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Methods of Ergonomic Evaluation in Upper Limb: A Review in Agricultural Manual Work

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Abstract

Background: Into literary collections exists a great availability of kinematic models for upper limbs; e.g. for shoulder modeling, were found that the number of published articles, since 1990 to 2009, can reach 100. **Aims**: To describe the main ergonomic methods adopted to evaluate the upper limb in manual agricultural work and the quality of available evidence in electronic databases.

Methods: A search in scientific literature made through Web of Science, Scopus, ScienceDirect, ESBCO - PubMed and IEEE databases. At the same time, in systematically classified and published articles during the period 2013 to 2018, based on Delphi consensus criteria and evidences analyzed under PRISMA declaration criteria and catalogued in accordance with the approaches of physical ergonomics. Papers selection had basis on the key words: farmers, musculoskeletal, farmers' upper limb, agricultural risk factor, and occupational risk factor. Along this retrospective study, initially were found 1508 articles, where 37 of them were analyzed. All selected papers met rigor of inclusion criteria (specific farmer population without mechanical aid), and exclusion (duplicity or triplicate in databases, and intervention with clinical or medical examinations).

Conclusion: Results showed that the most of evaluation techniques used are indirect: realized by self-administered questionnaires (SAQ) or self-reporting, this is an evidence of little ergonomic analysis in farmers doing manual work; most of the studies selected were catalogued as good or reasonable quality. This systematic review highlights the needing of adjusting tools in order to identify and evaluate potentially dangerous tasks by their movements and/or postures in real time.

Keywords: Upper extremity; Agricultural worker; Farmers; Ergonomics; Risk factors; Upper limb; Musculoskeletal system

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Introduction

Ergonomics renewed approaches suggest the application of more practicality in identification of possible ergonomic problems, before the appearance of Musculoskeletal Disorders (MSD's). Risks are presented by using of muscles when exerting a certain level of strength making any work, since the greater the demand, the greater the effort [1]. This effort can cause muscle injury, whether by repeated force, sustained force, or, even an uncomfortable posture [2]. In 2004, World Health Organization (WHO) pointed out that exists a causal link between MSD's and physical tasks during work activity, because of the muscles may require excessive effort to maintain the posture or support repetitive muscle charges during long periods of time such is likely to produce muscular fatigue [3]. Being exposed to these risk factors, labelled as MSD's, increases the likelihood of worker injuries [4]. Data from 5th European Survey of Working Conditions, Eurofound - 2012, frequently reveal that perceived risk to present MSD in workers, is mainly due to two factors: repetitive movements of upper limbs in more than a quarter of their working day: 63%, and, for adopting forced and/or tiresome postures: 46%, showing a prevalence increase since 2005 [5].

Worldwide high productivity rates force rural work to be more competitive, promoting the reduction in operating costs and yields increasing [6]. Saving in operation costs depends on types of crop, since the most of them are harvested manually, either by environmental conditions, the natural terrain where they are

cultivated or the type of fruit to be harvested, since these are traditionally separated from the tree by hand or with using hand-cutting tools. Those efficiency requirements make of process an activity that generates problems in worker's health [7,8]. Level of perception in agriculture workers shows discomfort or pain in 62.6% [9], either performing work by standee, on stairs, flexing lower limbs, or frequent uncomfortable postures during long periods of time [10].

Several models of kinematic valuation for upper limbs, require of choosing the model through body multiple kinematic optimization, and depends directly on limitations and degrees of freedom for analysis [10,11]. Into literary collections exists a great availability of kinematic models for upper limbs; e.g. for shoulder modeling, were found that the number of published articles, since 1990 to 2009, can reach 100 [12].

This set of applications for motion analysis can refer to medical evaluation, monitoring or activity recognition. These applications are supported by specialized high-precision systems, mobile systems or wireless sensor networks widely used in health areas, entertainment or leisure games [13].

In the same way into biomechanics allowing the measuring of posture; nowadays, electronic devices have great level of acceptance. Physical media such as sensors record angles, speeds and/or distances, which thanks to their accuracy and interconnection, can obtain automatically data from different variables, and even have the possibility of continuous monitoring [14,15].

In accordance with U.S. Department of Labor's Occupational Safety and Health Administration (OSHA), evaluation is necessary not only for recognition of risk factors, but also to measure periodically the effectiveness of ergonomic process, and so determine an effective compliance with implemented procedure [15].

Based on the above, the purpose of this review is identify available evidence in electronic databases, its quality, and detailed description of used methods in order to establish a basis to design direct measurement tools that bring support to an early identification of symptoms or incidence of MSD's in agricultural workers whom perform manual labours.

Literature and Method

Reviewing of literature by using and combining the keywords: agricultural worker (MeSH), farmers (MeSH), ergonomics (MeSH), risk factors (MeSH), musculoskeletal system (DeSH), upper limb (DeSH), upper extremity (MeSH), the latter used as an arm synonym. This set of words were chosen after an initial experimental search in order to understand the citated publications behaviour in databases and gray literature. As a search strategy for the articles, were chosen five databases catalogued for contents and information quality: Web of Science, Escopus, ScienceDirect, ESBCO - PubMed and IEEE. At the time, it was established a publication date restriction between the years of 2013 and 2018.

The following factors were selected as the inclusion criteria: original articles or comparative studies such as controlled trials, study subjects belonging to agricultural sector and whose results show method effectiveness and symptoms or discomfort presented by members of study group. Publication date of articles were stated since July 2013 to July 2018, texts written in English, classified by type and conditioned to be a full access document.

