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Risk assessment of cheese processing tasks using the Strain Index and OCRA Checklist

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Abstract

The purpose of this study was to conduct and compare two ergonomic risk assessment methods often used in occupational health research and practice: the Strain Index (SI) and Occupational Repetitive Actions (OCRA) Checklist. Seven raters used the SI and OCRA Checklist to assess task-level physical exposures to the upper extremity of workers performing 21 cheese-manufacturing tasks. Of the total task exposures assessed with both methods, nearly half (49.1%) were classified as hazardous using the OCRA Checklist while 60.2% were classified as hazardous using the SI. Although the underlying injury risk characterization constructs of the SI and OCRA Checklist differ, the results indicated that the SI and OCRA Checklist often classified job tasks into similar risk categories. The differences in risk classifications determined by the SI and OCRA Checklist for job tasks were likely related to the definition of variables measured by these assessment methods as well as the complexity of tasks evaluated. By design, the SI is specific to the distal upper extremity while the OCRA Checklist accounts for the entire upper extremity including the shoulder. When conducting risk assessments of industrial work tasks, the choice of analysis tools should be based on the purpose of the assessment and the complexity of task functions. Both the SI and OCRA Checklist yield risk assessment ratings that are similar for cheese processing tasks.

Keywords

Ergonomics; Physical exposure assessment; Semi-quantitative methods; Methodological reliability

1. Introduction

The choice of ergonomic assessment tools requires the analyst to consider the purpose of the assessment, the level of assessment detail desired, the relevance of the assessment model to the exposures, available resources and the practicality of assessment application (Li and Buckle, 1999, David, 2005, Takala et al., 2010). At times, analysts may opt to use multiple tools to assess the same physical exposures at the job site. The results derived from the use of multiple ergonomic risk assessment tools can enhance risk priority mapping and highlight common factors of exposure when the risk-level obtained with a single tool is unclear. Previous studies have compared the results of multiple semi-quantitative and observational ergonomic assessments tools (Drinkaus et al., 2003, Apostoli et al., 2004, Bao,

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2004, Jones and Kumar, 2007, Jones and Kumar, 2010, Spielholz et al., 2008, Joseph et al., 2011, Chiasson et al., 2012). In general, the agreement in results between Strain Index (SI) and Occupational Repetitive Actions (OCRA) methods has ranged from moderate to good (Apostoli et al., 2004, Jones and Kumar, 2007, Jones and Kumar, 2010, Chiasson et al., 2012). Previous studies, however, have either evaluated a limited number of tasks (Apostoli et al., 2004, Jones and Kumar, 2010), or a single individual or team assessed each task only once (Apostoli et al., 2004, Jones and Kumar, 2010, Chiasson et al., 2012).

Nearly 40% of occupational health researchers and ergonomics practitioners in the United States (US) report using the SI (Moore and Garg, 1995) to assess job physical exposures associated with increased risk of distal upper extremity (UE) musculoskeletal disorders (MSDs) (Dempsey et al., 2005). Longitudinal studies have demonstrated that the SI is a useful measure of physical risk exposure to multiple UE health outcomes (Garg et al., 2012, Garg et al., 2013, Gerr et al., 2013, Kapellusch et al., 2013). And the authors of a six-study research consortium studying UE MSDs recommended that future epidemiologic investigations collect job exposure data based on the SI model (Kapellusch et al., 2014).

The OCRA method (Occhipinti, 1998, Colombini et al., 2002) is an UE exposure assessment tool used by ergonomics researchers and practitioners globally. The International Organization for Standardization standard 11228–3 and the European Standard 1005–5 recommend that practitioners use the OCRA method to evaluate UE MSD risk exposure during repetitive work (Occhipinti and Colombini, 2012). Compared to the SI, the OCRA method appears a less popular tool among US ergonomists given the lack of reference to its application (Dempsey et al., 2005, Garg and Kapellusch, 2011). However, the OCRA method may provide users with the most comprehensive exposure model of any UE MSD tool (Takala et al., 2010, Chiasson et al., 2012), making it a valuable component of an ergonomics assessment toolkit. Both the SI and OCRA Checklist were found to have good and excellent inter-rater reliability, respectively (Paulsen et al., 2015).

