

# Whole body biomechanical burden of healthcare workers: Proposal for a complementary risk assessment and management tool (HOARA)

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**KEY WORDS:** WRMSDs; low back pain; risk assessment; risk management; whole body mechanical load

**PAROLE CHIAVE:** WRMSDs; lombalgia; valutazione del rischio; gestione del rischio; carico biomeccanico complessivo

## SUMMARY

**Introduction:** *We have developed a new tool, named Holistic Approach Risk Assessment (HOARA), to support occupational safety and health professionals (OSH) in risk assessment and management when evaluating the biomechanical load of healthcare workers.* **Objectives:** *The primary aim of the HOARA is to support OSH in risk assessment and management of biomechanical hazards in healthcare facilities. This tool ensures a superior level of analysis by targeting independently various body compartments during all activities completed throughout the work shift. These include: head, neck, back and upper and lower limbs.* **Methods:** *For each body segment, ergonomic determinants were defined on the basis of previous literature, according to which task and job analyses were performed. Upon direct observation, ergonomic factors were given a score based on their temporal extent. Subsequently, action-body segment raw indices and weighted indices were calculated.* **Results:** *Results of the application of the method are shown. Of note, a relational database was set up to improve its usability.* **Conclusions:** *From an occupational health perspective, the HOARA, integrated with other methods, is expected to allow a more effective management of human resources, especially when assigning workers to specific jobs or tasks. Overall, the HOARA will be instrumental in assessing the impact of fitness for work judgments on work organization and its resources, in compliance with the guidelines from the Società Italiana di Medicina del Lavoro (SIML).*

## RIASSUNTO

«Carico biomeccanico complessivo negli operatori sanitari: proposta di uno strumento integrativo di valutazione e gestione dei rischi (HOARA)». **Introduzione:** *Al fine di supportare i professionisti della sicurezza e della tutela della salute nei luoghi di lavoro nella valutazione e gestione del rischio è stato sviluppato nuovo strumento per la valutazione del carico biomeccanico complessivo negli operatori sanitari.* **Obiettivi:** *Lo strumento denominato HOARA (Holistic Approach Risk Assessment) è mirato alla valutazione del rischio del segmento capo / collo, rachide, arti superiori ed arti inferiori durante tutte le attività svolte nel turno di lavoro, con un livello di dettaglio superiore ad altri metodi.* **Metodi:** *Per ogni segmento corporeo sono stati individuati e graduati i principali determinanti ergonomici utilizzando come riferimento la più accreditata letteratura scientifica nazionale ed internazionale. Successiva-*

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mente sono state identificate le attività costituenti le mansioni e i compiti costituenti le singole attività. Ogni compito è stato analizzato mediante osservazione diretta alla ricerca della presenza/assenza dei determinanti ergonomici ed è stato assegnato un punteggio in base alla prevalenza nel singolo compito. I punteggi di rischio sono stati integrati nelle attività per dare origine ad indice ponderato (utile per graduare le singole prescrizioni/limitazioni lavorative e facilitare una ricollocazione dei lavoratori) ed infine in un indice di rischio complessivo per la mansione. **Risultati:** Sono riportati alcuni esempi di applicazione del metodo. Per facilitare l'usabilità dello strumento è stato creato un database relazionale. **Conclusioni:** Il metodo, integrato con altri metodi già pubblicati in letteratura, potrà consentire una gestione efficace delle risorse umane dal punto di vista della salute sul lavoro, facilitare il collocamento dei lavoratori nelle mansioni specifiche, e definire l'impatto delle idoneità lavorative sull'organizzazione del Lavoro applicando il concetto di compatibilità lavoro/uomo e uomo/lavoro come riportato nelle linee guida della Società Italiana di Medicina del Lavoro (SIML) sulla sorveglianza sanitaria.

## INTRODUCTION

Work-related musculoskeletal diseases (WRMSDs) comprise a wide range of inflammatory and degenerative conditions of the neck/shoulder, arm/wrist/hand, upper and lower back, knee, and ankle/foot. Despite not being exclusively caused by working activities, WRMSDs belong to the main category of all registered or compensable work-related diseases. According to the epidemiological data relative to 2017, in Italy WRMSDs accounted for 64.5% of all reported work-related illnesses, with a 47.1% increase since 2011 (19, 41).

WRMSDs are not just peculiar to a variety of industrial settings, but they are also frequently found in a number of healthcare settings, such as hospitals, nursing homes, emergency services, critical care, operating rooms, orthopedic units, and home healthcare environments (55), which, despite being visited by thousands of people on a daily basis, entail a variety of risks interfering with the constant need to ensure care services of the utmost quality and efficiency.

In this scenario, the lack of worker turnover and the rising mean age of the working population, associated with progressive degeneration of the musculoskeletal apparatus, have led to a substantial increase in the number of subjects suffering from WRMSDs requiring special needs (45). Unfortunately, the implementation of up-to-date standards and guidelines for risk assessment has failed to reduce the occurrence of WRMSDs, which have now instead become a common complaint among hospital healthcare staff. In particular, a study con-

ducted at the Center for Research on Health and Social Care Management (CERGAS) in Milan has shown WRMSDs to be the main cause of limited work ability in 19.7% of healthcare providers working at hospitals in the Piedmont region of Italy, with half of these WRMSD cases being related to manual handling of patients (10). Thus, Italian healthcare professionals have become one of the main causes of the rising number of fitness for work judgments with limitations or prescriptions, with potentially negative consequences on workplace organization and medical assistance quality. The presence of a high number of workers with limitations or prescriptions can in fact increase the risk of WRMSDs for subjects entirely fit to work.