About the exclusion criteria: at first it was excluded documents produced by publishing houses, legal entities presentations as well as review articles. With the same criterion, it was excluded investigations with directed populations to other economic activities such as agro-industrial workers whom use traction or locomotion tools machines.

As shown in the systematic review of Menegaz AM, Silva AER et al [16], a checklist was used to evaluate the methodological quality of studies [17] and encountered difficulties were adjusted due to comprehension in some elements definition. After this reviewing were selected 37, documents taking into account a basic documentary structure with 10 questions, internal and external validity with 8 questions, omitting those directed to attempt to blind study subjects or pretend to blind whom measure main results, all this considering logistical difficulties in the studies. Selection biases were assessed by choosing 6 questions and a statistical power value to detect the effect. Through the instrument adjusting, score was stated between 0 and 26, the studies were ranked in accordance with the quality of evidence on an established scale as: Excellent (24-26), Good (20 to 23), Reasonable (15 to 19) or Limited (14-0). These set of criteria were similar to those adjusted in the systematic review made by Cascaes AM, Bielemann RM et al [18].

Results

In Initial search were reported a total of 1508 articles (**Table 1**), after depuration by duplicity only left 1312. Made the reading both title and summary, another 1263 were excluded, so the set of selected articles for an entirely reading was reduced to 49. In

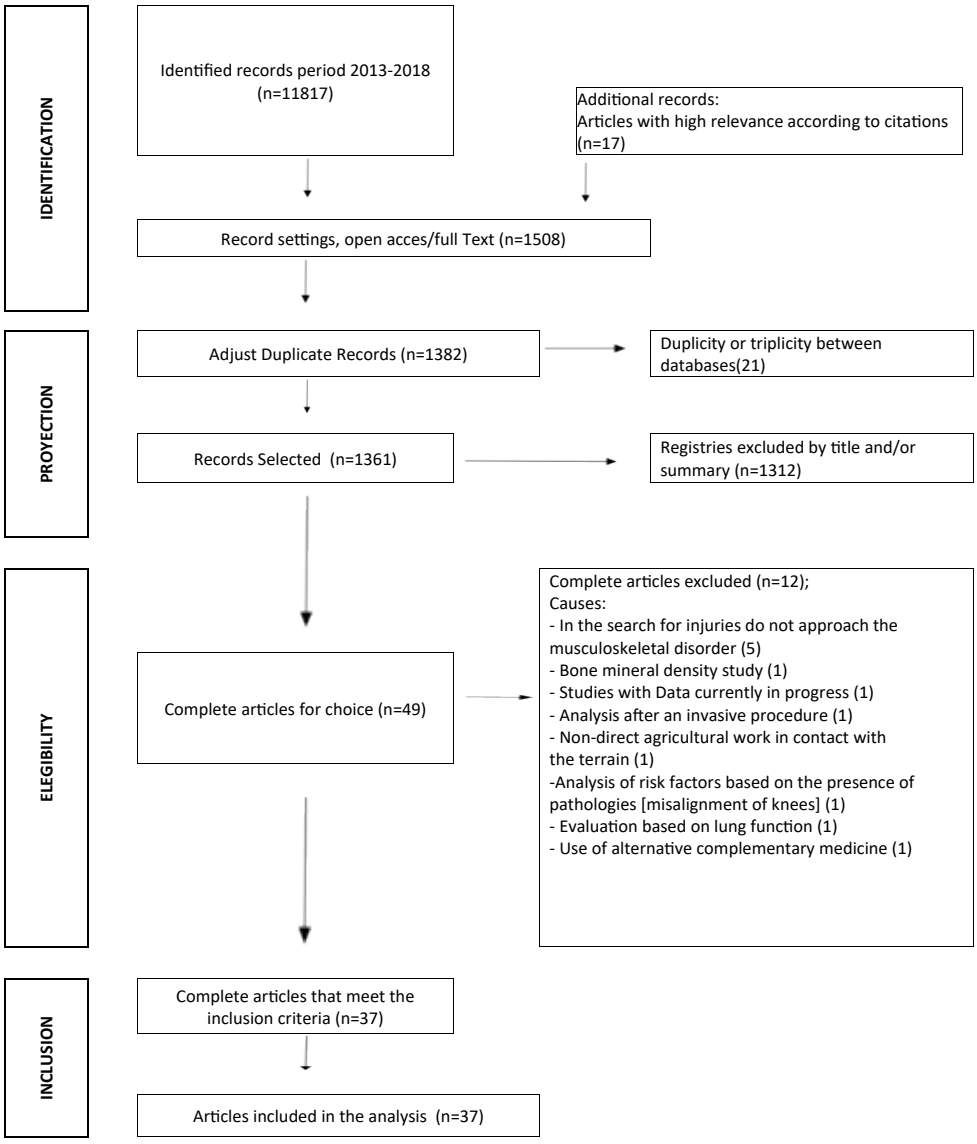
Table 1 Articles identified in bibliographic databases.