The purpose of the present study was to conduct and compare the risk assessments of cheese processing tasks utilizing the SI and OCRA Checklist. Both assessment tools are commonly used in occupational health research and practice. The results are expected to assist occupational health researchers and practitioners select the UE risk assessment tools that best fit their respective needs.

2. Methods

2.1. Procedures

The experimental methodology used in the present study was previously described in detail by Paulsen et al. (2015), which evaluated the inter-rater reliability of the SI and OCRA assessment methods. The study site was a Pecorino Romano manufacturing facility in Sardinia, Italy (Fig. 1). Twenty-one job tasks that represented stages of cheese production and packaging for 25 and 35-kilogram wheels of cheese were recorded on digital video. Of the 21 job tasks, ten tasks were essentially identical in terms of physical requirements and limb functions of the right and left upper extremities (Fig. 2). Thus, for those ten job tasks, raters only assessed one (dominant) extremity. For the other 11 asymmetric tasks in which the two upper limbs performed different task functions, each rater assessed both extremities (Fig. 3). Thus, a total of 32 (10 + 22) task functions were analyzed with each assessment method by each rater.

Tasks were cyclic and predominantly machine or process-paced. The tasks exposed workers to a variety of upper extremity activities of varying force, postures and repetitive motion. Task cycle times ranged from 6 to 106 s (mean = 41.5, SD = 31.2). The complexity of the cheese production task cycles varied; six tasks were comprised of a single subtask (mono-element), nine were comprised of two subtasks (dual-element), and six were comprised of three subtasks (tri-element) (see Fig. 3).

Video recordings captured a minimum of five work cycles of each task during the production and packaging processes. The task duration and break/non-work periods were assessed by direct observation and interviews with the facility management. The facility management agreed to the study procedures and participants consented to being videotaped. All data collection was performed during the work shift while workers were paid their usual wage. No personal or identifying information was collected. This study was carried out in accordance with the recommendations of Institutional Review Board of the investigator’s universities.

2.2. Rater assessments

Two research teams from universities in the US and Italy served as raters completing the SI and OCRA Checklist assessments. Five raters (two faculty, three students) were from the US and two raters (one faculty, one student) were from Italy. Among the three-university faculty, the two US members were Certified Professional Ergonomists, while the Italian faculty had three years of experience in applied ergonomics. All four of the graduate students were specializing in occupational safety and ergonomics at the time of the study. Two of the US raters were experienced SI users (using the tool for more than one year in manufacturing settings) and one Italian rater (student) was an experienced OCRA Checklist rater.

All the raters participated in assessment methods training prior to task assessments. Strain Index training was administered separately from OCRA Checklist training. All training sessions included instruction on principles and procedures as well as practice using each method. Practice applying the methods was performed with videotaped mono-element job tasks from other manufacturing industries. Throughout training, comments and advice were provided to the trainees by the most experienced rater regarding method application. Trainees continued practicing until achieving consistent competency, which was defined as three consecutive job assessments where trainees assigned task-variable (e.g., force, posture, frequency, etc.) exposure ratings that were identical or very similar to those values assigned by the experienced rater. The SI training lasted 4 h while the more complex OCRA Checklist training required 10 h for rater competency.

Raters independently conducted SI and OCRA Checklist assessments of all video-recorded job tasks. Three raters completed all SI assessments first while four raters competed all OCRA Checklist assessments first. Each rater was provided digital video copies of the 21 cheese processing tasks to assess 32 UE task functions with electronic SI and OCRA

Checklist worksheets. The SI worksheet was based on Moore and Garg's (1995) original procedures and the OCRA Checklist worksheet was based on Colombini et al. (2011) update of the method. For the SI, raters assessed 1) intensity of exertion, 2) duration of exertion in the duty cycle, 3) efforts per minute, 4) hand/wrist posture, 5) speed of work, and 6) duration of work. For OCRA Checklist raters assessed 1) force of exertion, 2) frequency, 3) awkward postures/movements, 4) lack of sufficient recovery, 5) task duration, and 6) additional factors. For consistency between force/exertion intensity estimates between methods, all raters applied the Borg CR-10 scale (Borg, 1982) independently rather than using self-reported force estimates from workers (as the OCRA methods suggest). Doing so required raters to rely on workers' facial expression changes and other biomechanical indicators of exertion intensity (shifts in whole-body posture, jerky versus controlled movements, and visible UE muscle contraction). Data for SI task duration per day variable and the OCRA Checklist lack of sufficient recovery and task duration variables were provided to the investigators by company management. Table 1 outlines risk classification criteria (cut-off points determining risk severity level) used in the present study, which were similar to those used in previous SI and OCRA method studies (Apostoli et al., 2004, Garg et al., 2007, Spielholz et al., 2008, Jones and Kumar, 2010, Chiasson et al., 2012).