In this context, the public administration, as well as private healthcare employers, has heavily invested in risk assessment strategies that could ameliorate current management guidelines for ergonomic working conditions. Despite the implementation of policies whose final goal is that of reducing the biomechanical load thanks to the introduction of operational techniques, auxiliary and minor aids, and targeted training, WRMSDs are fast becoming a major burden for the entire healthcare system. Since all efforts, for the most part, made by healthcare stakeholders have not led to the expected results, it has therefore become necessary to plan new medical and ergonomic strategies to address a number of related issue such as the integration of diseased workers, fitness for work judgments, design of work places and work organization and effective redistribution of resources, according to a more precise definition of the biomechanical load.

In light of the above, the current project was designed and developed using the Plan-Do-Check-Act (PDCA) cycle, with the involvement of health-care and occupational safety and health (OSH) professionals. The implementation of the project was made possible thanks to the collaboration among ergonomic and occupational medical staff, hospital and primary health care directorate (DIPSA) managers, employees, and workers' health and safety representatives (RLS), with the goal of overcoming the limitations of previous approaches.

Due to the multidisciplinary nature of the fields, two main branches were created, one medical and the other ergonomic, each with a specific goal. The ergonomic branch, herein described, is aimed to understand and codify the biomechanical load of healthcare workers, allowing:

- 1) OSH physicians to have detailed data to support their fitness for work judgments;
- 2) Environmental health and safety (EHS) managers to integrate risk assessment, currently based on generalist methods;
- 3) DIPSA managers to assess the impact of fitness for work judgments on work organization and its resources.

#### **GENERAL FRAMEWORK AND DEVELOPMENT OF A METHOD FOR WHOLE BODY BIOMECHANICAL LOAD RISK ASSESSMENT**

Assessing exposure to risks factors for WRMSDs is the first step in the management and prevention of such diseases. In this regard, even though practitioners would greatly benefit from the availability of fast, reliable, and easy-to-use methods assessing risk exposure to a wide range of hazards, the vast majority of the assessment techniques developed thus far have only partially met these requirements. In addition, while it is quite easy to identify and estimate a risk in a hospital setting where the mere presence of non-self-sufficient patients or the absence of adequate aids is itself indicative of risk exposure, it is more difficult to conduct a thorough and analytical risk assessment capable of considering all different hazards other than manual handling of patients able to guide preventive interventions. In this latter case, the simultaneous presence of multiple factors (e.g.

type of patient, care load and availability of nursing staff, facilities, logistics infrastructures and adequate equipment) and their interrelationships should be taken into account as well. Finally, the choice of the most appropriate risk assessment method has to consider its ability to verify and monitor the effectiveness of preventive measures in place (4, 15-18, 20, 23, 25, 27, 28, 32, 43, 49, 54). An exhaustive list of the advantages and disadvantages of risk estimation and risk evaluation methods from the literature can be found in paragraph A1 of the ISO Technical Report (24).

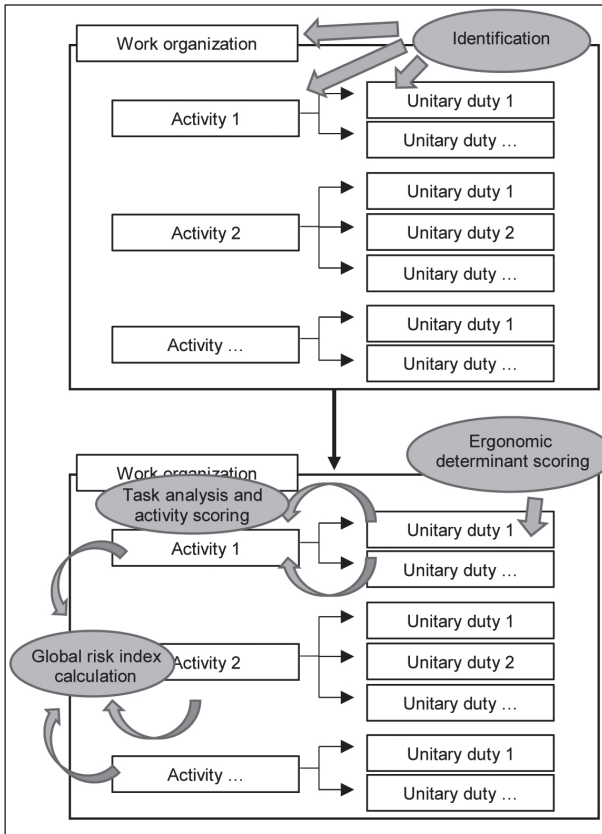
In this study, we have developed a new tool, named Holistic Approach Risk Assessment (HOARA), which can help define the whole body biomechanical load risk of health workers. This tool does not pretend to be alternative to other methods, but it should be considered as complementary to other instruments already in use for risk assessment and management of fitness for work judgments.

The HOARA method is structured in such a specific manner so as to provide the following output data (figure 1):

- 1) Identification of the overall organization of work including total shift duration, number of breaks, and perceived effort cadence;
- 2) Identification and description of activities;
- 3) Identification and description of unitary duties (UDs);
- 4) Job analysis and ergonomic determinant scoring at the UD level;
- 5) Task analysis and scoring of ergonomic determinants of specific activities;
- 6) Global risk index calculation.