	Farmers musculoskeletal	Farmers Upper Limb	Agricultural Risk Factor Occupational	Musculoskeletal Agricultural	Ergonomics Farmer	Ergonomics Agricultural
IEEE	4	1	1	3	3	7
PubMed	23	7	215	53	10	14
WEB OF SCIENCE	44	5	1	1	1	1
Science Direct	53	78	595	113	26	128
SCOPUS	5	1	60	15	4	9
EBSCO	11	1		8	2	5
Total	**140**	**93**	**872**	**193**	**46**	**164**

agreement with selected criteria, 6 articles which did not include in their results Musculoskeletal Disorders (SMD's) [19-23], were excluded. Another article was left out because of being a work in progress [24], another one was rejected due to its analysis took place after an invasive procedure [25], an additional one because of evaluation was made with farmers whom perform tasks without direct contact with nature [26], one of them due to its method involves clinical analysis (bone mineral density) [27], another one with risk assessment design based on tests of lung function and heart rate [28], one due to the approaching of analysis which was presented with a malformation in lower limbs (misalignment in knees) [29] and a last work because it was used a questionnaire with characteristics of World Health Organization (WHO) combined with qualities of complementary alternative medicine (CAM) [30]. At the end, only 37 articles met all established criteria. Selection process is shown in **Figure 1**.

According to Delphi consensus, peers who addressed the selection of articles (Ruíz A and Jaramillo S), suggested to keep articles directed to use an ergonomic method, either by observation, analysis with techniques of direct measurement or ergonomic evaluations methods with self-reported questionnaires. Intervention made with each one of selected articles was recorded in a table under criteria of PRISMA Declaration and classified according with approaches of physical ergonomics [31,32]. **Table 2** shows all of the 37 selected articles, classified in groups, according to the evaluation method included in methodological design.

It was found a little quantity of articles about upper limbs ergonomic evaluation in farmers. Those ones identified refer to musculoskeletal pain in at least one part of body during the last year, produced by activities or tasks that are repeated



(Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement)

Figure 1 Selection of articles for review.

regularly [33] or caused by unsafe postures adopted [8]. Most of MSD's in one or more regions of the body are associated with age [25,34,35], as well as common causes attributed to lumbar problems produced due to lifting, pulling, or pushing heavy loads [36]. In this point it is important to highlight that there are a few standardized tools available to assess safety and health in manual agricultural operations [37]. Near to 45.9% [17] of related articles in this review used the indirect method known as Nordic Musculoskeletal Questionnaire (NMQ), commonly used in occupational health and agriculture activities, among other uses [38]. Within these 17 articles, 4 used it only, 5 in combination with an observation method and 8 in combination with another questionnaire.

The selected articles are indexed in 24 different journals; in order of repetition: 4 in Annals of Agricultural and Environmental

Table 2 Ergonomic evaluation tools.

Evaluation Method	Quantity	Characteristics of the Tool
self-reports	3	Questionnaire self-reported musculoskeletal pain
		Questionnaire designed to investigate the risk perception
		Structured questionnaire self-reported. prevalence and characteristics of MSK pain, developed by the Korea Occupational Safety and Health Agency - KOSHA
Questionnaire administered	11	The modified Nordic Questionnaire for assessment of musculoskeletal disorders and questionnaire concerning job satisfaction
		Structured questionnaire. Monthly telephone interviews.
		Administered questionnaire (MYCASA Study)
		Questionnaire aimed at employers. incidence of MSD according to the standardized Nordic questionnaires.
		Administered questionnaire: The questionnaire was adapted from the Standard Nordic Musculoskeletal Questionnaire. Depression was measured using the Peradeniya Depression Scale
		Standard Nordic Questionnaire (Thai version). the Suan Prung stress test, which is widely used for stress measurement in Thailand.
		Questions from the Irish National Farm Survey (NFS). The Nordic back pain questionnaire
		Standardized Nordic Questionnaire (SNQ; 24).
		The Standardized Nordic Questionnaire. (sent home)
		Modified Nordic Questionnaires administered. Detailed posture analysis. Discomfort Scale.
		Modified Nordic Musculoskeletal Disorder Questionnaire.
Data base	3	Evaluation of ergonomic interventions for VI case studies
		Data from the third and most recent (2012) Korean Farmers' Occupational Disease and Injury Survey (KFODIS)
		This study used National Health Interview Survey data from 2004 to 2008. Annual survey of the US civilian noninstitutionalized population
Questionnaire and observation method	10	The RULA method, analysis of work postures nordic
		Interview and Analysis with rapid assessment of the upper extremities (RULA)
		The Nordic Musculoskeletal Questionnaire and RULA
		Nordic Musculoskeletal Questionnaire and the Rapid Upper Limb Assessment (RULA)
		Modified Nordic Musculoskeletal Questionnaire. OWAS
		(Thai version). the Suan Prung. OCRA index method
		Structured questionnaire. Rapid Upper Limb Assessment (RULA)
		Nordic body map. Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA.
		The Ovako Working Posture Assessment System (OWAS); questionnaire
		Specifically modified nordic questionnaire. the Global Physical Activity Questionnaire (GPAQ). the modified Oswestry back pain disability questionnaire (Thai version). The flexibility of muscles, measured with a box to sit and reach the floor.
Observation method	2	OWAS (Ovako Working Posture Analysing System). handling of loads: NIOSH Lift Index® application for Apple used
		Rapid Upper Limb Assessment (RULA)
Observation method and direct measurement	2	Participatory rural appraisal and photovoice
		REBA and OWAS methods. The Modified Nordic Questionnaire. Physiological assessment of workload (recording the heart rate and blood pressure)
Direct measurement	2	Exoskeleton electrogoniometer harness system.
		(Electromyograph) measure the muscular Maximal Voluntary Contraction percentage (% MVC)
Direct measurement and questionnaire administered or self-reports	4	Observational tool
		Wireless triaxial accelerometer placed on their trunk and questionnaire
		Nordic Musculoskeletal Questionnaire. Anthropometric measurements.
		Structured self-reported questionnaire. EuroQol-5D-3L (EQ-5D-3L). Serologic tests. Radiographic tests

Medicine, 3 in Work, and 3 in Journal of Agromedicine, among others. 27% point their objective to detect prevalence and 32% identify the exposure to risk factors, as seen in **Table 3**.

