DEVELOPMENT OF AN INNOVATIVE INDEX TO ASSESS WORKER'S HEALTH RISK: THE *WHRI* APPLIED TO AN OIL INDUSTRY IN BAHIA, BRAZIL

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ABSTRACT

Purpose: The objective of this study was to assess the worker's health (WH) risk, focused on sustainable development in a work context and based on the development and application of the Worker's Health Risk Index (WHRI) in the oil extraction and production industry in Bahia, Brazil.

Design/methodology/approach: The sample, obtained by quota sampling, comprised 965 participants. The development stage integrated a group of 10 specialists, including physicians, nurses, nutritionists, dentists and physical educators, all specialists in the WH area, as well as 3 experts in the area of data science. Three risk ranges were defined: "Low", "Moderate" and "High".

Findings: The WHRI validation revealed reliability and reproducibility, as well as the ability to identify differences among the population studied according to sex, age group and education level. The results indicate that the WH risk is higher in men, aged above 50 years old and with a low level of education ($p<0.001$). 74% of the participants are in the "Low", 21% in the "Moderate" and 5% in the "High" risk ranges. High-risk workers are also those with diabetes mellitus, altered triglyceride or glycemia levels, hypertension, poor oral hygiene and periodontal conditions, tobacco use, low levels of physical activity (all with $p<0.05$), or alcohol abuse.

Originality/Value: The WHRI's major contribution is to make available a useful tool for the identification of WH risk, helping to define clearer health promotion, prevention and intervention policies in the context of WH.

Keywords: Index development. Worker's health risk index (WHRI). Sustainable working conditions. Risk management

RESUMO
Objetivo: O objetivo deste estudo foi o de avaliar o risco em saúde do trabalhador, com foco no desenvolvimento sustentável em contexto de trabalho e com base no desenvolvimento e aplicação do Índice de Risco à Saúde do Trabalhador (WHRI) numa indústria de extração e produção de petróleo na Bahia, Brasil.
Desenho / metodologia / abordagem: A amostra, obtida por amostragem por cotas, é composta por 965 participantes. A etapa de desenvolvimento integrou um grupo de 10 especialistas, entre os quais médicos, enfermeiros, nutricionistas, dentistas e educadores físicos, todos especialistas na área da saúde do trabalhador, além de 3 especialistas na área de ciência dos dados. Três faixas de risco foram definidas: "Baixo", "Moderado" e "Alto".
Resultados: A validação do WHRI revelou confiabilidade e reprodutibilidade, bem como capacidade de identificar diferenças entre a população estudada, segundo sexo, faixa etária e escolaridade. Os resultados indicam que o risco em saúde do trabalhador é maior em homens, com idade acima de 50 anos e baixa escolaridade ($p < 0,001$). 74% dos participantes estão na faixa de risco "Baixo", 21% na "Moderada" e 5% nas faixa de risco "Alto". Trabalhadores de alto risco são aqueles com diabetes mellitus, triglicerídeos, glicemia e hipertensão alteradas, higiene oral e condição periodontal precárias, tabagismo, menos ativos fisicamente e níveis mais elevados de abstenção (todos com $p < 0,05$).
Originalidade: A principal contribuição do WHRI é o de disponibilizar uma ferramenta útil para a identificação do risco em saúde do trabalhador, contribuindo para definir políticas mais claras de promoção, prevenção e intervenção em saúde no contexto laboral.
Palavras-chave: Desenvolvimento de índices. Índice de risco em saúde do trabalhador (WHRI). Condições de trabalho sustentáveis. Gerenciamento de riscos

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1. INTRODUCTION

The continued growth of the world's population, the scarcity of resources and the threat of climate change expose numerous environmental and social problems. The Goals of the 2030 Agenda for Sustainable Development, adopted by all United Nations (UN) Member States in 2015 (Guerra & Brito Lourenço, 2018; United Nations, 2015), constitute a plan of action for people, for the planet and for prosperity. A total of 17 Sustainable Development Goals (SDGs), 169 targets and 230 global indicators were defined in order to enable monitoring of their implementation by 2030. The objectives and targets are intended to stimulate action in areas of critical importance to humanity and to the planet. Among these objectives, five of them are directly related to health and labour/employment issues, namely SDGs 2, 3, 6, 8 and 11, which, being related, are aimed at guaranteeing access to quality health and promoting well-being for all, at all ages, contemplating the implementation of sustainable economic growth strategies, inclusive and sustainable, full and productive employment and decent work for all, respectively (Leadership Council of the Sustainable

Development Solutions Network, 2015; United Nations General Assembly, 2018). In the same line of work, the European Union Strategic Framework on Health and Safety at Work 2014-2020 (Eurofound, 2015b, 2015a; Eurofound and EU-OHSA, 2014) identifies important challenges and objectives, including improvements in health and safety rules, prevention of occupational diseases, and issues related to an aging workforce. Risk prevention and the promotion of safer and healthier conditions in the workplace are essential not only to improve the quality of employment and working conditions, but also to promote competitiveness (Dinis et al., 2019). Keeping workers healthy has a direct and quantifiable positive impact on productivity, contributing to improving the sustainability of social security systems (European Comission, 2010, 2014; World Health Organisation, 2016).

According to the World Health Organization (WHO), the socioeconomic impact of chronic diseases is increasing and is considered a problem for world public health. In addition to premature deaths, Non-communicable Chronic Diseases (NCDs) are responsible for work disability, reduced family incomes and reduced productivity. In Brazil, in considering deaths, absenteeism and presenteeism, the impact of NCDs represented 5.4% of the 2015 gross domestic product (GDP) (USD 129.8 billion), and projections indicate that this number will reach 5.8% of the GDP in 2030 (USD 184 billion). This same study (Bloom et al., 2011) revealed that economic costs related to early retirement are projected to reach 2.9% in 2030, compared to 2.4% in 2015. The WHO indicator "Years of Life Lost by Disability" (YLD) (Rasmussen et al., 2015) showed Brazil as the country with the highest spending on chronic diseases (150 YLD) when compared to the other 20 countries in the same study. In a scenario of significant economic impact on health systems, health care regulation appears as a way to provide economic efficiency (Salgado, 2003) and can be understood as an essential instrument for maintaining the balance of a health system (Vilarins et al., 2012). Thus, regulation is seen as a set of actions that direct, adjust, facilitate or limit certain processes to achieve results that may be related to meeting the most pressing needs of a population (Schilling et al., 2006). In this sense, risk stratification of health system users is a central element of the health management of a population. The stratification of the population into subpopulations leads to the identification of users with similar needs in order to distribute specific resources to each group. When a population is not stratified by risk, care can be provided to those at lower risk and/or over-care instead of to those at higher risk, resulting in ineffective and inefficient attention (E. V. Mendes, 2015). An important model for the organisation of care regulation is the Risk Pyramid Model (RPM) [48], which operationalises the risk stratification of non-acute chronic conditions, relying heavily on the risk stratification of the population and defining intervention strategies for self-care and in professional care. The application of the RPM in health care has several practical applications, guiding an adequate distribution of self-care, professional care and specialised care in the agenda of health professionals (Pan American Health Organization, 2012).