Data collection follows a 5-step pattern: brainstorming, task analysis, job analysis, ergonomic qualification and quantification, and data synthesis for ergonomic job qualification. For clarity purposes, the glossary of the most relevant terms is listed below.

a) Perceived cadence: The perceived cadence represents an index of the operator commitment. It derives from the real observation during the job sampling of the times of non-biomechanical activity or interruption of this activity connected to the modalities of execution of the task in the specific context under examination. For instance, the activities carried out by two nurses working in very similar



**Figure 1** - HOARA whole body mechanical load assessment - Process flow

departments would provide the same risk index using traditional risk assessment methods. If however the different organizational/operational criteria (i.e. specific context) adopted in the two departments were to be considered, the analysis would result in different risk values. To measure the perceived cadence, the analyst classifies the observed situation into a discrete category based on minutes of non-biomechanical activity (table 1). This procedure is similar to the one used in time-method techniques. Since it relies on the analyst's experience, the value is defined as "perceived" instead of "measured". The survey is in fact carried out by sampling on the basis of which work shift dynamics are reconstructed. The observed biomechanical non-commitment times are however checked with the operators to reduce the likelihood of observer error. The duration of the entire work shift is classified according to the criteria indicated in table 1, and the average value of the range is defined as the "A" value;

**Table 1.** Perceived cadence ranges related to the whole work shift

Category	Range	"A" value
Quiet pace	>90 min	100
Modular pace	70-90 min	80
Manageable pace	50-70 min	60
Binding pace	30-50 min	40
Pressing pace	10-30 min	20
Burdensome pace	< 10 min	0

b) Activity: The task analysis (TA) is the methodology used to identify, within a task, the activities and, within them, the UD. In other words, activity is defined as a set of coherent activities, identifiable within a job. These activities are homogeneous aggregations of the tasks carried out within the work shift. The tasks must be aggregated in such a way that the identification of the activity is immediately recognizable;

c) Unitary duties: UD are those tasks that, as a whole, constitute the activities. That is to say that UD are the elementary units that constitute each single activity.

### Overall work organization

The HOARA method consists in recording the total shift duration, official breaks, and additional recovery periods. Once the data are collected with the help of healthcare and OSH professionals, the method calculates the effective working duration, given by the difference between total shift duration, the official recovery periods, intended as breaks, and additional recovery periods derived from the perceived cadence. The perceived cadence is divided into 6 categories according to whether it has a quiet, modular, manageable, binding, pressing, or burdensome pace, leading progressively to a decrease in additional recovery. The effective working time is calculated with the following formula:

$$TLeff = DT - R - A \quad (1)$$

where:

TLeff: Actual working time (min)

DT: Duration of the shift (min)

R: Recovery (min)

A: Perceived cadence (min)



Saturation is defined as the ratio between the actual working time and the duration of the entire shift according to the following formula:

$$\text{SatLeff} (\%) = \text{TLeff} / \text{DT} * 100 \quad (2)$$

where:

SatLeff (%): Saturation

TLeff: Actual working time (min)

DT: Duration of the shift (min)

The longer the pause, the lower the SatLeff (%), the shorter the pause, the greater the SatLeff (%).

The results of risk assessment performed with standardized methods, i.e. methods proposed by standard ISO 11228 (part 1-3) (20, 21, 22) and ISO-TR 12296 (24), are provided to the analyst by the EHS manager and recorded in the HOARA method. The final report of the analysis shows in an integral way the indexes calculated with the other methods together with the indexes calculated with the HOARA. The integrated reading of the results, knowing the advantages and disadvantages of the different methods, provides the professional with an integrated view of the risk. Since the results of this analysis allow assessing the risk under different perspectives, they represent an essential precondition of the HOARA method.

### Activity identification and description

Activity means a set of coherent activities, aimed at the same operational objective, clearly identifiable within the job. This identification process is carried out by the coordinator and three or more experi-

enced workers through a brainstorming approach. Based on the brainstorming data, the coordinator assisted by the ergonomic and medical staff identifies a maximum of 10 activities. Besides identifying activities, this step also consists in writing down the number of operators present at the moment of the analysis and all available operators.

### Unitary duty identification and description

It is then necessary to identify the UD's within each activity previously identified (i.e. the elementary units that constitute each single activity) through job analysis. For the purposes of the HOARA method, it was chosen a job analysis based on task-time-determining matrix.

### Job analysis and ergonomic determinant scoring at unitary duty level

For each UD, the ergonomist and/or the occupational physician evaluate the presence and duration of the established ergonomic determinants. The qualification of UD's began by selecting ergonomic determinants among those proposed by ISO, CEN, and UNI regulations and those reported in the literature (20, 23, 26, 30, 36, 38, 40, 42, 44, 48, 50, 52). The selected determinants were chosen by an ergonomic specialist panel that defined a provisional list of ergonomic factors.

Composite determinants, specifically designed to take in consideration awkward positions and simultaneous use of force by integrating the Borg scale, were then added (table 2).

**Table 2.** Ergonomic determinants

Body segment	Ergonomic determinant
Head/Neck	Head/Neck flexion >10°; Head/Neck rotation >10°
Trunk	Trunk flexion 20-60° with Borg scale score ≤ 3; trunk flexion >60° with Borg scale score ≤ 3; trunk flexion 20-60° with Borg scale score > 4; trunk flexion over 60° with Borg scale score > 4; rotation >10°
Upper limbs	Forward extension >60°; weight statically sustained > 3 kg; >10 kg and >15 kg
Lower limbs	Kneeling with erect trunk; kneeling with a forward flexed trunk
Patient movement	Patient movement over short distances using force Borg ≤ 3, patient movement over short distances using force Borg >4 patient movement over long distances using force Borg ≤ 3, patient movement over long distances using force Borg >4

The difference between "long" and "short" distances is given by structural factors, that is the sum of the length of a wardroom, the length of the ward and the distance to the first available lift, with short distances being less than 70 m and long distances exceeding 70 m