In Asia were made 48% [18] of investigation works: 5 in India [34,39-42], 3 in Thailand [43-45], 4 in Malaysia [7,8,46,47], 3 in South Korea [48-50], 2 in Indonesia [51,52], and 1 in Sri Lanka [53]. 72.9% of articles are based on cross-sectional studies; 18 of them used a population range between 100 to 900 farmers and only in one study were involved children with a sample of 120 participants [39]. In the same way, also in was identified a cohort study with a population of 1013 subjects [49], as well as two cross-sectional studies, one with 2469 subjects [54] and other with 2595 people [33]. Within the review, a cross-sectional study using 15980 people data from the 2012 Korean Farmers Occupational Diseases and Injuries Survey (KFODIS) [50] was also identified. Only one study used the observational method (RULA) to redesign tools [51], and the others were oriented to prevalence of MSD's.

The articles quality evaluation recorded in **Table 4** shows an average of 18.95 (PD=3.92), although a minimum value of 8 points was obtained in an article [40], it was possible to confirm a high value in another article of excellent quality with 25 points [41], followed by 7 articles of good quality with 23 points [33,35,36,42,50,55,56]. The greatest methodological difficulties encountered were related to external validity and confusion, whether during planning study, during sampling process, during data collection, or during analysis and interpretation stage.

Discussion

As a result of this review was possible determine that Nordic Questionnaire is the most widely used tool in these cases. Within its structure incorporates several questions addressed to detect effects on health, symptoms of discomfort or pain for detection of MSD's and allows a comparison with different regions of the body [57]. Perception of discomfort or pain risk is revealed in 5 papers with different values in effect magnitude: the first one refers to high physical stress associated with farm work produced by lifting or energetic movements, logistic regression model refers to significance in worker activity with values for p=0.021

Table 3 Identification of Articles and general characteristics.

TITLE	AUTHOR (S)	DATE	COUNTRY	EDITOR	Descriptors and indexed terms	OBJECTIVE
Redesign of thresher machine for farmers using rapid upper limb assessment (RULA) method	[51]	2016	Indonesia	IEEE	Design, Musculoskeletal, Thresher Machines, RULA method	Redesign thresher machine based on method RULA
Investigation of oil palm harvesters' postures using RULA analysis	[8]	12 2014	Malaysia	IEEE Conference on Biomedical Engineering and Sciences,	/	The objective of this study is to investigate manual material handling work that can affect the agricultura workers
A Cross-sectional Study of Musculoskeletal Symptoms and Risk Factors in Cambodian Fruit Farm Workers in Eastern Region, Thailand.	[43]	09 2018	Thailand	Safety and Health at Work	agricultura, Cambodian workers, eastern Thailand, migrant, musculoskeletal disorder	The objective of this research are to study the factors contributing to MSDs among Cambodian migrant farm workers in eastern Thailand
Risk factors for musculoskeletal disorders in manual harvesting farmers of Rajasthan.	[34]	2018	Rajasthan	Industrial Health	Agriculture, Farmers, Logistic models, Low back pain, Risk factors	The current study was carried out to determine the MSDs prevalence and contributing risk factors (individual and work-related) among manual harvesting farmers in Rajasthan, India.
Dissatisfaction with work as a risk factor of musculoskeletal complaints among foresters in Poland.	[64]	12 2017	Poland	Annals of Agricultural and Environmental Medicine	work, job satisfaction, forestry employees (foresters), musculoskeletal disorders	Evaluation of the relationship between the level of job satisfaction and occurrence of musculoskeletal disorders among employees of the State Forests
The prevalence of low back pain and its associated factors in Thai rubber farmers.	[44]	09 2016	Thailand	Journal of Occupational Health is an Open Access article	Low back pain, Risk factors, Rubber farmers	Examine the prevalence of LBP in rubber farmers and to identify the associations between potential risk factors and 12-month LBP in rubber farmers
Prevalence and Characteristics of Musculoskeletal Pain in Korean Farmers.	[48]	08 2015	South Korea	Annals of Rehabilitation Medicine ARM	Agriculture, Musculoskeletal pain, Low back pain, Injuries, Workload	Examine the prevalence and characteristics of agricultural workrelated MSK pain, and its association with farming duration