In a world scenario where people spend most of their day at work, it is important to make the work context safe and conducive to the quality of life and health. Thus, both public and private institutions must develop and implement interdisciplinary mechanisms and interventions in the same direction (Almeida, 2000; Task Force on Community Preventive Services, 2010; Viterbo et al., 2018; Viterbo, Dinis, Vidal, et al., 2019), contributing to the implementation of the SDGs at the micro level. WHO proposes that the action on risk factors has the potential to produce sustainable improvement in the health of populations, and there are many ways to address this. However, for risk reduction, two main approaches stand out: identifying high-risk people, those most likely to benefit from health interventions, and identifying the risk across the population, regardless of the risk and potential benefit of each individual (World Health Organization (WHO), 2009). Although the RPM is a relevant model for stratifying populations in risk ranges, their theoretical frameworks do not describe the methodology that determines their classes. Still at this level, other existing indices are either not accessible for application, such as the Total Health Index (*THI*) Assessment (Morneau Shepell, 2019), or are very focused on measuring work performance anchored to OHSAS 18001 and ISO 14001 standards, thus neglecting, in part, the worker's personal dimension and health, as an indicator resulting from a set of related factors, such as the Occupational Health Index (*OHI*) (Kulkarni, 2017). In addition to existing indices, some initiatives have emphasised worker's well-being concerns, such as the International Social Security Association's "Vision Zero" initiative (International Social Security Association, 2019), which is a transformational approach to prevention by integrating dimensions of safety, health and well-being at work, and The National Institute for Occupational Safety and Health's "Total Worker Health®" initiative (The National Institute for Occupational Safety and Health, 2019), which - anchored in a holistic approach to workers and their well-being - takes into account the policies and actions that address occupational risk factors, based not only on the sole well-being of the worker but rather on the common good at work, i.e., workers, employers.

Although there are indices and initiatives that deal with the theme, such as those mentioned above, there is a knowledge gap in occupational health in terms of a method that - in addition to considering aspects related to social determinants of health, global burden of disease, environmental aspects, the SDGs and, particularly, the working conditions affecting the individual's health - also makes it possible to extract the population into risk classes, which becomes absolutely necessary. Specifically, the International Labour Organization (International Labour Organization, 2019) establishes the relevant SDG targets related to the future of work, SDG 8 "Decent Work and Economic Growth", including target 8.8 - "Protect labour rights and promote safe and secure working environments of all workers, including migrant workers, particularly women migrants, and those in precarious employment", and it is specifically in this scope where the *WHRI* seeks to be relevant.

In line with the need for risk stratification and with the intention of covering a lack of availability of health and sustainability indicators within the work context, this study proposes the Worker's Health Risk Index (*WHRI*), which aims to assess the worker's health (WH) risk, focusing on sustainable development in the workplace. This approach assumes that the WH results from a set of associations between environment, human health and working relationships, which, interrelated, contribute to the general health status of the working population. For this reason, and in an interdisciplinary perspective, the development of an index such as the *WHRI* is considered relevant, enabling the integral promotion of health in the collective work environment, which will allow its widespread application in various working contexts without direct additional associated costs.

2. METHODOLOGY

2.1. Study design

The research is based on a strong methodological component, carried out in the period of August to October 2018, in the worker's occupational health service in the oil extraction and production industry in Bahia, Brazil. The study involved 10 specialists, all of whom are active in the WH field with a minimum of five years of interdisciplinary experience, and three data science experts analysing the database composed by population (N = 1275 workers) and sample (quota sampling) (n = 965 workers). Data were collected during the annual occupational assessment of the subjects, in the appropriate offices, by professionals of medicine, nursing, nutrition, dentistry and physical education with vast experience in the specific area of work. All calls were performed in an integrated, single shift and lasted an average of 40 min with each professional. The Interdisciplinary Worker's Health Approach Instrument (IWHAI) (Viterbo, Dinis, Costa, et al., 2019), previously validated, was used for data collection purposes. Data were treated to standardise variable names, and a randomly generated code was created to ensure anonymity of the study participants. To assess the *WHRI*'s ability to identify differences/associations among the participants by sex, age group and educational level, the Chi-square test was applied (α = 5%).

In all stages of the study, the recommendations and guidelines of Resolution 466/2012 of the Brazilian Ministry of Health, on ethical aspects regulating research with human beings, were followed. The study was approved by the Research Ethics Committee of the Bahiana School of Medicine and Public Health and CAAE no. 84318218.2.0000.5544. Before participating in the study, all subjects gave their informed consent for inclusion.

Figure 1 details the *WHRI* development steps.