**Table 3.** Ergonomic determinant scoring

Time	Posture and posture-force binomial score			
	Very low	Low	Medium	High
No	0	0	0	0
Up to 10%	0.5	1	1.8	2.6
11-30%	1	2	3.6	5.2
31-50%	1.5	3	5.3	7.7
Over 50%	2	4	7	10.2

In the medium category there is a use of force with a score of Borg between 1 and 3, whereas in the high category there is a use of force with a Borg score >4. The very low category is used to score head/neck body segment (CF, CR) and AIG

Each determinant is supposed to assume a numeric value as it follows: 0 (zero) if absent; 1 if maintained for less than 10% of the duration of the UD; 2 if maintained for a total duration of 11% to 30%; 3 if maintained from 31% up to 50% of the duration of the UD; and 4 if maintained for more than 50%. Depending on the anatomic district considered and the presence of ergonomic composite determinants, it was decided to attribute graduate scores as indicated in table 3.

For each UD, a raw risk score of the individual body district is calculated as follows:

$$\text{Head/Neck UD Raw Risk} = \text{CF score} + \text{CR score} \quad (3)$$

$$\text{Trunk UD Raw Risk} = (\text{TFL score} + \text{TFH score}) / 2 + (\text{THFL score} + \text{THFH score}) / 2 + \text{TR} \quad (4)$$

$$\text{Upper Limbs UD Raw Risk} = \text{AE} + (\text{AEPL} + \text{AEPM} + \text{AEPH}) / 3 \quad (5)$$

$$\text{Lower limbs UD Raw Risk} = \text{AIG} + \text{AIGF} \quad (6)$$

$$\text{Patient Movement UD Raw Risk} = (\text{MMBL} + \text{MMBH}) / 2 + (\text{MLBL} + \text{MLBH}) / 2 \quad (7)$$

where:

CF: Head/Neck flexion > 10°

CR: Head/Neck rotation > 10°

TFL: trunk flexion 20-60° using force Borg <=3

TFH: trunk flexion 20-60° using force Borg >=4

THFL: Trunk flexion >60° using force Borg <=3

THFH: Trunk flexion >60° using force Borg >=4

TR: Trunk rotation >10°

AE: Upper limbs with a frontal extension greater than 60°

AEPL: The upper limbs statically support a weight greater than 3 kg, but less than 10 kg

**Table 4.** Prevalence correction factor introduced at UD level

Prevalence	% of the UD in the Activity	Correction Factor
Low	<10%	1
Medium	10%-33%	1.6
High	>33%	2.2

AEPM: The upper limbs statically support a weight above 10 kg, but less than 15 kg

AEPH: The upper limbs statically support a weight above 15 kg

AIG: Kneeling position with erect trunk

AIGF: Kneeling position with trunk flexed forward

MMBL: Patient movement over a short distance using force Borg <= 3

MMBH: Patient movement over a short distance using force Borg >= 4

MLBL: Patient movement over a long distance using force Borg <= 3

MLBH: Patient movement over a long distance using force Borg >= 4

A UD that is carried out for the most part within a high-risk activity together with other UDs performed in the context of a low-risk activity would result in a progressive dilution of the risk. For this reason, we decided to adopt a “prevalence of the UD” correction factor graduated on three levels (table 4), which assigns a higher weight to the most represented UD and a lower weight to the least represented one.

For each UD, a weighted risk score for single body segment is calculated as follows:

$$\text{Weighted UD Risk Head/Neck} = [\text{Prevalence}] * [\text{Head/Neck UD Raw Risk}] \quad (8)$$

$$\text{Weighted UD risk district Trunk} = [\text{Prevalence}] * [\text{Trunk UD Raw Risk}] \quad (9)$$

$$\text{Weighted UD risk index Upper Limbs} = [\text{Prevalence}] * [\text{Upper Limbs UD Raw Risk}] \quad (10)$$

$$\text{Weighted UD risk index Lower Limbs} = [\text{Prevalence}] * [\text{Lower limbs UD Raw Risk}] \quad (11)$$

$$\text{Weighted UD Risk Index Patient Movement} = [\text{Prevalence}] * [\text{Patient Movement UD Raw Risk}] \quad (12)$$

### Task analysis and scoring for activity specific ergonomic determinants

The task analysis (29) pertains to the scoring of single activities. The raw activity risk score consisting of N-UDs per single district is defined by the average of individual district-based weighted UD indexes, using the following formula:

$$IRGAd = (\Sigma (IRPCd n)) / N \quad (13)$$

where

IRGAd: Raw activity risk index for the district under review

IRPCd: Weighted unitary duty risk Index for the body segment under consideration

N: number of unitary duties

The ensuing risk index for the underlying activity has to be deemed crude because it has not yet been weighted for the percentage of time in which the activity is performed during the shift. The percentage (%) of the single activity during the work shift is given by the following formula:

$$\text{Individual activity duration (\%)} = DA / DT * 100 \quad (14)$$

where:

DA: Duration of activity (min)

DT: Duration of shift (min)

The sum of the percentage durations of each single activity must be SatLEff (%).