2.3. Data analysis and statistical methods

Descriptive statistics (mean, median, standard deviation, and range) for the 32 task exposures across all raters and tasks were calculated for the SI and the OCRA Checklist risk assessment tools. The statistics used to characterize the degree of consistency between the two risk assessments included: proportion of overall agreement (po), Bowker's test of symmetry, Spearman's rank-order correlation coefficient (rs), and Cohen's weighted kappa coefficient (κ). Proportion of overall agreement described the distribution of SI and OCRA Checklist risk classifications in a 3 × 3 contingency table. Bowker's test of symmetry characterized whether rater differences were significantly clustered above or below the main diagonal of the contingency table. A significant Bowker's test ($p < 0.05$) indicated that risk classification was biased; that is, the rater(s) consistently assessed exposures as more hazardous when using either the SI or the OCRA Checklist. Spearman correlations represented the strength of association between SI and OCRA Checklist risk classifications. Kappa coefficients with Fleiss-Cohen weights characterized chance-corrected agreement. Chi-square tests were used to evaluate the equivalency of kappa coefficients between individuals and groups of raters. Kappa coefficients and their lower confidence limits were interpreted according to Landis and Koch's (1977) verbal criteria: $\kappa < 0.20$, poor or slight agreement; $0.21 \le \kappa \le 0.40$, fair agreement; $0.41 \le \kappa \le 0.60$, moderate agreement; $0.61 \le \kappa \le 0.80$, substantial agreement; and $\kappa > 0.80$, almost perfect agreement. All statistical analyses were completed using SAS/STAT software (SAS Institute, Cary, NC) version 9.3 (2012).

3. Results

Two hundred and twenty-four pairs of assessments from the seven raters that each rated 32 task functions using the SI and OCRA Checklist were conducted. Of the 224 task functions, nearly half (49.1%) were classified as hazardous using the OCRA Checklist while 60.2%

were classified as hazardous using the SI. Across all raters and tasks, the overall mean SI risk index for all raters and tasks was 25.6 (SD = 30.7), median of 13.5, and a range from 0.1 to 161.9. The overall mean OCRA Checklist score was 15.8 (SD = 9.8), median was 13.7, and a range from 0.0 to 47.6. Greater variance in exposure scores was observed for SI assessments as compared to OCRA Checklist assessments. Additionally, the majority of risk indexes were greater than the hazardous exposure cut-points of 7.0 for the SI and 14.1 for the OCRA Checklist. In general, exposures associated with high variance in risk indexes were associated with asymmetric and tri-element tasks.

To compare the SI and OCRA Checklist risk classifications we stratified the results by task complexity and by rater. Stratification of results by all other group-level traits (e.g. task symmetry, rater education, and rater experience) did not reveal any statistically significant associations or trends. Table 2(a) through 2(g) display the within-rater disagreement/agreement for SI and OCRA Checklist risk classifications. Raters A and C assessed more tasks as safe when using the OCRA Checklist compared to the SI, and the reverse was true for the other raters.

Table 3 depicts the agreement statistics for risk classifications stratified by task complexity. Overall agreement, Spearman, and weighted kappa statistics were lowest for tri-element risk classification comparisons. Tests for assessment bias were significant for dual-element and tri-element tasks, and the p-value was lowest for tri-element tasks. A Chi-square test of kappa equivalency for the three task categories was close to significant (p = 0.0692).

Table 4 summarizes the agreement between risk assessment methods stratified by rater. Rater B exhibited the lowest overall agreement between the assessment methods whereas rater E exhibited the highest agreement. In general, chance-correct agreement was fair to moderate for individual raters; the kappa LCL was <0.60 for all raters while the central tendency ranged from 0.52 to 0.76. Most raters displayed some method bias given the low p-values for Bowker’s test, although significant levels of bias were associated with assessments with high and low agreement. A Chi-square test of kappa equivalency for all raters was insignificant (p = 0.3019).