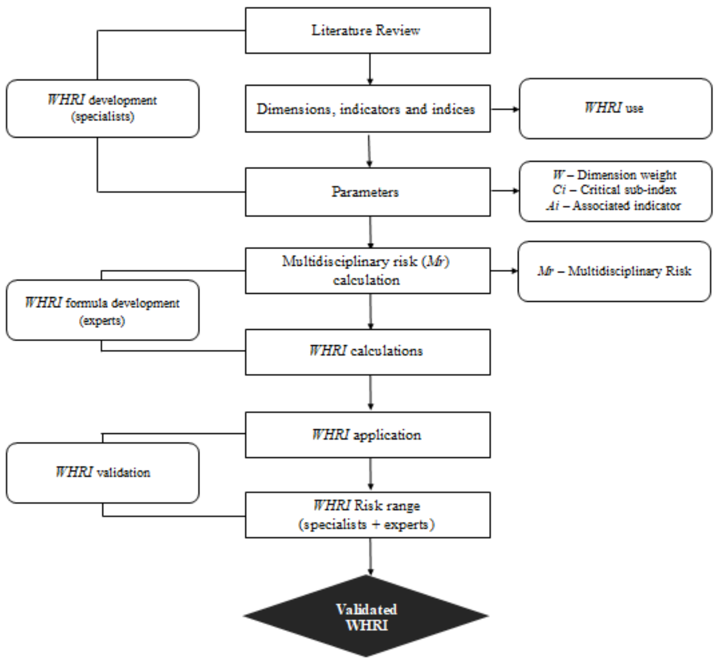

Figure 1. *WHRI* development steps

2.2. *WHRI* indicators' selection

Based on the literature review, 6 dimensions, 44 indicators and 220 sub-indices, integrating the IWHAI (Viterbo, Dinis, Costa, et al., 2019), were included. To the IWHAI structure, the "Personal factor" dimension was added, corresponding to the "Age group" indicator and the respective sub-indices. For the definition of the variables, aspects related to social determinants were considered, i.e., health (Commission on Social Determinants of

Health, 2008; Graham & White, 2016; Kelly et al., 2007), global disease burden (Forouzanfar et al., 2016; Malta et al., 2017; Organization, 2009), environmental aspects (Bini & Bech, 2014), SGDs (United Nations, 2015) and, in particular, working conditions affecting the health of the individual. The *WHRI* was coded in closed responses with an interval scale of 0 to 4, where zero represents non-existent or inadequate risk control and four represents optimal risk control, with the following graduation: 0 - non-existent or inadequate; 1 - tolerable; 2 - reasonable; 3 - good and 4 - excellent.

The *WHRI*'s alignment with the SDGs (United Nations, 2015), UN indicators (Leadership Council of the Sustainable Development Solutions Network, 2015) and Brazilian indicators for sustainable development (IBGE - Instituto Brasileiro de Geografia e Estatística, 2019) are presented in Table 1.

Table 1. *WHRI*'s alignment with SDGs, and UN and Brazil Indicators

SDGs	*WHRI* Indicator	UN Indicator	Brazil Indicator
2	Energy balance intake	2.7	ni
	Simple carbohydrate intake	2.8	ni
3	Work environment health conditions	nci	nd
	Family relationships	nci	ni
	Social aspects - leisure	nci	ni
	Self-care level	nci	ni
	Dyslipidemia	23	ni
	Diabetes mellitus	23	uac
	Altered glycemia	3.23	ni
	Arterial hypertension	3.18	ni
	Blood pressure	23	ni
	Tobacco use	30	uac
	Musculoskeletal pathology	nci	uac
	Psychiatric pathology	28	ni
	Stress level and symptoms	28	ni
	Saturated lipids intake	3.23	ni
	Sodium mineral intake	3.24	ni
	Fibre intake	3.25	ni
	Alcohol use	3.19	uac
	Level of food knowledge	nci	ni
	Body weight condition	24	ni
	Altered triglycerides	23	ni
	Oral hygiene quality	nci	ni
	Periodontal condition	nci	ni
	Periodontal disease	nci	ni
	Caries	nci	ni
	Oral lesion on soft or hard tissues	nci	ni
	Bruxism	nci	ni
	Physical activity level	3.22	ni
	Contemplation stage for physical activity practice	nci	ni

SDGs	*WHRI* Indicator	UN Indicator	Brazil Indicator
	Feeling of pain	nci	ni
	Cardiorespiratory fitness	nci	ni
	Abdominal strength level	nci	ni
	Flexibility level	nci	ni
	Manual gripping force	nci	ni
	Age Group	nci	ni
6	Pests and vectors	nci	uac
	Drinking water Quality	45	pr
8	Environmental hazards exposure (physical, chemical and biological agents)	57	uac
	Ergonomic risks - physical aspects	57	uac
	Ergonomic risks - organizational aspects	57	uac
	Work accident	nci	uac
	Work-related absenteeism	nci	ni
11	Air quality	69	nd

Note: nci - there is no UN corresponding indicator; ni - no Brazil indicator; nd - no data; uac - indicator under analysis/construction; pr - produced indicator.

In Table 1, the indicators selected to be included in the *WHRI* are aligned with some of the SDGs and corresponding UN indicators (if any). The last column shows the correspondence of the *WHRI* indicators with the Brazilian indicators (if any). In the latter case, and based on the consultation of the Brazil Indicators for SDGs [32], the Brazil indicators are divided into the following: according to the IBGE (IBGE - Instituto Brasileiro de Geografia e Estatística, 2019), this indicator does not apply to Brazil (ni), there is not enough data in Brazil to construct the indicator (nd); the indicator is under construction (uac); or the indicator already exists and is produced (pr). This table, inspired by the construction of the WeGIx (Wellbeing Global Index) (Oliveira, Vidal, Viterbo, et al., 2020), allows one to understand how the indicators that make up the *WHRI* can help in monitoring the SDG targets and, in part, address the shortcomings in providing indicators on Brazilian reality, although in a specific context, such as the worker in the oil industry.

The 3 data science experts defined the parameters' values to be applied in all *WHRI* development steps, as detailed in Table 2.