Given this, the weighted activity indexes are calculated as follows:

$$\text{Weighted activity risk Head/Neck} = [\text{Single Activity Duration (\%)} / 100] * [\text{Raw activity index Head/Neck}] \quad (15)$$

$$\text{Weighted activity risk Trunk} = [\text{Single Activity Duration (\%)} / 100] * [\text{Raw activity index Trunk}] \quad (16)$$

$$\text{Weighted activity risk Upper limbs} = [\text{Single Activity Duration (\%)} / 100] * [\text{Raw activity index Upper limbs}] \quad (17)$$

$$\text{Weighted activity Lower Limbs} = [\text{Single Activity Duration (\%)} / 100] * [\text{Raw activity index Lower Limbs}] \quad (18)$$

$$\text{Weighted activity Patient Movement} = [\text{Single Activity Duration (\%)} / 100] * [\text{Raw activity index Patient Movement}] \quad (19)$$

### Global risk index calculation

The final risk index for the individual districts considered is thus given by:

$$IRMd = \Sigma (IRPAd n) \quad (20)$$

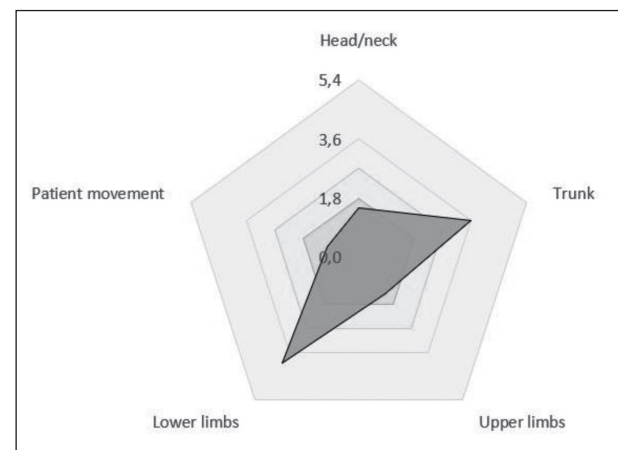
where:

IRMd: Job risk index for the specific body segment

IRPAd: Weighted activity risk index for the considered district

The synoptic representation of the indices of the individual body segments adds a direct knowledge of the loads on the whole body and of the ergonomic intervention priorities, as shown in figure 2.

The method provides for grading scores derived from the formulas given in the previous paragraphs according to a semaphorical logic (i.e. green, yellow, and red), in accordance with Directive 98/37/EU. It is therefore possible to define the following HOARA index classification criteria and to indicate the consequent preventive actions (table 5).



**Figure 2** - HOARA synoptic representation of the indices of the individual body segments

**Table 5.** HOARA value classification criteria and consequences

HOARA values	Area, risk level and consequences
< 1,8	Green – Acceptable Low risk, indicating that most employees are at a low risk of developing MSDs
1,8 ≤ x ≤ 2,7	Yellow - Not recommended Moderate risk, meaning that certain individuals are at increased risk of developing MSDs. It is advisable to set up improvements with regard to structural risk factors or to suggest other organizational and educational measures. Further evaluation is required, and adequate measures have to be taken if necessary.
> 2,7	Red – Unacceptable/ To be avoided Elevated risk, indicating that many employees are at increased risk of developing MSDs, and that improvement measures should be completed as soon as possible

### Example of use

In this chapter, two application examples are provided.

Example 1: In an internal medicine department, we conducted an evaluation of a social healthcare professional (OSS) with the following work organization: 480 min morning shift, 45 min break, manageable rhythm (50-70 min, average given 60 min) and 3 assigned workers.

#### A1. Overall work organization

$$T_{\text{Leff}} = 480 - 45 - 60 = 375 \text{ min}$$

$$\text{SatLeff} (\%) = 375 / 480 * 100 = 78.1\%$$

#### B1. Activity identification and description

Three activities were identified in the job: meal distribution, hospital linen and laundry management, and inpatient unit management, lasting 100, 50, and 225 min, respectively.

#### C1. UD identification and description

Within the meal distribution activity, three UDs were identified: 1) meal cart delivery, 2) meal distribution, and 3) food tray pick-up. As for the hospital linen and laundry management, two UDs were identified: 1) clean linen collection and storage and 2) dirty linen sorting and disposal. Concerning the inpatient unit management activity, three UDs were identified: 1) occupied bed making, 2) personal linen change and 3) diaper change.

#### D1. Job analysis

Activity No.1 - Meal distribution - Ergonomic determinant scoring at unitary duty level.

Unitary Duty	Prev	Head/ Neck		Trunk					Upper limbs				Lower limbs		Patient movement				RH	RT	RU	RL	RM	
		CF	CR	TF L	TF H	TF HL	TH FH	TR	AE	AE PL	AE PM	AE PH	AI G	AI GF	MM BL	MM BH	ML BL	ML BH						
1	1	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	1	0.7	0	0
2	1,6	0.5	0.5	2	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0	1.6	3.2	3.7	0	0
3	1,6	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	4.8	0	0



Activity No. 2 - Hospital linen and laundry management - Ergonomic determinant scoring at UD level.

Unitary Duty	Prev	Head/Neck		Trunk					Upper limbs				Lower limbs		Patient movement				RH	RT	RU	RL	RM	
		CF	CR	TF L	TF H	TF HL	TH FH	TR	AE	AE PL	AE PM	AE PH	AI G	AI GF	MM BL	MM BH	ML BL	ML BH						
1	2.2	0	0	0	3.6	0	0	2	3	2	0	0	0	1.8	0	0	0	0	0	0	8.4	8.1	4	0
2	1	0	0	0	0	0	0	1	0	0	1.8	0	0	0	0	0	0	0	0	0	1	0.6	0	0

Activity No. 3 - Inpatient unit management - Ergonomic determinant scoring at UD level.

