



Assessment of Muscular Activity and Postural Load During Coffee Harvesting Activities – A Case Study*

Evaluación de la carga muscular y postural de la actividad de recolección de café: caso de estudio

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Sebastián Peláez^a

Pontificia Universidad Javeriana, Bogotá, Colombia.
ORCID: 0000-0002-3399-9135

Leonardo Quintana

Pontificia Universidad Javeriana, Bogotá, Colombia.
ORCID: 0000-0001-5625-0111

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^a Corresponding author. Email: pelaezs@javeriana.edu.co

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Abstract

Objective: The goal of this case study was to analyze and evaluate the posture, force and repetitive movement risks associated with manual coffee harvesting activities. *Materials and Methods:* A self-discomfort report was administered to 28 participants, of whom 4 volunteered for an evaluation of postural load on muscular activity using electromyography and electrogoniometry. Eight upper limb muscles and the kinematics of the wrist and upper arm of the dominant arm were assessed. *Results:* The results of the self-discomfort report showed a greater demand, from the harvester's perception, in areas such as the back, lower back, knees and feet during a period of one week of work. The outcomes of the muscular activity assessment showed that the extensor carpi ulnaris (ECR) was the muscle with the highest demand during the assessment. The dynamic activity of the muscle exceeded 20% of the maximum voluntary contraction (MVC), which classifies coffee harvesting as a threatening activity. The postural load on the body segments revealed that wrist deviation was critical due to an abnormal range of the wrists during the activity. *Conclusions:* It is necessary to improve the working conditions of the coffee harvesters.

Keywords: mechanical demand; manual harvesting; ergonomics

Resumen

Objetivo: Analizar y evaluar los riesgos de postura, fuerza y movimientos repetitivos asociados con las actividades manuales de recolección de café. *Materiales y métodos:* Autorreporte de incomodidad en 28 participantes, de los cuales 4 se ofrecieron como voluntarios para una evaluación de la carga postural sobre la actividad muscular mediante electromiografía y electrogoniometría. Se evaluaron 8 músculos de las extremidades superiores y la cinemática de la muñeca y la parte superior del brazo dominante. *Resultados:* Los resultados del autorreporte arrojaron que existe una mayor demanda, desde la percepción del recolector, en áreas como la espalda, la espalda baja, las rodillas y los pies durante un periodo de una semana de trabajo. Los resultados de la evaluación de la actividad muscular mostraron que el extensor cubital del carpo era el músculo con mayor demanda durante la evaluación. La actividad dinámica del músculo excedió el 20% de la contracción voluntaria máxima, que clasifica la cosecha de café como una actividad amenazante. La carga postural en los segmentos del cuerpo reveló que la desviación de la muñeca era crítica, debido a un rango anormal de las muñecas durante la actividad. *Conclusiones:* Es necesario mejorar las condiciones de trabajo de los recolectores de café.

Palabras clave: exigencia mecánica; recolección manual; ergonomía

Introduction

Internationally, the agricultural sector is one of the most hazardous industries to the human body. Ergonomic risks and musculoskeletal disorders are important elements to consider in this sector [1], [2] due to the constant exposure of workers to them [1], [3]. In addition, according to Bureau of Labor Statistic (BLS) from 2014, 33.8 out of 10,000 workers had diseases related to musculoskeletal disorders. This is one of the highest disorder rates compared to other economic sectors [4].

Per the Labor Minister of Colombia, a combined 9.47% of labor illnesses were in agriculture, hunting and forestry. Additionally, illness data from the agricultural sector indicated a rate of 169.73 per 100,000 workers, and 37 qualified diseases corresponded to crop harvesting activities [5].

In 2014, the coffee crop represented 10% of the agricultural gross domestic product (GDP) in Colombia [6], and this is a motive for why this sector of agriculture was selected for the present research, which focuses on coffee harvesting tasks such as planting, cultivating and harvesting, which are activities that may be precursors to musculoskeletal disorders. These same factors have been included in past studies.

In Colombia, there are a few studies related to the working conditions in the agriculture sector (floriculture and coffee). In floriculture, researchers evaluated discomfort using surveys, a video analysis and direct measures of postural change and muscle activity. As a result, a patented prototype tool was designed for cutting, and it was evaluated in real conditions [7]-[10]. In coffee crop research, Oliveros and Sanz emphasized the advantages and disadvantages of mechanization in farming harvesting and the different tools that can help increase production [11].

On the other hand, international research in the agricultural sector has helped to identify factors that generate discomfort or fatigue in different parts of the body. These factors, including repetitive movements in awkward postures, extreme flexion and extension of the upper limb and lifting loads, have been evaluated using tools such as self-discomfort reports, Nordic questionnaires, observational analyses and direct measurements [3], [12]-[20].

The activity of Colombian coffee harvesters depends on the cropping stations; normally, the first harvest is from May to June, and the other harvest is from September to October. Additionally, the activity starts at 5 a.m. and continues until 5 p.m. On some farms, depending on the owners, food is provided for the harvesters. The cropping time depends on the size of the farm; normally, it will take them two or two and a half weeks to harvest a medium-sized farm (10 hectares). In Colombia, we have different topography conditions. The coffee is on the slopes of the mountains to the top of the mountains in the coffee triangle region, but normally, it is common to find the same conditions in other regions.