Table 2. *WHRI* dimensions, indicators and associated indicators

Dimension	*W*	Indicator Code	Indicator	*Ci*	*Ai*						
					I01	I02	I03	I04	I05	I06	I07
Personal factor	0	G01	Age group								
Dentistry	1	O02	Oral hygiene quality								
		O03	Periodontal condition	0							
		O04	Periodontal disease	1	O02	M06					

Dimension	*W*	Indicator Code	Indicator	*Ci*	***Ai***						
					I01	**I02**	**I03**	**I04**	**I05**	**I06**	**I07**
		O05	Caries	0	N02						
		O06	Oral lesion on soft or hard tissues	0	M06	N06					
		O07	Bruxism		M09						
Nutrition	2	N01	Energy balance intake		P01						
		N02	Simple carbohydrate intake	0							
		N03	Saturated lipids intake	0							
		N04	Sodium mineral intake	0							
		N05	Fibre intake								
		N06	Alcohol use	0	E05	E06					
		N07	Level of food knowledge								
		N08	Body weight condition								
		N09	Altered triglycerides	0	N06						
Physical education	3	P01	Physical activity level		E06	E07					
		P02	Contemplation stage for physical activity practice	1							
		P03	Feeling of pain	2	M07	E02					
		P04	Cardiorespiratory fitness								
		P05	Abdominal strength level								
		P06	Flexibility level								
		P07	Manual gripping force								
Nursing	4	E01	Environmental hazards exposure (physical, chemical and biological agents)	1							
		E02	Ergonomic risks - physical aspects	1							
		E03	Ergonomic risks - organizational aspects								
		E04	Work environment health conditions	0							
		E05	Family relationships								
		E06	Social aspects - leisure								
		E07	Self-care level	1	E05						
		E08	Pests and vectors		E04						
		E09	Drinking water Quality		E04						
		E10	Air quality		E04						
		E11	Work accident		E01	E02					
		E12	Work-related absenteeism		P03						
Medicine	5	M01	Dyslipidemia	0	N03	N09					
		M02	Diabetes mellitus	2	N02	P01	E05	E07	M04	M06	O06
		M03	Altered glycemia	1	N02	P01	E05	E07			
		M04	Arterial hypertension	0	N04	P01	E05	E07			
		M05	Altered blood pressure	1	N04	P01	E05	E07			
		M06	Use of tobacco	1							
		M07	Musculoskeletal pathology	0							
		M08	Psychiatric pathology	1							

Dimension	W	Indicator Code	Indicator	Ci	Ai						
					I01	**I02**	**I03**	**I04**	**I05**	**I06**	**I07**
		M09	Stress level and symptoms	0	N06						

Note: *W* - Dimension weight; *Ci* - Critical sub-index; *Ai* - Associated indicator.

As shown in Figure 1 and Table 2, the first parameter refers to the Dimension Weight (*W*), comprising an integer number, ranging from 0 to 5. The highest value, i.e., $W = 5$, characterises the dimension whose indicators have a major impact on the interdisciplinary assessment, corresponding to the medicine dimension. The second parameter corresponds to the criticality for each indicator, which was defined by the Critical Sub-index (*Ci*), ranging from 0 to 2. The third parameter is the Associated Indicator (*Ai*), establishing the association between indicators. As an example, there is the feeling of pain indicator, which has *Ci* at level 2, so the indicator will be considered critical whenever one of the sub-indices 0, 1 or 2 is chosen, with no difference between these scores. Feeling of pain is associated with musculoskeletal pathology and ergonomic risks, physical aspects indicators, which means that it is influenced by them and can be either positive or negative.

2.3. WHRI calculations

2.3.1. Stage 1: Multidisciplinary Risk

The development of the *WHRI* calculation was mainly based on the model of calculation of the potential risk by Leite and Dourado (Leite & Dourado, 2012) and Navarro (Navarro, 2009). Also, the studies from Nishijima and Biasoto (Nishijima & Biasoto Junior, 2013), Brilhantes and Caldas (Brilhantes & Caldas, 1999), Castiel and collaborators (Castiel et al., 2010) and also Finch (Finch, 2003) have contributed to the *WHRI* calculation. The Multidisciplinary Risk (*Mr*) is the value calculated from a weighted average of the sub-indices filled in the indicators of each dimension, added by a factor calculated from the number of risk associations that each indicator had with other dimensions, or with the dimension itself. The worker will have an *Mr* score for 5 dimensions, i.e., medicine, nursing, physical education, nutrition and dentistry, and to calculate it, all *WHRI* indicators must be filled. The *Mr* calculation is shown in Equation 1.

$$Mr = \left\{ \frac{\left[\frac{\log(W+1)}{(W+Q)} \right]}{(W+I)} \right\} + \left\{ R + \left[A \times \left(\frac{0.05}{T} \right) \right] \right\} \quad (1)$$

Where W is the dimension weight, Q is the number of dimensions integrating disciplinary care, I is the number of indicators by dimension, R is the reference value, detailed below, A is the number of indicators with sub-index ranging from 0 to 2, i.e., Ai, associated with some dimension indicator, considering all the dimensions assessed for a particular individual, and T is the number of total associations between indicators of all dimensions. 0.05 is a constant responsible for a bigger data detail of the negative weights of the associated indicators. R = 0.95, when there is at least one indicator in the dimension whose sub-index is less than or equal to the value defined as critical (see Table 2, critical sub-index (Ci)), 0.95 is a constant that limits the maximum that the Mr can reach before the Ai. In all other cases, R= 0.95 - M/4.3, where M is the sub-indices arithmetic mean, and 4.3 is a constant responsible for increasing the *WHRI*'s accuracy, increasing its probability of identity.

2.3.2. Stage 2 – Worker's Health Risk Index (*WHRI*)

The *WHRI* is calculated from the Mr mean (Equation 1) of the worker, according to Equation 2. Each worker will have a specific *WHRI* score, and the same result will not be possible for more than one individual.

$$WHRI = \frac{\left\{ 0.95 - \left(\frac{Is}{3.3} \right) \right\} + \sum Mr}{Q+1} \quad (2)$$

Where Is is the indicator corresponding to the subject's age group (see Table 3), Mr is the multidisciplinary risk, Q is the number of dimensions integrating disciplinary care, 0.95 is a constant that limits the maximum that the Mr can reach before the Ai, and the difference between 4.3, the constant from Equation 1, and 1, i.e., equal to 3.3, is another constant responsible for making the sum of Mr proportional to the calculation of the age dimension.

Table 3. Indicator assigned to the subject's age group

Age Group	***Is***
$As \geq 60$	0
$50 \leq As < 60$	1
$40 \leq As < 50$	2

$30 \leq As < 40$	3
$As < 30$	4

Note: *As* is the age of the subject; *Is* is the indicator corresponding to the subject's age group

2.3.3. Example of *WHRI* calculation

Each specialist, i.e., physician, nurse, nutritionist, dentist and physical educator, is responsible for the data collected in their respective dimensions. Table 4 presents the results obtained in the assessment of a worker relating the Nursing dimension, as an example.