4. Discussion

The present study compared the results of the SI and the OCRA Checklist in the assessment of risk for UE MSDs for job tasks associated with cheese processing work. Agreement between the two methods was fair to moderate. As expected, the SI and OCRA Checklist classified the same task exposures to physical risk factors in a similar but not identical manner.

The primary difference between the OCRA Checklist and the SI is that the former quantifies exposure to the full upper extremity including the shoulder, whereas the SI only applies to the distal upper extremities, from the elbow to the hand (Moore and Garg, 1995, Colombini et al., 2002). Several of the risk variables rated, such as intensity or force of exertion, used in determination of an overall risk score, are common to both the SI and OCRA methods and scored in a similar fashion. Other risk variables, however, are common to both methods but defined differently (Delleman et al., 2004). For example, the SI task variable related to repetition is efforts per minute and based on the frequency of complex upper extremity hand exertions per task cycle. In contrast, the OCRA Checklist variable related to repetition is frequency of technical actions and is based on the frequency of fundamental groupings of upper extremity exertion or motion (Occhipinti, 1998; Colombini et al., 2002). Other risk variables, used to determine an overall task risk score such as speed of work for the SI and lack of sufficient recovery for the OCRA, are similar constructs but scored and rated differently for the two assessment methods. Still other OCRA Checklist risk variables, such as additional factors (vibration, inadequate gloves, low ambient temperatures), have no analogue in the SI methodology.

Epidemiological validity studies have been performed for the SI and the OCRA method assessments to evaluate how well their exposure estimates predict UE MSD incidence. The SI has been studied more rigorously than the OCRA methods. The SI has demonstrated ecological (Moore and Garg, 1995, Knox and Moore, 2001, Rucker and Moore, 2002), cross-sectional (Spielholz et al., 2008), and longitudinal associations with UE MSDs (Garg et al., 2012, Garg et al., 2013, Gerr et al., 2013, Kapellusch et al., 2013). The OCRA Index has demonstrated a linear association with UE MSD diagnoses in cross-sectional studies (Grieco, 1998, Occhipinti and Colombini, 2007). The validity of the OCRA Checklist is based on the strong exponential relationship between it and the more comprehensive OCRA Index (Colombini et al., 2000, Colombini et al., 2011).

For the present study SI and OCRA Checklist assessments of tri-element tasks classified exposures less consistently than did assessments of mono- or dual-element tasks. Agreement and strength of association measures were strongest for the simplest mono-element tasks (po = 67.3%, rs = 0.71, κ = 0.71) and were similarly strong for dual-element tasks. As one would expect, the tri-element tasks with greater work variability had appreciably less agreement between assessment methods than did simpler tasks. The near-significant chi-square test (p = 0.0692) suggests that agreement between the two methods for tri-element task exposures was low and that task complexity noticeably affected the agreement of multiple exposure assessments. It is unclear what proportion of this disagreement effect was related to the characteristics of the cheese production tasks, the raters, the assessment tools or a combination of these factors. In terms of the SI, the quantification of biomechanical risk of complex work tasks may be improved with the relatively new Composite Strain Index (Garg et al., 2016b). The Composite Strain Index was designed to specifically quantify biomechanical stressors for complex tasks.

Other group-level analyses did not reveal any significant associations between level of agreement of the SI and OCRA methods and the rater experience, rater profession/education, or task symmetry. However, too few expert and novice raters were included in the present study to expect significant effects due to experience. Others who have compared similar semi-quantitative methods reported that rater experience affected agreement between the measurement tools (Spielholz et al., 2008).

4.1. Comparisons to other studies

Other studies comparing the SI and OCRA methods on risk classification of job tasks have only reported overall agreement and correlation statistics. The present study is the first to report chance-corrected agreement between SI and OCRA Checklist assessments. None of the previous studies have reported tests of rater bias, which is an important measure when comparing risk assessment methods. As with the present study, others have reported that the SI assessments rank a greater percentage of job tasks as hazardous than do OCRA method assessments (Apostoli et al., 2004, Jones and Kumar, 2010, Chiasson et al., 2012).