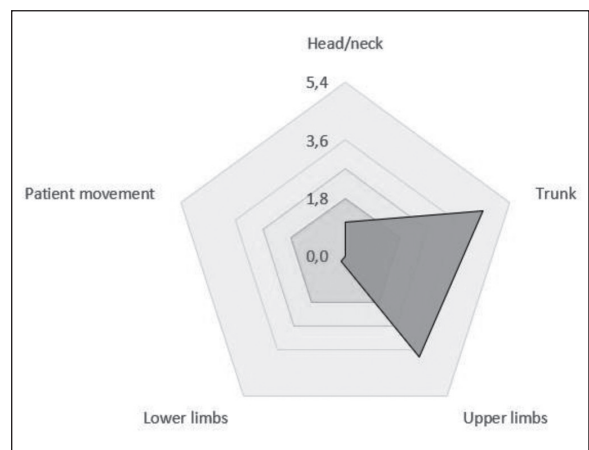
Unitary Duty	Prev	Head/Neck		Trunk					Upper limbs				Lower limbs		Patient movement				RH	RT	RU	RL	RM		
		CF	CR	TF L	TF H	TF HL	TH FH	TR	AE	AE PL	AE PM	AE PH	AI G	AI GF	MM BL	MM BH	ML BL	ML BH							
1	2.2	1	1	0	0	0	10.2	3	4	0	5.3	0	0	0	0	0	0	0	0	0	4.4	17.8	12.7	0	0
2	1	1	0	0	0	5.3	0	1	3	0	0	0	0	0	0	0	0	0	0	0	1	3.7	3	0	0
3	1	0.5	0	3	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0.5	2.5	2	0	0

Raw activity risk indexes for single body segments.

Activity	Head/Neck	Trunk	UL	LL	Patient movement
1	0.53	1.4	3.1	0	0
2	0	4.7	4.3	2	0
3	1.96	8	5.9	0	0

Weighted activity risk considering the percentage of time in which the activity is performed in the shift and job risk index for the specific body segment.

Activity	Duration	%	Head/Neck	Trunk	UL	LL	Patient movement
1	100	20.8	0.1	0.3	0.6	0	0
2	50	10.4	0	0.5	0.5	0.2	0
3	225	46.9	0.9	3.7	2.8	0	0
JOB			1.0	4.5	3.9	0.2	0





Activity No. 4 - Patient observation - Ergonomic determinant scoring at UD level.

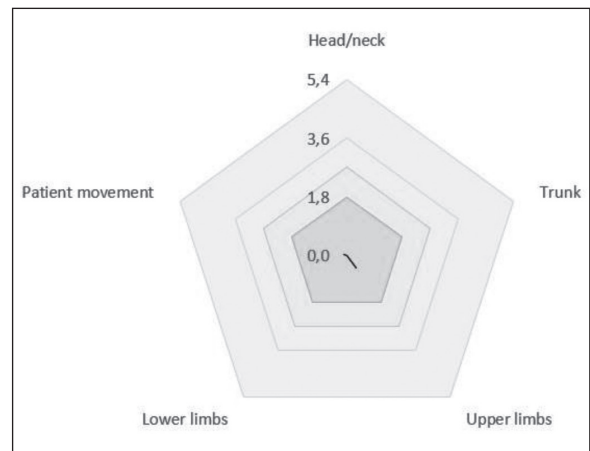
Unit Duty	Prev	Head/Neck		Trunk					Upper limbs				Low limbs		Patient movement				RH	RT	RU	RL	RM												
		CF	CR	TF L	TF H	TF HL	TH FH	TR	AE	AE PL	AE PM	AE PH	AI G	AI GF	MM BL	MM BH	ML BL	ML BH																	
1	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Raw activity risk indexes for single body segments.

Activity	Head/Neck	Trunk	UL	LL	Patient Movement
1	0	0	0	0	2.2
2	0	0.8	0	0	0
3	0	0	3.2	0	0
4	0	0	0	0	0

Weighted activity risk considering the percentage of time in which the activity is performed in the shift and job risk index for the specific body segment.

Activity	Duration	%	Head/Neck	Trunk	UL	LL	Patient movement
1	25	5.6	0	0	0	0	0,1
2	25	5.6	0	0	0	0	0
3	70	15.6	0	0	0.5	0	0
4	240	53.3	0	0	0	0	0
JOB			0	0	0.5	0	0.1



DISCUSSION

In summary, this study describes a complementary method for the assessment of the biomechanical load of healthcare workers integrated in a wider framework consisting of two main management system branches (i.e. medical and ergonomic) involving various healthcare and OSH professionals and taking advantage of the collaboration of the ergonomic staff with DIPSA and HSE managers

as well as with hospital employees and the Workers' Health and Safety Representative (RLS) in the attempt to overcome the limitations of previous approaches regarding the efficient protection of workers with special needs.

As stated in the ISO Technical Report 12296 (24), one of the most important determinants of efficient patient handling intervention is a comprehensive and multi-factorial approach. The introduction of complex flows requires dynamic managerial

processes and efficient organizational frameworks instrumental in reducing the risk associated with patient handling activities. The development of a positive safety culture is also needed as it shows a good correlation with the processes aimed at managing the effects of WRMSDs on healthcare organizations.

As risk assessment is one of the main pillars of preventive strategies, in the absence of a reliable predictive risk assessment, it is quite difficult to devise an effective strategy of risk management.

Given that the use of consolidated methods applicable to manual handling of objects (57) for patient handling is difficult and usually unfeasible (46), many authors have proposed that an accurate analytical risk assessment, including data collection for consequent preventive measures, should consider the presence of several factors and their interrelationship such as: type of patient; induced "care load"; available caregiver staff; available and adequate equipment; building; environment and workspace; and training and skills of nursing staff (13, 16, 31, 32, 36, 40, 48, 53, 56).

