediate mechanisms, including improved knowledge, recovery opportunities, supervisor support and workload management; (4) intermediate outcomes, such as reduced burnout, psychological distress and mental effort; and (5) functional outcomes, including wellbeing, work performance, safety behaviour, near misses and sickness absence, where organisational records permit.

Third, the main study should include a formal process evaluation. Intervention effectiveness cannot be interpreted adequately without determining whether the programme reached the intended workers, was delivered as planned, was adopted by supervisors and was maintained by the organisation. Recent workplace studies involving shift workers have applied implementation frameworks such as

RE-AIM to evaluate reach, adoption, implementation and maintenance (Monnaatsie et al. 2023; van Elk et al. 2024).

The main study should therefore document the numbers of workers approached, eligible, enrolled, attending each intervention component, completing follow-up assessments and withdrawing from the study. Intervention dose, fidelity, participant satisfaction, implementation barriers, facilitator support, scheduling disruption and management participation should also be recorded.

Fourth, the assessment schedule should be refined. The mean completion time of approximately 27 minutes appears manageable for a scheduled baseline session. Nevertheless, the main study should establish an a priori acceptable completion-time threshold and record individual rather than group-average completion times. Assessments should also be scheduled consistently in relation to shift timing because responses concerning mental effort, fatigue-related symptoms, psychological distress and work performance may differ before and after a shift. Repeated assessments should be scheduled to minimise production disruption and respondent burden.

Finally, the main study should clearly distinguish fatigue-risk indicators from direct measures of fatigue. Burnout, psychological distress, mental effort, wellbeing and work performance provide important but indirect information on fatigue-related vulnerability and its potential consequences. Where feasible, the intervention evaluation should include direct measures of acute fatigue, sleepiness, sleep duration or quality, recovery and work-schedule exposure.

Objective or organisational indicators, such as overtime records, shift patterns, environmental heat exposure, near misses, errors, sickness absence or selected physiological measures, may further strengthen data triangulation. Incorporating these measures would address the limitation associated with reliance on self-reported outcomes while retaining the practical advantages demonstrated by the paper-based protocol.

CONCLUSION

This pilot study demonstrated that a multi-domain fatigue-risk assessment protocol was feasible for use among shift workers in a Malaysian palm oil mill. All enrolled participants completed the paper-based questionnaire, no missing responses were identified in the primary assessment sections, and the average completion time was approximately 27 minutes. The small-group administration format, standardised briefing, and completion setting without supervisors were practical and can be retained for the main study.

The pilot also provided preliminary evidence that several multi-item domains had acceptable to good internal consistency reliability. The personal burnout and work-related burnout domains of the CBI, the PWI-A and the IWPQ domains demonstrated acceptable to good preliminary internal consistency, with Cronbach's alpha coefficients ranging from 0.722 to 0.894. However, selected items, particularly the reverse-scored CBI item B13 and several PWI-A items, require further review of wording, scoring, translation, and conceptual relevance before full-scale implementation.

The findings should not be interpreted as evidence of fatigue prevalence, poor wellbeing, or intervention effectiveness because the pilot involved a small sample from one palm oil mill and was designed primarily to assess procedural feasibility and preliminary measurement performance. Nevertheless, the study provides an important foundation for the main fatigue-risk intervention study. The refined protocol can be used to identify workplace factors relevant to fatigue risk and to inform practical controls involving work-rest planning, fatigue awareness, communication, supervisor involvement and work-system improvements within palm oil mill operations.

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DECLARATION OF COMPETING INTEREST

None.