Table 4. Nursing indicators with simulated responses to their sub-index

Indicator Code	Sub-Index
E01	3
E02	1
E03	3
E04	1
E05	1
E06	3
E07	3
E08	1
E09	2
E10	3
E11	4
E12	1

For the calculation of the value of *Mr* it is necessary to extract the values of *W*, *I*, *M*, *A*, *R, Q*, and *T* of each dimension, already defined in Equation 1. In the example of the Nursing dimension, the values to use are: $W = 4$ (predefined according to Table 2 for the Nursing dimension), $I = 12$, $M = 2.17$, $A = 5$, $R = 0.95$ (as explained before). The values of *Q* and *T* were predefined by the method, as follows: $Q = 5$ and $T = 42$. Applying all values to Equation 1, the obtained result is $Mr = 0.9608$. The same calculations are made for each dimension, except for the personal factor dimension. The results are presented in Table 5.

Table 5. *Mr* values to each *WHRI* dimension

Dimension	*Mr*
Medicine	0.9678
Nursing	0.9608
Physical education	0.9599
Nutrition	0.3889
Dentistry	0.9637

$\sum Mr$	4.2411

To complete the *WHRI* calculation it is necessary to extract the values of *Is*, *Q* and $\sum Mr$, as defined in Equation 2. Considering that the worker in the example is 52 years old, the value of *Is* to be used is *Is* = 1 (Table 3), with *Q* = 5 (as indicated above) and $\sum Mr$ = 4.2411 (sum of all *Mr* values in Table 5). Applying all values to Equation 2, the obtained result is *WHRI* = 0.8146 (High-risk).

2.4. WHRI validity

In *WHRI* internal validation, excellent Kappa coefficient (*k*) (Landis & Koch, 1977) values were found, namely for its applicability (*k* = 0.88), clarity (*k* = 0.80) and relevance (*k* = 0.82). In addition, moderate and strong positive associations were identified among the variables, using the Spearman's correlation coefficient (r_s) , i.e., ranging from r_s= 0.23 to 0.79 ($p < 0.01$). From the multivariate analysis, i.e., factor analysis, 14 components were extracted, explaining 62.6% of the data variability (KMO = 0.66; Bartlett's test: $x^2 = 5252.03$, $p < 0.001$). The reliability obtained was moderate to high, i.e., Cronbach's alpha (α) is 0.61, as confirmed by other studies (Hair et al., 2003; Landis & Koch, 1977; Ruiz Bolívar, 2002), and its reproducibility is also confirmed by the reasonable value of the intraclass correlation coefficient (0.61; 95% Confidence Interval = 0.562–0.652, $p < 0.001$). The Kruskal–Wallis test was used to compare the sub-indices' medians of the three risk ranges and to verify if the *WHRI* is able to identify differences between the risk ranges.

2.4.1. *WHRI* application

The *WHRI* was applied to a sample of 965 workers, where men (91.6%), aged 50-59 years (43.6%) and with a complete secondary level of education (60.4%) prevailed. The sample does not differ from the population in terms of the distribution of the percentages by sex ($p > 0.05$) and age group ($p > 0.05$), contributing to a more robust analysis and also allowing one to infer the results found for the population (see Table 6).

Table 6. Population and sample characterisation

	Population *N* (%)	**Sample *n* (%)**	***p***
Sex			
Male	1 117 (87.6)	884 (91.6)	
Female	158 (12.4)	81 (8.4)	> 0.05
Age Group			
≤29	50 (3.9)	44 (4.6)	
30 a 39	350 (27.5)	261 (27.0)	

40 a 49	245 (19.2)	209 (21.7)
50 a 59	556 (43.6)	410 (42.5)
≥60	74 (5.8)	41 (4.2)
Total	1275	965

2.4.2. *WHRI* Risk range

In order to transform the data generated from the *WHRI* calculations into information that supports decision-making in the WH field, specialists and data experts met to define three distinct risk ranges, according to Table 7.

Table 7. *WHRI* risk range

Risk range	*WHRI* reference value
Low	*WHRI* < 0.530
Moderate	0.530 ≤ *WHRI* < 0.662
High	≥ 0.662

As a theoretical basis for the definition of the risk range, models by the Leeds Department of Health (Department of Health, 2005), Leutz (Leutz, 1999), Porter and collaborators (Porter & Kellogg, 2008) and Mendes (E. V. Mendes, 2012) that stratify the population by risk levels were used. The following classifications were considered:

Low-risk: In this range, the risk value varies from 0.007 to a defined value of 0.529. Individuals who have these *WHRI* values are considered to be at low WH risk, particularly for behavioural risks (Committee on Health and Behavior: Research, Practice and Policy, 2001) and with needs for interventions related to health promotion actions (Aust & Ducki, 2004; Hendriksen et al., 2016; Meng et al., 2017).

Moderate-risk: In this range, the risk value varies between the lower limits of 0.530 and the higher limits of 0.661. Individuals with these *WHRI* values are considered to be at moderate WH risk, specifically in terms of biopsychosocial and environmental risks (Dinis, 2016; Yarahmadi et al., 2016) and with needs for interventions related to health prevention actions (Verra et al., 2019; World Health Organization, 2010, 2016).

High-risk: In this range, the value is above the acceptability limit of 0.662. Individuals who present these *WHRI* values are considered to be at high WH risk and need interventions related to complex health care actions (Kompier, M. A. J. Kristensen, 2001).

3. RESULTS

The *WHRI* was applied in the study sample (965 workers). Figure 2 shows the distribution of the percentage of workers in each risk range.