Musculoskeletal pain, depression, and stress among Latino manual laborers in North Carolina.	[55]	11 2016	USA	International Archives of Occupational and Environmental Health	Occupational health; immigrant health; organization of work; minority health; health disparity; immigrant workers	The goals of this analysis are to: (1) compare levels of musculoskeletal disorders reported by Latino farmworkers to levels reported by Latino manual workers employed in other industries; (2) compare mental health between Latino farmworkers and Latino manual workers; and (3) determine if differences in musculoskeletal disorders between Latino farmworkers and Latino manual workers are associated with indicators of mental health and work organization
Farmers' Cohort for Agricultural Work-Related Musculoskeletal Disorders (FARM) Study: Study Design, Methods, and Baseline Characteristics of Enrolled Subjects.	[49]	2016	South Korea	J Epidemiol	farmer; agriculture; work; musculoskeletal disorders; health	Study developed to evaluate health status and related factors in farmers
Chronic low back pain among tobacco farmers in southern Brazil.	[54]	2015	Brazil	International Journal of Occupational and Environmental Health	Chronic low back pain, Prevalence, Tobacco farming, Occupational health, Agriculture, Brazil, Musculoskeletal disorders	Prevalence and associated factors among tobacco farmers in southern Brazil
Assessing Hmong farmers' safety and health.	[37]	2014	USA	Workplace Health Saf.	/	Identify agricultural safety and health issues among Hmong farmers in Washington State
Child work in agriculture in West Bengal, India: assessment of musculoskeletal disorders and occupational health problems.	[39]	2013	West Bengal	Journal of Occupational Health	Child agricultural workers, Musculoskeletal disorder (MSD), Occupational health, Physiological stress, Posture analysis, Thermal stress	The main aims of the present study were 1) to investigate the causation of discomfort related to working postures 2) to assess the physiological strain among the child farmers and 3) to assess the thermal stress during work in an agricultural field
Safety Knowledge and Changing Behavior in Agricultural Workers: an Assessment Model Applied in Central Italy.	[35]	2018	Italy	Safety and Health at Work	agricultura, PCA, risk perception, Rizzi index	Relationship between risk perception among farmers and the main risk factors to which they are exposed
Risk factors for work-related injury among farm workers: a 1-year study.	[58]	05 2015	Argentina	The international electronic journal of rural an remote health research	agriculture, Argentina, farm, livestock farming, work injury.	The objective of this work was to estimate the frequency of farm-related injuries among farm workers and to identify possible risk factors.
Design and evaluation of ergonomic interventions for the prevention of musculoskeletal disorders in India.	[40]	2014	West Bengal	Annals of Occupational and Environmental Medicine	Informal sector, Musculoskeletal disorders, Ergonomic interventions	A strategic plan was drawn on the implementation of interventions for the prevention of WMSDs among these groups of workers. A post intervention study was formulated to find out the effect of the implemented interventions

Safety and health hazard observations in Hmong farming operations.	[37]	2014	USA	J Agromedicine	Hazard assessment; Hmong farming; injury risk; safety and health	The first was to develop an observational tool to assess the presence of a wide range of agricultural health and safety hazards. The second was to pilot the use of this tool to document these hazards among workers at Hmong-operated farms near Seattle, Washington, USA.
Agricultural work and chronic musculoskeletal pain among Latino farm workers: the MICASA study.		2013	USA	Am J Ind Med	agriculture; hired farm workers; chronic musculoskeletal pain; working posture; MICASA	Characterize the association between agricultural work and chronic musculoskeletal pain among a community-based sample of both male and female Latino farm workers in California.
Ergonomic conditions in manual harvesting in Swedish outdoor cultivation.	[59]	2018	Sweden	Annals of Agricultural and Environmental Medicine	agriculture, ergonomics, horticulture, musculoskeletal disorder, posture analysis, questionnaire	The aim of this study was to determine the ergonomic conditions during manual work in Swedish outdoor cultivation.
The prevalence of musculoskeletal disorder and association with productivity loss: a preliminary study among labour intensive manual harvesting activities in oil palm plantation.	[46]	2014	Malaysia	Industrial Health	Ergonomics, Musculoskeletal disorders, Oil palm, Harvesters, Productivity	The association between self-reported prevalence of musculoskeletal disorders and productivities expressed in 4 different indicators; daily harvesting quantity, efficiency score, sick leave and presenteeism
Development and Evaluation of Ergonomic Interventions for Bucket Handling on Farms.	[66]	2016	USA	Hum Factors	family farm; intervention; youth; low back disorders; bucket	The aim of this study was to introduce and evaluate two interventions, The evaluation approach focused on the effectiveness of these two interventions in reducing LBD risk during the lifting, carrying, and dumping of water buckets
Ergonomic assessment of natural rubber processing in plantations and small enterprises	[65]	2016	Colombia	Ingeniería y Competitividad	Ergonomic assessment, natural rubber industry, OWAS, posture.	This work is focused on working postures and posture risks of workers in Antioquia (Colombia) who perform operational tasks in small plantations of natural rubber and small rubber factories.
Prevalence and risk factors of musculoskeletal disorders among Sri Lankan rubber tappers	[53]	2016	Sri Lankan	Patient Preference and Adherence	lower extremity malalignment, prevalence, rice farmer, risk factors	the objectives of this study were to provide a description of the rubber tapping profession, quantify the musculoskeletal problems and ergonomic job exposures experienced by rubber tappers, and assess factors associated with MSDs in the population.
Risk factors of musculoskeletal disorders among oil palm fruit harvesters during early harvesting stage	[7]	2015	Malaysia	Annals of Agricultural and Environmental Medicine	musculoskeletal disorders, harvesters, oil palm, risk factors, ergonomics	the main objective of this study was to explore the association of MSDs among foreign workers with individual, occupational and ergonomics risk factors during early stage of harvesting activities
An evaluation of low back pain among farmers in Ireland	[36]	08 2012	Ireland	Occupational Medicine	Causes; farmers; low back pain; work disability.	Relationship between LBP and personal and work-related factors and measure the impact of LBP.