A number of risk assessment methods have been published in the literature, from the simplest one to the most complex. According to the Società Italiana di Medicina del Lavoro (SIML) classification, those methods that simultaneously evaluate and integrate risk-related determinants are classified as "multi-dimensional". They collect data through interviews with staff and cognitive inspections in the workplace or by means of direct observation of handling activities. On the other hand, other methods, defined as "sectorial", focus on the measurement of parameters directly or indirectly related to the biomechanical load (i.e. physical, psychophysical, and physiological), and thus require high-precision measures more commonly used in basic research settings.

The ISO Technical Report 12296 (24) lists several methods (12) useful for the purposes of risk estimation or evaluation, which have been derived from the literature and relevant national or international guidelines. Some of them, such as OWAS (27) and REBA (17), focusing on determinants such as body posture, force, and frequency, can be applied to nearly all working tasks and healthcare sectors. By contrast, other methods, such as MAPO (4, 37),

which examine determinants like work organization, average frequency of handling, type of patients, equipment, environment, and education and training of care givers, are definitely more complete and aimed at specific sectors (e.g. healthcare).

All the aforementioned methods allow the analyst to take a snapshot of the risk under different perspectives. However, since only a few of these methods have been validated (5), none of them can be considered gold standard of risk assessment being capable to show the entire picture (8, 55). Indeed, these methods aim to quantify the risk of the entire work shift on the basis of qualitative data related to the manual handling of patients. The ensuing intrinsic variability hampers the effectiveness of each single method. While these methods have proven to be particularly useful in identifying risk/problems that can lead to the implementation of focused risk reduction measures by combining improvements to different risk factors, they lack in effectiveness when their main objective is that of improving the management of human resources in terms of occupational health, guiding the positioning of a worker in a specific job, or assessing the impact of fitness for work judgments on the work organization and its resources (7, 11, 38).

To overcome these problems, here we propose a new ergonomic evaluation method, that moves from well-accepted ergonomic principles and offers an appropriate detail for the intended purposes. Since there is no single method able to study all the different situations, this ergonomic method valorizes the results of other risk assessment methods such as MAPO. It is understood that if any of the applied methods have an index in the red area, the causes of this critical condition must be corrected irrespective of the application of the HOARA method.

As previously mentioned, the level of detail achieved by the HOARA method is not just limited to the identification and evaluation of the "job" as a whole, but it also reaches a much deeper detail level, being able to examine the "activities" that are the building blocks of the job, that is a set of coherent activities aimed at the same operational objective identifiable within that job. Importantly, the HOARA method also takes into account the UDs, which are the building blocks of the activities.

With regard to the task analysis, the choice of an official and standardized approach to study job descriptions would not have been specific enough for the purpose of our study. Thus, we have chosen instead an ergonomic brainstorming approach that was made possible thanks to the help of several healthcare professionals, as shown previously by others (34). In this regard, the integrated collaboration between healthcare professionals (e.g. coordinators, skilled workers and expert analysts) appears to be the strength of our analysis if this is carried out in a highly effective and well-organized system. If the analysis is instead performed in a poorly organized system characterized by scarce collaboration among caregivers, it becomes a weakness, but at the same time it can offer an opportunity for improvement.

The work sampling could have been done according to different protocols: observational work sampling; observational work sampling with video recording; observational work analysis based on a task-time-determining matrix. However, for the purposes of the HOARA method and given the cost-benefits of the aforementioned methods, we decided to adopt a job analysis based on a task-time-determining matrix.

An analysis extending to activities and UD is crucial to assess more complex ergonomic risk activities that are not structured in a linear manner or not well documented. In this regard, it is essential to adopt a much more holistic approach able to encompass each single task related to patient assistance, thereby extending the evaluation to the entire health care work. Such analysis would also allow to better assess the additional risk weighing on "healthy" workers when lighter activities, which would normally be equally shared among healthcare workers, are assigned to subjects with disabilities.

According to the literature, ergonomic exposure assessment methods should be based on three dimensions (9):

- 1) frequency/repetitiveness of shifts between force intensity;
- 2) time required for performing physical activity;
- 3) level/intensity of the force.

The HOARA method encompasses all of the aforementioned dimensions, the first two thanks to its intrinsic characteristics, and third one due to the

fact that it integrates the Borg scale in the composite determinants, thus allowing the gathering of force level data during various static or dynamic tasks.

Another distinctive feature from current methods is that the HOARA method does not focus exclusively on a single anatomic district but on the whole body according to holistic principles. In this regard, the first attempt to apply a holistic approach to workers subjected to biomechanical load dates back to over 15 years ago, with the REBA method devised by Hignett *et al.* (17). Briefly, this method was based on the assumption that addressing the biomechanical load on the entire musculoskeletal system would ameliorate the effectiveness of preventive interventions with respect to those obtained with methods assessing just one single functional compartment.

In accordance with several other models, our scoring system of the majority of the ergonomic determinants was built according to previously published criteria (2, 14, 47, 51), with only few determinants (e.g. UD prevalence) being customized for the purposes of this study. However, it is worth pointing out that one important limitation of all these scoring systems, including ours, is that they have yet to be validated, a delay that is probably due to the lack of standardized validation protocols aimed to assess the relationship between the results of the evaluation and the onset of musculoskeletal pathologies (i.e. exposure/effect or dose/effect relationship).