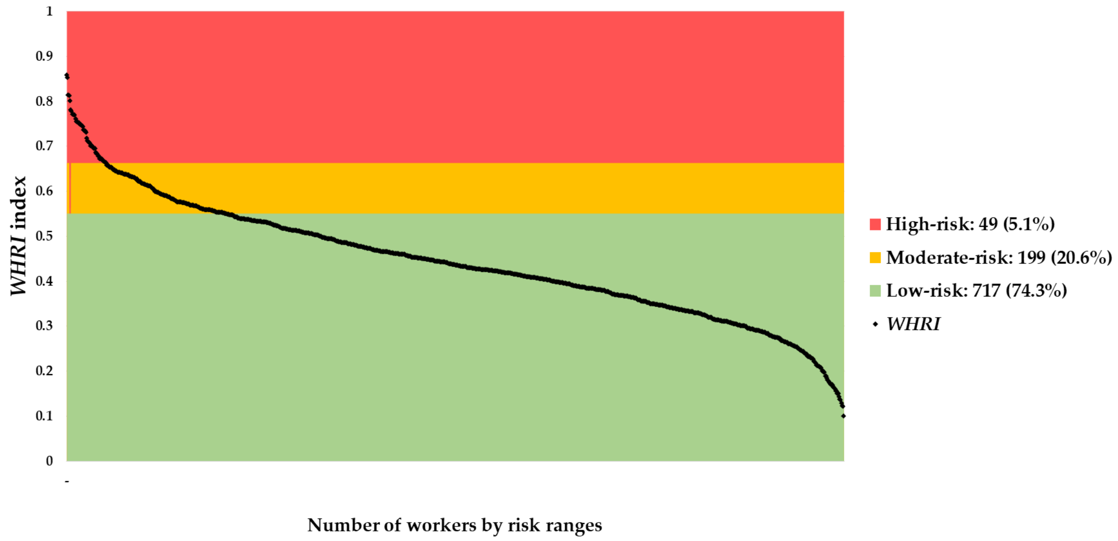

Figure 2. *WHRI* risk range by workers' number and relative frequencies (%)

5.1% of the workers were classified as high-risk, 20.6% as moderate-risk and 74.3% as low-risk. The *WHRI* graphical distribution demonstrates that each individual has a value that is not repeated, confirming the accuracy of the calculations.

In addition to *WHRI* stratifying the worker population as to health risk, it enables the optimisation of the provision of services appropriate to the needs of the worker. The need for professional care is related to the multidisciplinary risk classification (*Mr*) in the high, medium or low risk ranges. For the presentation of the results, all *Mr*'s were considered in the high-risk range, i.e., when the *Mr* of one dimension has high risk, it means that the worker needs the corresponding professional attention. Figure 3 shows the distribution of the number of health professionals needed for intervention by risk range. This is a particularly important factor to be considered with economic implications, enabling a better management of the funds available.

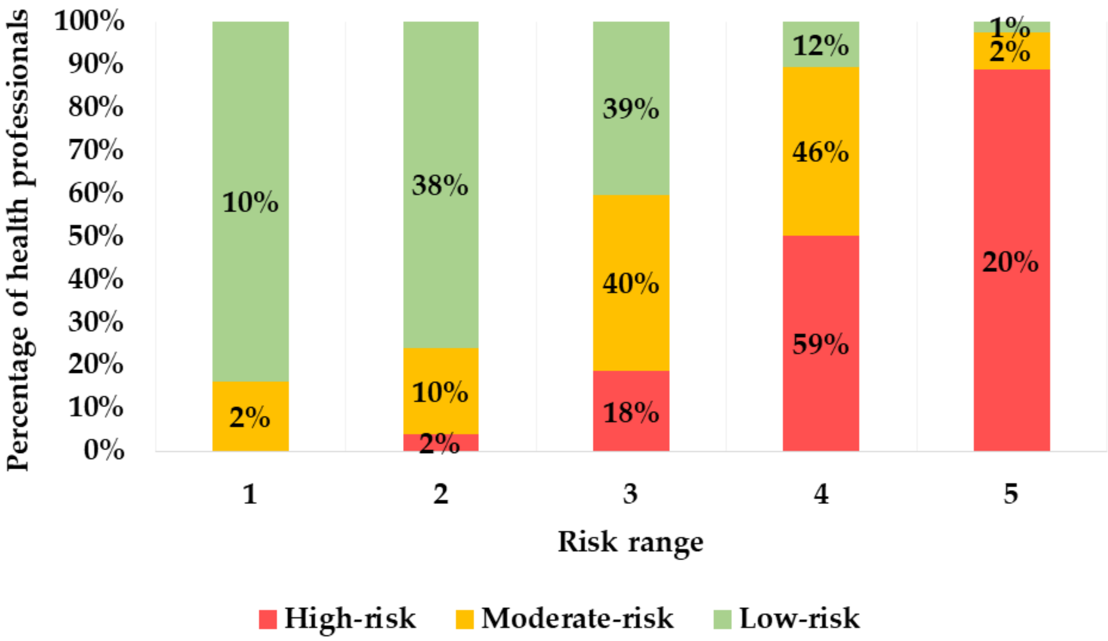

Figure 3. Distribution of the number of health professionals needed for intervention by risk range.

It can be observed that 79% of the individuals classified as high-risk need support from more than four health professionals, while 86% of those classified as moderate-risk require care from three to four professionals, and finally 87% of workers who are low-risk individuals need attention from up to three health professionals.

The *WHRI* risk range distribution was compared by sex, age group and education level of the sample, according to Table 8.

Table 8. *WHRI* risk range comparison by sample sociodemographic characteristics

	***n* = 965**			***p***
	Low-risk	**Moderate-risk**	**High-risk**	
	WHRI < 0.530	0.530 ≤ *WHRI* < 0.662	≥ 0.662	
	n (%)	*n* (%)	*n* (%)	
Sex				
Male	644 (72.9)	191 (21.6)	49 (5.5)	0.002
Female	73 (90.1)	8 (9.9)	0 (0.0)	
Age group				
≤ 29	44 (100)	0 (0.0)	0 (0.0)	
30 a 39	247 (94.6)	13 (5.0)	1 (0.0)	
40 a 49	173 (82.8)	33 (15.8)	3 (1.4)	0.000
50 a 59	233 (56.8)	143 (34.9)	34 (8.3)	
≥ 60	20 (48.8)	10 (24.4)	11 (26.8)	
Education				
Incomplete intermediate level	29 (51.8)	19 (33.9)	8 (14.3)	0.002

Complete intermediate level	438 (75.3)	116 (19.9)	28 (4.8)
Incomplete higher level	28 (84.8)	4 (12.1)	1 (3.0)
Complete higher level	124 (78.5)	28 (17.7)	6 (3.8)
Complete higher level with postgraduate degree	32 (84.2)	6 (15.8)	0 (0.0)

The results (Table 8) indicate a heterogeneous distribution of workers across the three risk ranges. In the high-risk range there are predominantly male workers ($p<0.05$), aged 50 or older ($p<0.05$) and with complete or incomplete intermediate education levels ($p<0.05$).