Musculoskeletal Load Assessment of Farmers during Selected Agricultural Works	[67]	2015	Poland	Procedia Manufacturing	Milking; Electromyography; Job Strain Index; Risk; Agriculture	Measuring of the burden on the musculoskeletal system of milkers while performing mechanical milking of cows in a "herringbone" milking parlor, as well as the measurement and evaluation of the strain on the arms and hands of tractor operators and strain on the upper limbs during manual handling of objects
Trunk kinematics and low back pain during pruning among vineyard workers - A field study at the Chateau Larose-Trintaudon		04 2017	France	PLOS ONE	/	Objectives of the study: (1) to carry out a kinematics analysis of vineyard-workers' pruning activity by extracting the duration of bending and rotation of the trunk, (2) to question separately the relationship between the duration of forward bending or trunk rotation with low back pain intensity and pressure pain sensitivity and (3) to question the relationship between the combined duration of forward bending and trunk rotation on low back pain intensity and pressure pain sensitivity
The risk of musculoskeletal disorders due to repetitive movements of upper limbs for workers employed in hazelnut sorting		2013	Italy	Journal of Agricultural Engineering	repetitive movements, hazelnut, ergonomics, manual sorting.	Assess the risk of musculoskeletal disorders due to repetitive work, for workers employed in manual sorting of hazelnut
Assessment of postural load during melon cultivation in mediterranean greenhouses	[15]	08 2018	Spain	Sustainability	sustainable agriculture; musculoskeletal disorders; work postures; melon;	Assess forced postures in farmers who perform melón cultivation tasks in Almería-type greenhouses
Prevalence of Musculoskeletal Disorders Among Saskatchewan Farmers.	[33]	2015	Canada	Journal of Agromedicine	Agriculture, ergonomics, musculoskeletal disorders	(1) determine the prevalence of MSDs among farmers in one Canadian province; and (2) describe the types and severities of these disorders and patterns in their occurrence.
Gender differences in prevalence of musculoskeletal disorders among the rice farmers of West Bengal, India.	[41]	08 2013	Kolkata, India	work	Discomfort feeling, nordic questionnaire, heart rate, net cardiac cost, lung function values, posture analysis	Objectives of the study: (1) the assessment and identification of the risk factors leading to the development and prevalence of musculoskeletal disorders during rice cultivation among men and women farmers, (2) to analyze the relationship of discomforts associated with awkward postures and (3) to assess physiological and thermal stress among men and women rice farmers
Ergonomics-related risk identification and pain analysis for farmers involved in rice field preparation.	[45]	08 2013	Khon Kaen, Thailand.	work	Rice cultivation, job screening, farmer demographics, pain ratings	To examine the relationship of farmer experience and demographics to perceptions of pain and to identify body areas exposed to ergonomics risks, unknown to farmers
Prevalence of musculoskeletal disorder among agricultural workers in rural area of Tamil Nadu: A cross sectional study.	[42]	2017	Tamil Nadu, India	HECS International Journal of Community Health and Medical	agriculture, factors, musculoskeletal disorders, prevalence, workers	prevalence and the factors associated with musculoskeletal disorders (MSDs) and to identify the remedies used by the agricultural workers to relieve the problems associated with MSDs

Musculoskeletal Disorders and Agricultural Risk Factors Among Korean Farmers.	[50]	2016	Korean	JOURNAL OF AGROMEDICINE	Agriculture; ergonomic;	Understand the distribution and characteristics of MSDs among selfemployed Korean farmers and to identify the related risk factors
Prevalence of musculoskeletal symptoms among agricultural workers in the United States: an analysis of the National Health Interview Survey, 2004-2008.	[56]	2014	USA	J Agromedicine.	Agriculture; joint pain; low back pain; musculoskeletal symptoms; national survey	Estimate the prevalence of musculoskeletal symptoms in US agricultural workers by demographic and employment characteristics using NHIS data from 2004 to 2008.
Evaluation of Musculoskeletal Disorders Prevalence during Oil Palm Fresh Fruit Bunches Harvesting Using RULA.	[47]	2013	Malaysia	Advanced Engineering Forum	Prevalence, WMSD, RULA, oil palm harvesters	Prevalence of WMSD during harvesting FFB by using the RULA method.
Ergonomic Checkpoint in Agriculture, Postural Analysis, and Prevalence of Work Musculoskeletal Symptoms among Indonesian Farmers: Road to Safety and Health in Agriculture.	[52]	01 2018	Indonesian	Jurnal Teknik Industri	Indonesian, farmer, musculoskeletal symptom, 3D SSPP, RULA, REBA.	The purpose of this study is to apply ergonomics checkpoint in agriculture (developed by ILO) in Indonesian as well as to observe the prevalence of musculoskeletal symptoms among Indonesian farmers
Ergonomic evaluation, with the RULA method, of greenhouse tasks of trellising crops.		2016	Spain	Work	Agricultural ergonomics, risk prevention, repetitive movements, musculoskeletal disorders, MSDs	The aim is to prevent potential musculoskeletal disorders to the upper limbs in workers in greenhouse plants based on the simulation by lowering the height of the crop

Table 4 Quality of the articles, according to the criteria of Downs and Black [17].