The observed agreement between the SI and OCRA Checklist is similar to, or stronger than, results reported by previous investigators. Apostoli et al. (2004) used the SI and OCRA Checklist to assess 12 repetitive job exposures. The authors reported a low proportion of overall agreement (po = 41.7%) with all of the disagreement stemming from SI assessments ranking more jobs as hazardous or at the action-level. Of the seven raters involved in the present study, five exhibited an overall proportion of agreement between the SI and OCRA greater than or equal to 65.6%. Higher agreement percentages reported in the present study may have been due to the greater number of exposures analyzed (32 in the present study as compared to 12 for Apostoli et al.).

Jones and Kumar (2010) reported 83% overall agreement between the SI and the OCRA Index risk classifications. This is higher than the observed proportion in the present study, but Jones and Kumar (2010) evaluated 87 individuals performing just four different high-hazard repetitive sawmill tasks. The high agreement between SI and OCRA Index risk scores reported in the sawmill study may not be applicable for work tasks characterized by higher levels of exposure variability.

Chiasson et al. (2012) reported 60.1% overall proportion of agreement between OCRA Index and SI risk classifications. The authors assessed 167 different job exposures in a variety of industries, and many exposures were likely associated with multi-element tasks. The authors did not describe the complexity of the jobs or task functions in their study, but average work cycle times ranged from 0.8 to 450 min. Based on the wide range of their reported work cycle times, it was probable that many tasks were multi-element in nature, which would contribute to observation of a weak correlation (Pearson $r = 0.32$) between the SI and OCRA Index assessments (Chiasson et al., 2012). Correlation analyses for risk classifications in the present study were higher across all raters overall ($0.51 \leq rs \leq 0.85$).

4.2. Practical implications of findings

Semi-quantitative methods are a popular type of ergonomic exposure assessment due to their low cost, systematic design, and moderate to good validity and reliability (Spielholz et al., 2001, David, 2005, Takala et al., 2010). Further, studies have demonstrated that semi-quantitative methods are strong predictors of work-related UE MSD development (Waters et al., 1998; Spielholz et al., 2008, Bonfiglioli et al., 2013, Garg et al., 2012, Garg et al., 2013, Gerr et al., 2013, Kapellusch et al., 2013), and they may even be more strongly predictive than direct measures of individual physical risk factors (Gerr et al., 2013).

The present study suggests that SI and OCRA Checklist exposure assessments both yield moderately similar results when applied to repetitive cheese manufacturing tasks. Yet, as expected, the agreement between these two methods is too low to assume that both ergonomic tools would yield identical risk assessment ratings for the same tasks. This is not surprising considering that the two methods summarize physical exposure scores differently; the SI considers the intensity of exertion to be the central predictor of risk whereas the OCRA Checklist considers the frequency of technical action to be the most important predictor. Nevertheless, based on the results of previous agreement studies of the SI and OCRA methods, the SI and OCRA Checklist may be more similar to each other than to any other semi-quantitative upper extremity exposure assessment method (Drinkaus et al., 2003, Apostoli et al., 2004, Spielholz et al., 2008, Jones and Kumar, 2010, Chiasson et al., 2012). An additional factor that likely significantly influences the agreement between the SI and OCRA Checklist is the exposure of the shoulder to risk factors associated with MSDs. The OCRA Checklist raters must assess physical exposures affecting the shoulder, whereas the SI raters only assess exposures to distal upper extremities (elbow to hand). This differential contribution of anatomical areas in the overall assessment of risk by the two methods decreases the level of agreement and strength of association between risk indexes.

The results of the study also indicated that tri-element tasks may be associated with greater variance in individual risk indexes. It is reasonable to assume that the inter-rater reliability of risk indexes would also be reduced when multi-element tasks are assessed. Researchers and practitioners should consider these limitations when deciding which measures of physical exposure are most appropriate for the purpose of the assessment and the work environment.

4.3. Strengths and limitations

The strengths of the present study include: group and individual-level comparisons of SI and OCRA Checklist exposure assessment classifications, stratification of agreement results according to possible covariates, and the participation of multiple raters with varied background and experience applying exposure assessment tools. Additionally, all raters assessed all physical parameters of the 21 cheese production tasks, and a variety of statistics were used to measure the agreement and strength of association between methods and raters.