Table 9 presents the prevalence of the sub-indices of each indicator by risk range and the respective p-value.

Table 9. Sub-indices prevalence by risk range

Dimension	Code	Age group	Risk Ranges			*p*
			Low	Medium	High	
Dentistry	O02	Oral hygiene quality	4 (36.9)	2 (44.7)	2 (61.2)	0.001
	O03	Periodontal condition	4 (41.2)	1 (41.2)	1 (57.1)	0.001
	O04	Periodontal disease	3 (55.6)	2 (50.0)	2 (42.9)	0.126
	O05	Caries	1 (46.1)	1 (63.6)	1 (60.0)	0.001
	O06	Oral lesion on soft or hard tissues	4 (100)	4 (100)	1 (100)	0.480
	O07	Bruxism	2 (54.2)	3 (47.3)	2 (60.0)	0.335
Nutrition	N01	Energy balance intake	3 (54.0)	2 (48.7)	2 (53.1)	0.001
	N02	Simple carbohydrate intake	3 (78.1)	3 (68.3)	3 (65.3)	0.001
	N03	Saturated lipids intake	3 (93.6)	3 (91.0)	3 (87.8)	0.201
	N04	Sodium mineral intake	3 (98.5)	3 (98.0)	3 (100)	0.902
	N05	Fibre intake	3 (69.8)	3 (57.3)	3 (61.2)	0.002
	N06	Alcohol use	3 (57.9)	3 (51.3)	3 (38.8)	0.003
	N07	Level of food knowledge	3 (59.5)	2 (56.3)	2 (57.1)	0.001
	N08	Body weight condition	2 (47.3)	2 (45.7)	2 (49.0)	0.002
	N09	Altered triglycerides	3 (67.9)	3 (43.4)	1 (40.8)	0.001
Physical education	P01	Physical activity level	3 (44.8)	0 (40.2)	0 (65.3)	0.001
	P02	Contemplation stage for physical activity practice	3 (73.9)	3 (58.3)	1 (32.7)	0.001
	P03	Feeling of pain	4 (93.4)	4 (67.9)	4 (79.6)	0.002
	P04	Cardiorespiratory fitness	3 (60.1)	3 (63.1)	3 (77.1)	0.001
	P05	Abdominal strength level	4 (35.6)	0 (33.5)	0 (28.1)	0.001
	P06	Flexibility level	0 (27.9)	0 (43.7)	0 (46.2)	0.001
	P07	Manual gripping force	3 (66.7)	3 (65.5)	3 (63.0)	0.003
Nursing	E02	Ergonomic risks - physical aspects	3 (81.7)	3 (68.9)	3 (63.3)	0.001
	E03	Ergonomic risks - organisational aspects	3 (94.9)	3 (94.9)	3 (91.8)	0.956
	E04	Work environment health conditions	3 (85.1)	3 (81.1)	3 (89.8)	0.259
	E05	Family relationships	3 (98.2)	3 (96.4)	3 (87.8)	0.001
	E06	Social aspects - leisure	3 (97.5)	3 (96.4)	3 (100)	0.019
	E07	Self-care level	3 (54.0)	2 (55.1)	2 (55.1)	0.001
	E08	Pests and vectors	2 (52.2)	1 (55.8)	1 (62.5)	0.031
	E09	Drinking water quality	0 (52.0)	0 (54.8)	0 (60.4)	0.733
	E10	Air quality	3 862.5)	3 (55.3)	3 (55.1)	0.147

Dimension	Code	Age group	Risk Ranges			p
			Low	Medium	High	
	E11	Work accident	4 (99.6)	4 (100)	4 (100)	0.595
	E12	Work-related absenteeism	4 (48.7)	2 (32.7)	2 (32.7)	0.001
Medicine	M01	Dyslipidemia	3 (37.2)	4 (33.7)	4 (30.6)	0.082
	M02	Diabetes mellitus	4 (46.7)	2 (50.0)	2 (33.3)	0.002
	M03	Altered glycemia	4 (80.9)	4 (72.4)	4 (80.0)	0.002
	M04	Arterial hypertension	3 (84.6)	3 (74.3)	3 (37.5)	0.001
	M05	Altered blood pressure	4 (50.7)	3 (37.2)	2 (49.0)	0.001
	M06	Use of tobacco	4 (75.0)	4 (44.5)	2 (47.1)	0.001
	M07	Musculoskeletal pathology	4 (49.3)	2 (39.4)	2 (56.3)	0.001
	M08	Psychiatric pathology	4 (47.9)	4 (60.0)	3 (52.1)	0.165
	M09	Stress level and symptoms	4 (91.9)	4 (85.7)	4 (87.5)	0.021

According to Table 9, most of the indicators identify significant differences among the three risk ranges. In the dimension of medicine, nursing, physical and dental activity, the most significant differences are observed, suggesting that workers with higher levels of diabetes mellitus ($p<0.05$), altered triglycerides ($p<0.05$), glycemia ($p<0.05$), blood pressure ($p<0.05$) and use of tobacco ($p<0.05$) are found in the high-risk range. Workers in the high-risk range are also those with poorer oral hygiene ($p<0.05$) and periodontal conditions ($p<0.05$) and are the least physically active ($p<0.05$). For these reasons, these are also the workers with the highest levels of workplace absenteeism ($p<0.05$).