REFERENCES

- Allison, P., Tiesman, H.M., Wong, I.S., Bernzweig, D., James, L., James, S.M., Navarro, K.M. & Patterson, P.D. 2022. Working hours, sleep, and fatigue in the public safety sector: A scoping review of the research. *American Journal of Industrial Medicine* 65(11): 878–897. <https://doi.org/10.1002/ajim.23407>
- Amran, M., Mohd Suadi Nata, D.H., Ishak, I. & Mohamad Jamil, P.A.S. 2026. Integrating Quick Exposure Checklist (QEC) for ergonomic risk management in the food manufacturing sector. *Jurnal Kejuruteraan* 38(3): 1003–1015. [https://doi.org/10.17576/jkukm-2026-38\(3\)-01](https://doi.org/10.17576/jkukm-2026-38(3)-01)
- Bugvi, S.A., Hameed, K., Hussain, A., Mufti, N.A., Ahmad, A., Jamil, F. & Ghauri, F. 2022. Impact of worker demographics and shift rotation on work stress factors in manufacturing. *Jurnal Kejuruteraan* 34(4): 689–702. [https://doi.org/10.17576/jkukm-2022-34\(4\)-17](https://doi.org/10.17576/jkukm-2022-34(4)-17)
- Chin, R.W.A., Chua, Y.Y., Chu, M.N., Mahadi, N.F., Wong, M.S., Yusoff, M.S.B. & Lee, Y.Y. 2018. Investigating validity evidence of the Malay translation of the Copenhagen Burnout Inventory. *Journal of Taibah University Medical Sciences* 13(1): 1–9. <https://doi.org/10.1016/j.jtumed.2017.06.003>
- Cunningham, T.R., Guerin, R.J., Ferguson, J. & Cavallari, J. 2022. Work-related fatigue: A hazard for workers experiencing disproportionate occupational risks. *American Journal of Industrial Medicine* 65(11): 913–925. <https://doi.org/10.1002/ajim.23325>
- Dawson, D. & McCulloch, K. 2005. Managing fatigue: It's about sleep. *Sleep Medicine Reviews* 9(5): 365–380. <https://doi.org/10.1016/j.smrv.2005.03.002>
- Goldberg, D.P. 1972. *The detection of psychiatric illness by questionnaire: A technique for the identification and assessment of non-psychotic psychiatric illness*. Maudsley Monograph No. 21. London: Oxford University Press.
- International Wellbeing Group. 2013. *Personal Wellbeing Index: Adult manual*. 5th ed. Melbourne: Australian Centre on Quality of Life, Deakin University.
- Koopmans, L. 2015. *Individual Work Performance Questionnaire: Instruction manual*. Amsterdam: TNO Innovation for Life–VU University Medical Center.
- Koopmans, L., Bernaards, C.M., Hildebrandt, V.H., de Vet, H.C.W. & van der Beek, A.J. 2014. Construct validity of the Individual Work Performance Questionnaire. *Journal of Occupational and Environmental Medicine* 56(3): 331–337. <https://doi.org/10.1097/JOM.0000000000000113>
- Kristensen, T.S., Borritz, M., Villadsen, E. & Christensen, K.B. 2005. The Copenhagen Burnout Inventory: A new tool for the assessment of burnout. *Work & Stress* 19(3): 192–207. <https://doi.org/10.1080/02678370500297720>
- Kusmawan, D., Izhar, M.D. & Aswin, B. 2024. Assessing the relationship between mental workload and work fatigue among oil and gas workers in PT X, Jambi Province, Indonesia: PLS-SEM analysis. *Journal of Public Health Research* 13: 22799036241287660. <https://doi.org/10.1177/22799036241287660>
- Monnaatsie, M., Biddle, S.J.H. & Kolbe-Alexander, T. 2023. The feasibility of a text-messaging intervention promoting physical activity in shift workers: A process evaluation. *International Journal of Environmental Research and Public Health* 20(4): 3260. <https://doi.org/10.3390/ijerph20043260>