TITLE	AUTHORS	DATE	Basic documentary structure (0 to10)	External validity (0 to 3)	Internal validity – bias (0 to 5)	Internal validity - confounding (Selection bias) (0 to 6)	Power (0 to1)	Sum (0 to 25)
Redesign of thresher machine for farmers using rapid upper limb assessment (RULA) method	[51]	2016	4	0	3	3	0	10
Investigation of oil palm harvesters' postures using RULA analysis	[8]	10 dec 14	6	0	4	3	0	13
A Cross-sectional Study of Musculoskeletal Symptoms and Risk Factors in Cambodian Fruit Farm Workers in Eastern Region, Thailand.	[43]	09 2018	7	3	5	4	1	20
Risk factors for musculoskeletal disorders in manual harvesting farmers of Rajasthan.	[34]	2018	7	3	5	4	1	20
Dissatisfaction with work as a risk factor of musculoskeletal complaints among foresters in Poland.	[64]	15 12 2017	7	3	5	3	1	19
The prevalence of low back pain and its associated factors in Thai rubber farmers.	[44]	30-Sep-16	9	3	4	4	1	21
Prevalence and Characteristics of Musculoskeletal Pain in Korean Farmers.	[48]	Accepted 7 Aug 2015	7	3	4	5	1	20

Musculoskeletal pain, depression, and stress among Latino manual laborers in North Carolina.	[55]	2016 November 01	9	3	4	6	1	23
Farmers' Cohort for Agricultural Work-Related Musculoskeletal Disorders (FARM) Study: Study Design, Methods, and Baseline Characteristics of Enrolled Subjects.	[49]	2016	7	3	3	6	1	20
Chronic low back pain among tobacco farmers in southern Brazil.	[54]	2015	8	2	4	5	1	20
Assessing Hmong farmers' safety and health.	[37]	2014	7	2	3	3	1	16
Child work in agriculture in West Bengal, India: assessment of musculoskeletal disorders and occupational health problems.	[39]	2013	8	3	4	3	1	19
Safety Knowledge and Changing Behavior in Agricultural Workers: an Assessment Model Applied in Central Italy.	[35]	2018	9	3	4	6	1	23
Risk factors for work-related injury among farm workers: a 1-year study.	[58]	06 de mayo de 2015	5	2	5	6	1	19
Design and evaluation of ergonomic interventions for the prevention of musculoskeletal disorders in India.	[40]	2014	3	3	1	1	0	8
Safety and health hazard observations in Hmong farming operations.	[37]	2014	5	3	3	3	0	14
Agricultural work and chronic musculoskeletal pain among Latino farm workers: the MICASA study.		2013	9	3	4	5	0	21
Ergonomic conditions in manual harvesting in Swedish outdoor cultivation.	[59]	2018	4	2	1	3	1	11
The prevalence of musculoskeletal disorder and association with productivity loss: a preliminary study among labour intensive manual harvesting activities in oil palm plantation.	[46]	2014	6	2	4	4	1	17
Development and Evaluation of Ergonomic Interventions for Bucket Handling on Farms.	[66]	2016	8	3	4	5	1	21
Ergonomic assessment of natural rubber processing in plantations and small enterprises	[6]	2016	4	3	2	5	0	14
Prevalence and risk factors of musculoskeletal disorders among Sri Lankan rubber tappers	[53]	2016	8	2	4	6	1	21
Risk factors of musculoskeletal disorders among oil palm fruit harvesters during early harvesting stage	[7]	2015	9	3	5	3	1	21
An evaluation of low back pain among farmers in Ireland	[36]	26 septiembre de 2012	9	2	5	6	1	23
Musculoskeletal Load Assessment of Farmers during Selected Agricultural Works	[67]	2015	7	2	5	4	1	19
Trunk kinematics and low back pain during pruning among vineyard workers - A field study at the Chateau Larose-Trintaudon		April 6 2017	8	2	5	3	1	19
The risk of musculoskeletal disorders due to repetitive movements of upper limbs for workers employed in hazelnut sorting		2013	6	2	3	4	1	16

Assessment of postural load during melon cultivation in mediterranean greenhouses	[15]	02 de agosto de 2018	7	2	4	5	1	19
Prevalence of Musculoskeletal Disorders Among Saskatchewan Farmers.	[33]	2015	8	3	5	6	1	23
Gender differences in prevalence of musculoskeletal disorders among the rice farmers of West Bengal, India.	[41]	August 2013	10	3	5	6	1	25
Ergonomics-related risk identification and pain analysis for farmers involved in rice field preparation.	[45]	07 de agosto de 2013	8	2	5	5	1	21
Prevalence of musculoskeletal disorder among agricultural workers in rural area of Tamil Nadu: A cross sectional study.	[42]	2017	9	3	5	5	1	23
Musculoskeletal Disorders and Agricultural Risk Factors Among Korean Farmers.	[50]	2016	9	3	5	5	1	23
Prevalence of musculoskeletal symptoms among agricultural workers in the United States: an analysis of the National Health Interview Survey, 2004-2008.	[56]	2014	9	3	5	5	1	23
Evaluation of Musculoskeletal Disorders Prevalence during Oil Palm Fresh Fruit Bunches Harvesting Using RULA.	[47]	2013	4	3	4	4	1	16
Ergonomic Checkpoint in Agriculture, Postural Analysis, and Prevalence of Work Musculoskeletal Symptoms among Indonesian Farmers: Road to Safety and Health in Agriculture.	[52]	enero de 2018	4	3	4	6	1	18
Ergonomic evaluation, with the RULA method, of greenhouse tasks of trellising crops.		2016	9	3	5	4	1	22
Average (A)			7.11	2.51	4.05	4.43	0.84	18.95
Standard Deviation SD			1.86	0.76	1.06	1.24	0.37	3.92

and OR=3.74 [58]. The second showed that 31% of vegetable farmers report physical problems due to manual harvesting, within of them 91% report back disorders followed by arms and hands problems [59]. In the third article it was determined the prevalence of total MSD's during the last 12 months in any part of the body, showing a value of 93%. When prevalence values were segregated for each part of body, the highest one was found in lower back with 58% followed by knee 45.5%, shoulder 32.9%, and neck 32.9% as the most representative results [60]. The fourth article showed the most significant prevalence related to time spent on biomechanical tasks, over shoulders p=0.024 or lifting objects under lower back p=0.001, knee p=0.019 [33]. And the last article showed a comparison of pain perceived by experienced and inexperienced farmers. In experienced farmers forearm p=0.0109, hand p=0.0026 and leg p=0.0015; and in inexperienced farmers neck p=0.0001 and lower back p=0.0001 [45].