4. DISCUSSION

In the context of sustainable development, the composite indices are particularly important in the process of monitoring the implementation of the 17 SDGs, aims and scopes, previously contextualised in the introduction section of this text. The *WHRI* proposes to analyse the WH risk through the combination of interrelated variables that contribute to the final score to be assigned to each individual. A gap in the literature has been identified in the availability of indices that first conceive the WH, covering all its complexity and not facing it as an isolated dimension, and then make it possible to measure WH. This perspective addresses the need for a comprehensive and integrated approach in the WH field, as well as the implementation of health strategies directed towards the demands of each group and/or individual, as reported by Viterbo and collaborators (Viterbo, Dinis, Vidal, et al., 2019). One of the important highlights of this work is the lack of availability of composite indicators aligned with the SGDs. As confirmed in Table 1, many of the *WHRI* indicators are not covered by the UN indicators (45.5%), and in Brazil, only 2.3% of indicators are produced. The remaining *WHRI* indicators do not have Brazilian correspondence (72.7%) or do not have data (4.5%), and all the rest are under construction (20.5%). In this sense, *WHRI* can contribute as an aggregating index of several indicators aligned with the SGDs, helping in the instrumentation of the WH field in the Brazilian reality, almost without indicators that allow for the implementation and monitoring of the SDGs.

With a representative sample of the population, Figure 2 allows one to identify that 74.3% of the population is in the "Low" risk range, 20.6% in the "Moderate" risk range and 5.1% in the "High" risk range. These results are in accordance with the RPM from the Leeds Health Department (Department of Health, 2005), which stratifies the Brazilian population into three levels related to the need for health care, and defines that the span from 70-80% represents level 1 (people in simple conditions), that between 20-30% represents level 2 (people in complex conditions), and 1-5% represents level 3 (people in highly complex conditions), as reported by Mendes (E. V. Mendes, 2012). Figure 3 demonstrates the *WHRI*'s ability to optimise company resources by prioritising and targeting health care delivery according to individual and collective needs, as demonstrated by other studies, such as those of the Association of American Medical Colleges (LaPointe, 2018) and also by private institutions such as EY (EY, 2017).

Table 8 associates the distribution of the participants in the three risk groups with the socio-demographic characteristics of sex, age group and education level. In all situations, an association is identified, namely: male participants who are more likely to be in the "High" risk range (p<0.01), as well as individuals with more than 50 years of age ($p < 0.001$), as stated by Jousilahti and collaborators (Jousilahti et al., 1999), Regitz-zagrosek (Regitz-zagrosek, 2012), Niccoli and Partridge (Niccoli & Partridge, 2012), Dhingra and Vasan (Dhingra & Vasan, 2012) and Maurer (Maurer, 2003). In line with these results, an education level below the university degree is also a risk factor (p<0.01) (Hahn & Truman, 2015; Johnston, 2019; Vidal et al., 2018, 2019). Regarding this aspect, the *WHRI* makes a full and integrated diagnosis of the health condition of each individual and the community, enabling the construction of health education actions directed specifically to each audience and thereby increasing the effectiveness of prevention and promotion of health through knowledge of their own health condition.

In the high-risk range (Table 9) there are workers with worse levels in the critical indicators for their health, particularly those related to the medical field, such as glycemia, blood pressure and diabetes, which, when associated with sedentary lifestyles and consumption of harmful substances such as tobacco and alcohol, lead to the development of chronic conditions that severely affect their health and productivity at work, as already mentioned by Farhud (Farhud, 2015), Pontes (Pontes, 2015) Oliveira and collaborators (Oliveira, Vidal, & Ferraz, 2020) in previous studies. Severe periodontal conditions are also associated with the consumption of tobacco, alcohol, diabetes, and foods rich in sugar, as already identified by Braga and colleagues (Braga et al., 2009) and Llambés and colleagues (Llambés et al., 2015).

5. CONCLUSIONS

The importance of composite indices that make it possible to quantify a phenomenon of difficult measurement, such as WH, is visible in the efforts of several world organisations, as in the case of the UN with the publication of Agenda 2030. As a multidimensional phenomenon with different impacts in distinct quarters of life in society, the WH field implies a plural look at it through the combination of variables that positively and negatively interfere in health. The application of the *WHRI* in the WH context allowed for the validity of the *WHRI* in identifying the percentage of workers in the “low”, “moderate” and “high” defined risk ranges. The *WHRI*’s robustness is also visible in the ability to identify differences among workers’ sociodemographic characteristics ($p < 0.001$), helping to define health policies in the workplace that promote overall WH and also contribute to the increase of worker’s productivity and associated sustainable development. It was verified that the sex, age and education level influence the WH risk, being higher in men over 50 years old and with a low educational level ($p < 0.001$), as noted by the World Health Organization in several reports [30, 53]. The fact that 74% of workers are in the "low" risk range does not mean that they should be considered as free to develop disease, and consequently, it is crucial to monitor WH. This result is of fundamental importance for the oil industry studied, as oil production in old fields such as Bahia, Brazil is declining, leading to an economic scenario of business resource constraints. The application of a tool such as *WHRI* enables the definition of risk management strategies aimed at the better use of economic resources to match care resources in different situations.

From this work, it is important to focus on actions centred on promotion - "low-risk", prevention - "moderate-risk", and, above all, intervention - "high-risk", so that the work context, as a dominant dimension in the everyday life of individuals, may be assumed as an increasingly empowering space in terms of well-being and healthy lifestyles.

The *WHRI* is considered a reliable tool, being an innovation for the WH interdisciplinary approach in different labour contexts. Another important expected contribution of *WHRI* is the reduction of WH costs, considering that *WHRI* acts simultaneously in disease prevention and health maintenance, and for this reason, deepening the Return on Investment (ROI) calculation in future studies is recommended. Although *WHRI* is valid and reproducible, three main limitations must be considered: (i) the need to maintain an interdisciplinary team that is able to respond to the various dimensions of the index, (ii) the existence of minimal environmental and health monitoring and (iii) the need to increase and diversify the sample, namely in the sex and age dimensions, to allow a reliable and reproducible external validation. This methodology implies further studies, in other labour contexts, to verify that the proposed method is actually useful in disease prevention and health promotion within the work context.

WHRI can be applied to assess the risks of WH in other industries through periodic worker assessments that cover medicine, nursing, nutrition, dentistry and physical education in an interdisciplinary approach. This tool enables *WHRI* indicators to be addressed by healthcare professionals, automatically generating the worker health risk value for each worker, as well as generating information that relates results through graphs.

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