Although generalizability of the results is limited to cheese processing tasks as discussed, the study results enhance the body of knowledge related to the use of SI and OCRA assessment methods. The results may not be applicable to job exposures of other manufacturing tasks, especially those that are highly variable and involve multiple task functions. Further, the range of SI and OCRA Checklist scores for each rater suggest that training did not eliminate systematic bias. The magnitude or direction of this bias is uncertain. Authors of similar studies estimated the effects of systemic bias by using the scores of an expert to serve as the “true” or “benchmark” score (Waters et al., 1998; Ketola et al., 2001).

In the case of the SI, the reliability of expert ratings is not ideal and systemic bias should be expected (Spielholz et al., 2008). The systemic bias is related to determination of risk, which is based on semi-quantitative observational methods that are strongly influenced by the subjective estimation of physical exposure parameters, primarily estimations of force exertion magnitude (Kilbom, 1994, Takala et al., 2010). The recently revised SI (Garg et al., 2016a) and the Composite Strain Index (Garg et al., 2016b) incorporate continuous rather than categorical multipliers in the estimation of biomechanical risk for work tasks. The use of continuous multipliers may provide greater discrimination of biomechanical risk, thereby reducing misclassification in the spectrum of safe to hazardous job tasks.

5. Conclusions

Strain Index and OCRA Checklist risk assessments for upper extremity MSDs yielded similar (fair to moderate agreement), but not identical, results for cheese processing tasks. The differences in overall risk classifications determined by the SI and OCRA Checklist for job tasks were likely related to the definition of risk variables measured by the assessment tools, the characteristics of the job tasks and the experience of the rater. By design, the SI is specific to the distal upper extremity while the OCRA Checklist accounts for the entire upper extremity including the shoulder. When conducting a risk assessment of industrial work tasks, the choice of analysis tools should be based on the purpose of the assessment and the complexity of task functions.

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Fig. 1.
Workers at the Pecorino Romano cheese processing facility where video data of work tasks was recorded.

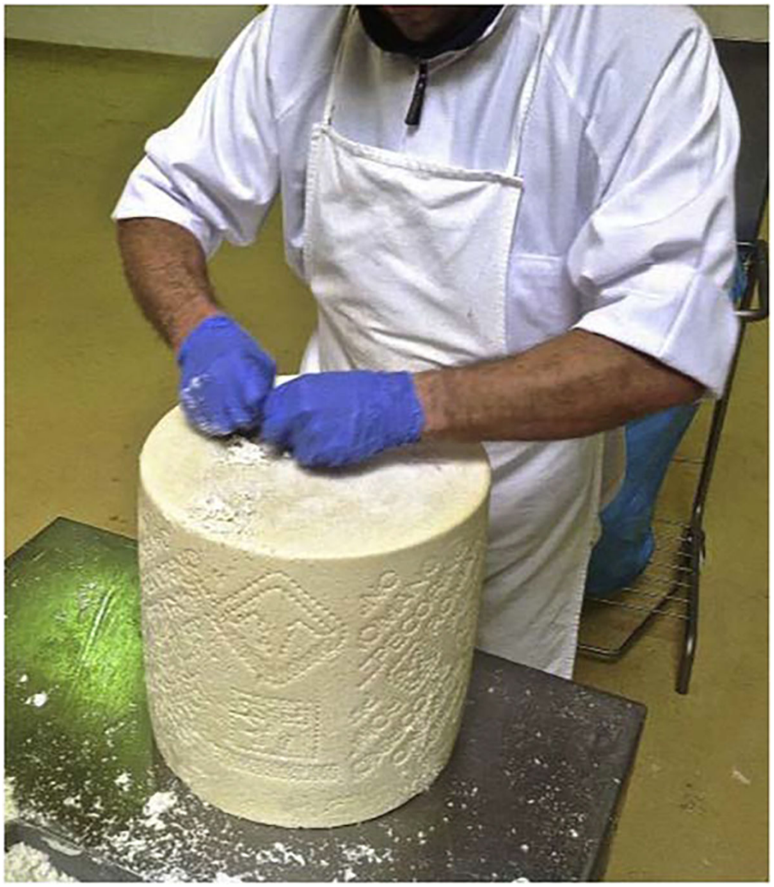

Fig. 2.
A scraping task consisting of bilateral upper extremity actions to remove the external layer of aged cheese.