Nevertheless, in general, Nordic Musculoskeletal Questionnaire (NMQ) [61] is used as a previously pre-validated version [62,63] in combination with another tools and adjusted modifications to the specific objective of each research. In a total of 11 articles which demonstrated this condition, four were combined with other questionnaires, one [64] of them with job satisfaction, another [44] with the Global Physical Activity Questionnaire (GPAQ), an additional one with a stress scale and the Peradeniya depression scale designed in Sri Lanka based on cultural traits [53]. One of the most interesting articles [36] showed a combination of questions with another from the National Farmers' Survey in Ireland (NFS), the Survey for Lifestyle, Attitudes and Nutrition in Ireland (SLAN) and the NMQ, used to find causes and consequences of low-back pain (LBP) in farmers; the article was evaluated with 23 points and ranked in the scale as Good Quality. In the statistical analyses, latter article also showed that probability of LBP in farmers operating larger farms was significantly higher (OR=1.71, 95% CI: 1.08-2.72) than in small farms, but it was found no statistical significance among those whom operate medium farms compared to farmers operating small farms.

The set of works mentioned above show that using of NMQ tool is adjusted to identify symptoms or musculoskeletal pathologies and allows a MSD's comparison in different regions of the body in order to develop epidemiological studies for large populations [57]. Even, it has been used in a long variety of fields of knowledge, as seen with some documents showing 68% of them were directed to activities of attending human health and social assistance [38].

Other results showed the use of observation methods such us RULA, REBA, OWAS, and OCRA. In general, these methods were accompanied by evaluation instruments to capture the respondent perception, inherently subjective models. Among this type of works were those by Putri [51] where only was used RULA method for tools redesigning based on user ergonomics. Another by Deros [8] where REBA was used to TMEs exposition

detection in agricultural workers. The OWAS method was used by Velásquez S, Valderrama D et al [65], focused on the study of work postures and postural risk in rubber plantation workers. The OWAS method was used in combination, NMQ and RULA by Thetkathuek [43], to assess posture risk in the work of migrant farmers in Thailand, and also in work by JAIN [34] to determine the prevalence of MSDs in farmers whom harvest manually. Combination of NMQ, REBA and OWAS methods was used by Das [39] to identify posture-related discomfort in child farm workers; statistical analysis showed that prevalence of discomfort was statistically significant in the group of exposed workers and greater than such in the control group for different body parts: neck (OR=9.3; p=0.000), shoulder (OR=12.5; p=0.000), elbow (OR=9.6; p=0.000), wrist (OR=8.4; p=0.000), hand (OR=9.3; p=0.000), upper back (OR=9.6; p=0.000), lower back (OR=72.1; p=0.000) and knee (OR=6.5; p=0.000).

In fact, in only two works were used direct measurement methods which demonstrates the limited use of motion capture technologies or postural angles. In first document by Tang [66], two interventions were evaluated to reduce risk of lumbar disorders produced by loads lifting through designing new tools, where each one of participants was equipped with a three-dimensional spinal electrogoniometer while lifting, transporting and throwing buckets of water, using both those two proposed methods and the one accustomed. Clearly this type of studies direct the efforts to prevent MSDs in agricultural activities and show that electronic aids allow a direct, exact and in real time evaluation, which contributes in this case to design ergonomic and suitable elements. In the second work [67], ergonomic evaluation tools were combined in order to determine musculoskeletal load in farmers' manual tasks. Upper limb tension occurred during manual handling of loads is measured based on the work effort index study, through an electromyography device (EMG), this way percentage of maximum contraction is measured. At the end, the obtained data were analyzed, both time-distance parameters and kinetic values so as to determine the correct corporal posture of farmers during muscular work.

In this point is particularly important to highlight the use of direct measurements which can be useful in developing of ergonomic interventions, in manual tools redesign, workplace adjustments, training guidelines on physical behaviour and ergonomic assessment methods. These objective interventions related to agricultural ergonomics must take into account the environment, activities and specific products [68]. Electronic elements of easy handling and access such as video capture or inertial sensors [69], can be directed to state a permanent control in real time to prevent MSD's in work activities with suspicion occurrence or presence of body discomfort/pain. This type of monitoring can contribute to achieve an improvement in levels of quality life of workers and mitigate public health overdemand which increases social security expenses.

Conclusion

Results showed that the most of evaluation techniques used are indirect: realized by self-administered questionnaires (SAQ) or self-reporting, this is an evidence of little ergonomic analysis in farmers doing manual work; most of the studies selected were catalogued as good or reasonable quality. This systematic review highlights the needing of adjusting tools in order to identify and evaluate potentially dangerous tasks by their movements and/or postures in real time.

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Conflicts of Interest

None of the authors declares conflicts of interest.

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