- Quek, K.F., Low, W.Y., Razack, A.H. & Loh, C.S. 2001. Reliability and validity of the General Health Questionnaire (GHQ-12) among urological patients: A Malaysian study. *Psychiatry and Clinical Neurosciences* 55(5): 509–513. <https://doi.org/10.1046/j.1440-1819.2001.00897.x>
- Seong, S., Park, S., Ahn, Y.H. & Kim, H. 2022. Development of an integrated fatigue measurement system for construction workers: A feasibility study. *BMC Public Health* 22: 1593. <https://doi.org/10.1186/s12889-022-13973-5>
- Shahirah, M.R., Hanif Farhan, M.R. & Dayana Hazwani, M.S.N. 2023. Translation, validation and reliability testing of the Subjective Mental Effort Questionnaire (SMEQ) from English into the Malay language. *Medicine & Health* 18(2): 515–529. <https://doi.org/10.17576/MH.2023.1802.14>
- Shriane, A.E., Vincent, G.E., Ferguson, S.A., Rebar, A., Kolbe-Alexander, T. & Rigney, G. 2024. Improving sleep health in paramedics through an app-based intervention: A randomised waitlist control pilot trial. *BMC Public Health* 24: 2395. <https://doi.org/10.1186/s12889-024-19823-w>
- Tavakol, M. & Dennick, R. 2011. Making sense of Cronbach's alpha. *International Journal of Medical Education* 2: 53–55. <https://doi.org/10.5116/ijme.4dfb.8dfd>
- Thiruchelvam, S., Kabilmiharbi, N., Syaifoel, F.N.A., Mohamad Rafeai, Z.F., Ghazali, A., Mustapha, K.N. & Muda, R.S. 2021. A conceptual approach for developing an ergonomic intervention for preventing work-related musculoskeletal disorders (WMSD) amongst workforce at power plants. *Jurnal Kejuruteraan SI* 4(2): 93–100. [https://doi.org/10.17576/jkukm-2021-si4\(2\)-14](https://doi.org/10.17576/jkukm-2021-si4(2)-14)
- van Elk, F., Lammers-van der Holst, H.M., Robroek, S.J.W., Burdorf, A. & Oude Hengel, K.M. 2024. Effects and implementation of an intervention to improve sleep, fatigue and recovery among healthcare workers with night shifts: A pre- and post-test study. *International Journal of Nursing Studies* 160: 104881. <https://doi.org/10.1016/j.ijnurstu.2024.104881>
- Vallennie, V., Isa, S.N.I., Mazlan, A.Z. & Mohamad Shaifuddin, S.N. 2024. Impact of heat stress on health-related symptoms and physiological changes among workers at a palm oil mill in Mukah, Sarawak, Malaysia. *Medical Journal of Malaysia* 79(Suppl. 1): 83–87.
- Vallières, A., Pappathomas, A., de Billy Garnier, S., Mérette, C., Carrier, J., Paquette, T. & Bastien, C.H. 2024. Behavioural therapy for shift work disorder improves shift workers' sleep, sleepiness and mental health: A pilot randomised control trial. *Journal of Sleep Research* 33(6): e14162. <https://doi.org/10.1111/jsr.14162>
- Wong, I.S., Popkin, S. & Folkard, S. 2019. Working Time Society consensus statements: A multi-level approach to managing occupational sleep-related fatigue. *Industrial Health* 57(2): 228–244. <https://doi.org/10.2486/indhealth.SW-6>
- Wu, T., Tan, X., Li, Y., Liang, Y. & Fan, J. 2024. The relationship between occupational fatigue and well-being: The moderating effect of unhealthy eating behaviour. *Behavioral Sciences* 14(1): 32. <https://doi.org/10.3390/bs14010032>
- Yusoff, M.S.B., Rahim, A.F.A. & Yaacob, M.J. 2010. The sensitivity, specificity and reliability of the Malay version 12-items General Health Questionnaire (GHQ-12) in detecting distressed medical students. *ASEAN Journal of Psychiatry* 11(1): 36–43.
- Zeng, Z., Zhou, S. & Liu, M. 2024. Research progress on assessment tools related to occupational fatigue in nurses: A traditional review. *Frontiers in Public Health* 12: 1508071. <https://doi.org/10.3389/fpubh.2024.1508071>
- Zijlstra, F.R.H. 1993. *Efficiency in work behaviour: A design approach for modern tools*. PhD thesis, Delft University of Technology, Delft.
- Zijlstra, F.R.H. & van Doorn, L. 1985. *The Construction of a Scale to Measure Perceived Effort*. Delft: Department of Philosophy and Social Sciences, Delft University of Technology.