Fig. 3.
An example of a cheese processing station consisting of three subtasks: turning, tightening and tying plastic mold covers around the cheese.

Table 1.

Strain Index and OCRA Checklist risk classification criteria used for comparisons of methods.

Classification criteria	Risk index	
	SI	OCRA
Safe	<3	<7.6
Caution	3–6.9	7.6–14
Hazardous	≥7	≥14.1

Table 2.

(a)-(g). Agreement frequencies for each rater for SI and OCRA Checklist risk classification.

Table 2(a). Rater A

OCRA	Strain Index: Safe	Caution	Hazardous	Total
Safe	4	1	0	5
Caution	4	8	4	16
Hazardous	0	1	10	11
Total	8	10	14	32

Table 2(b). Rater B

OCRA	Strain Index: Safe	Caution	Hazardous	Total
Safe	3	0	3	6
Caution	0	2	8	10
Hazardous	0	0	16	16
Total	3	2	27	32

Table 2(c). Rater C

OCRA	Strain Index: Safe	Caution	Hazardous	Total
Safe	3	1	0	4
Caution	4	3	3	10
Hazardous	0	2	16	18
Total	7	6	19	32

Table 2(d). Rater D

OCRA	Strain Index: Safe	Caution	Hazardous	Total
Safe	2	9	1	12
Caution	0	1	5	6
Hazardous	1	0	13	14
Total	3	10	19	32

Table 2(e). Rater E

OCRA	Strain Index: Safe	Caution	Hazardous	Total
Safe	5	5	1	11
Caution	0	3	2	5
Hazardous	0	0	16	16
Total	5	8	19	32

Table 2(f). Rater F

OCRA	Strain Index: Safe	Caution	Hazardous	Total
Safe	3	2	0	5
Caution	0	5	2	7
Hazardous	0	5	15	20
Total	3	12	17	32

Table 2(g). Rater G

OCRA	Strain Index: Safe	Caution	Hazardous	Total
Safe	2	7	3	12
Caution	1	2	2	5
Hazardous	0	0	15	15
Total	3	9	20	32

Table 2(h) All Raters

OCRA	Strain Index: Safe	Caution	Hazardous	Total
Safe	22	25	8	55
Caution	9	24	26	59
Hazardous	1	8	101	110
Total	32	57	135	224

Table 3.

Agreement statistics for OCRA Checklist and Strain Index risk classifications stratified by task complexity.

Task complexity	Overall agreement, p_o	Test of bias*	Spearman, r_s	Kappa, κ**	95% CI for κ
Mono-element	67.3%	p = 0.3618	0.71	0.71	0.56–0.87
Dual-element	67.1%	p = 0.0110	0.70	0.61	0.49–0.74
Tri-element	62.3%	p = 0.0068	0.47	0.27	0.11–0.44

* Bowker’s test for symmetry for which a significant result indicates that raters disproportionately evaluated exposures as more hazardous with either the SI or OCRA Checklist.

** Chi-square test of differences among weighted kappa coefficients was close to significant (p = 0.0692).

Table 4.

Agreement statistics for OCRA Checklist and Strain Index risk classifications stratified by rater.

Rater	Overall agreement, p_o	Test of bias*	Spearman, r_s	Kappa, κ**	95% CI for κ
A	68.8%	p = 0.3080	0.74	0.72	0.56–0.88
B	65.6%	p = 0.0117	0.51	0.46	0.14–0.78
C	68.8%	p = 0.5724	0.75	0.73	0.58–0.89
D	50.0%	p = 0.0029	0.70	0.52	0.30–0.74
E	75.0%	p = 0.0460	0.85	0.76	0.59–0.94
F	71.9%	p = 0.3496	0.66	0.72	0.52–0.91
G	59.3%	p = 0.0233	0.70	0.53	0.31–0.75

*Bowker's test for symmetry for which a significant result indicates that a rater disproportionately evaluated exposures as hazardous with either the SI or OCRA Checklist.

**Chi-square test of differences among weighted kappa coefficients was not significant (p = 0.3019).