According to the HOARA method, the scoring of UD biomechanical risk factors is performed through direct observation, which requires much less time in comparison with other scoring systems. This time-saving approach has therefore the advantage of allowing a more thorough evaluation of all the operative scenarios present in the hospital and the activation of a systematic follow-up that constantly updates the process of identification and corrections of critical issues within the organization. Obviously, this approach would strongly benefit from the implementation of analyst training programs aimed to minimize detection errors and intra-observer variability (3, 12, 35, 39).

Another important aspect that needs to be taken into account is that the HOARA method for the assessment of the biomechanical load of healthcare



workers is not only aimed to appraise manual handling of patients, but it is also extremely useful in evaluating the fundamental measurement according to the international standards *vs* the parameters included in the proposed method.

When assessing the risk of patient manual handling, the presence of the following factors and their interrelationships should be taken into account: 1) amount of handling (i.e. number and type of patient transfers); 2) type of handling; 3) work organization; 4) posture and force exertion; 5) assistive devices; 6) environment; and 7) individual characteristics and training.

The amount of handling was not included extensively in the present assessment because reliable data regarding this activity are extremely difficult to standardize in hospital sectors experiencing extreme patient admission variability. On the other hand, these data can be easily standardized in other sectors with fewer hospital admissions (e.g. Spinal Injury Departments). Thus, in the present assessment, we decided to calculate the amount of handling indirectly by taking into account the prevalence of the specific manual handling UD for each specific activity and the duration of such activity, expressed as % of time, during the work shift.

The type of handling is defined by the task to be performed and by the handling technique applied for task execution. Once again, this factor can be derived indirectly by estimating posture and force. The same goes for environment and assistive device with an additional note. The proposed method includes the recording of risk evaluation methods indexes, such as MAPO, that include data on environment and assistive devices and are used for comparative evaluation.

Work organization data, graduation of posture and force, and temporal presentation of UDs and activities are the key factors of the present method, whereas no data are recorded on individual characteristics and training.

Commonly used risk assessment methods are supposed to classify the risk according to the three-zone model (i.e. green, yellow, and red) and address all actions to be taken in that regard (20–23). Our proposed method meets all these requirements as the estimated risk falls in any of the three afore-

mentioned zones, with the ergonomic risk being expressed as “average” and “peak values”.

Overall, the present method for the assessment of the biomechanical load of healthcare workers fulfills almost all the basic considerations in establishing a measurement strategy for WRMSDs:

- 1) Etiological relevance: whole body segmentary posture and force evaluation;
- 2) Exposure dimensions: it considers level, duration, and frequency;
- 3) Technique and devices: no costly devices are required, and the protocol is easy-to-use—for usability purposes a relational database was developed;
- 4) Flexibility: it is a flexible assessment because it can be applied on single subjects or groups;
- 5) Workplace and sampling conditions: sampling procedures include a brief interview and direct observation, without workforce disruption. Moreover, it can be based on a multistep pattern, fractioned observation of the working shift, or whole shift observation at one point in time;
- 6) Temporal variation: the assessment can be performed whenever needed.

Preliminary results (see “example of use” section) seem to indicate that the HOARA method is an easy-to-use assessment tool. To ease the implementation process, we have developed a specific software that simplifies some difficult steps such as the uploading of ergonomic determinant data weighted by the percentage of time during which these factors occur and the execution of the calculations. The preliminary results have also shown a high concordance between the HOARA risk index and the recommendations of a panel of ergonomist using a walk-through methodology for biomechanical overload risk factor inspection. No association study has been yet carried out between methods (e.g. HOARA *vs* MAPO) since these methods, as previously stated, assess complementary perspectives. Studies to evaluate inter- and intraobserver variability are ongoing. However, as reported in literature, empirical data suggest that reliability and variability are highly dependent on the training and expertise of the analyst.

Regardless of variability, some items might need few refinements in future studies such as the grading

system or the add-on of potential relevant factors. Some limitation of the study, such as the absence of the evaluation of psychosocial factors, the indirect evaluation of some aspects, the dependence on other methods when dealing with ward characteristics (e.g. number of beds for inpatients, ratio of staff to inpatients, and mean dependence level of residents) (40), and the characteristics of the workers, will be evaluated in follow-up studies.

## CONCLUSIONS

We have developed a complementary method, termed HOARA, for the assessment of the biomechanical load of healthcare workers as a part of a wider framework involving the creation of two main management system branches (i.e. medical and ergonomic) thanks to the participation of various healthcare and OSH professionals.

The development of this framework arose from the need to manage and provide better solutions to the widespread burden of WMSDs in healthcare workers exposed to manual handling risk factors. This framework thus required an integrated collaboration among several healthcare professionals, such as coordinators, expert analysts, and skilled workers, and was designed to facilitate the improvement of measures concerning health risks of the workers and to facilitate an effective management of human resources from an occupational health point of view. More specifically, the HOARA method allows scaling the biomechanical load for each body district with a variable level of detail, ranging from the job to the activity and deeper down to the UD.

The division into risk areas makes it possible to express fitness to work judgments with respect to the individual activities or, if a level of greater detail is needed, with respect to the elementary tasks, which allows the worker to be recruited in the same job previously redesigned according to the results of the applied method. This approach is consistent with the concept of “work/worker and worker/work compatibility” reported in the Medical Surveillance guidelines recently published by the Società Italiana di Medicina del Lavoro (SIML) (1). Moreover, being a dynamic tool, it enables to evaluate the biomechanical load trend by varying the organizational condi-

tions (e.g. the number of workers assigned to the overall formulated fitness) and to indicate the single situations requiring technical or organizational improvements. Lastly, our assessment tool allows the evaluation of the biomechanical load of healthcare professionals belonging to the same department or hospital sector at both the individual and group level.

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