Methodology

Participants

This research involved 28 volunteers from a farm in El Caimo, Quindio, Colombia, and only coffee harvesters participated. The demographic characteristics of the study population are shown in Table 1.

Table 1. Demographic data

Demographic Data	
Men	71%, n=20
Women	29%, n= 8
Age range	18 to 73
Average Age	38.2 (SD=14.6)
Left Handed	n=28

Source: Authors own elaboration.

Experimental design and procedure

The experimental study analyzed the working conditions of coffee harvesting activities, considering the discomfort of the workers in their daily tasks. The self-discomfort report was administered for five days, three times during the working day [12]. A postural and muscular analysis was applied using electrogoniometry (EGM) and electromyography (EMG), while the worker performed the activity for 20 minutes. A video recording was made to analyze three specific postures: arms up, arms in a neutral position and arms down [8], [12].

Condition of the body with respect to the task

A self-report questionnaire of discomfort was administered at the beginning of the workday and at the middle and at the end of the day for each day on a 5-day workweek. The questionnaire consisted of a human figure, on which 16 parts of the human body were shown. The volunteer had to indicate the level of discomfort for each part of the body using a scale from 0 to 10 (Borg's Scale).

Physical workload

To analyze the mechanical demand associated with the postural load and muscular activity, it was necessary to take 20-minute measurements for each person at the beginning of the workday. The variables for postural load were flexion-extension and radial-ulnar deviations of the wrist (SG65, Biometrics Ltd, UK) and flexion and extension of the shoulder (SG150, Biometrics Ltd., UK). Signal tests were recorded at an initial reference position of 0°. The muscular activity was evaluated using EMG sensors (SX230, BioMetrics Ltd., UK) on the

skin surface; they had a 10 mm diameter and were separated by a distance of 20 mm to preamplify the signal. The sensors were placed on the extensor carpi radialis (ECR), extensor carpi ulnaris (ECU), flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), biceps (B), deltoid (D), extensor carpi radialis nondominant arm (ECR ND) and biceps nondominant arm (B ND). The correct positions of the sensors were determined by touch, according to the length of each muscle. Before the sensors were attached, the skin was cleansed following European standardized norms [21]-[23]. The signal was filtered with a bandwidth of 20-460 Hz, and a band reject filter at 60 Hz was used to reduce the interference induced by the electric network (i.e., interference below 5 μ V and input impedance higher than 1000 Ω).

Analysis of the results

Depending on the number of reports greater than 3 on the level of discomfort reported by the volunteers, a color was assigned to classify the parts of the body that were identified as the most affected by the participants, as shown in Table 2.

Table 2. Classification of the discomfort levels

COLOR	DISCOMFORT GREATER THAN 3	LEVEL
Blue	Less than 10%	Very Low
Green	From 10% to 20%	Low
Orange	Less 20% to 30%	Medium
Red	Equal or greater than 30%	High

Source: Authors own elaboration.

The video recordings were analyzed using chronicle activities with the software Actogram Kronos 2 (France), where three arm postures were evaluated (arms up, arms in a neutral position and arms down). The ergonomic chronicle, actogram software and video, were used when the arms were in the different positions mentioned above.

Surface electromyography signals recorded in ASCII were processed using algorithms developed in MATLAB R 2013a (USA). The RMS signal (root mean square) was estimated from a moving window of 200 ms [8] and normalized with each muscle's MVC (Maximum Voluntary Contraction) record. P10 (static level), P50 (medium level) and P90 (dynamic level) were estimated using the amplitude probability distribution function (APDF).

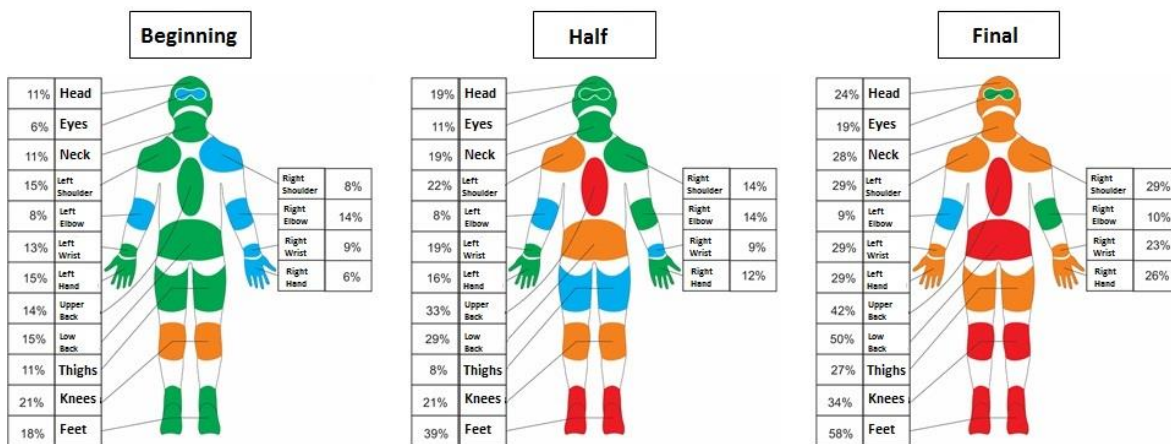
Posture load information signals were processed by the data link software from the equipment (Biometrics Ltd., UK), recorded in ASCII (after filter) and measured in degrees. The angles of interest were associated with the corresponding APDF analyses, particularly emphasizing the averages and considering P10, P50 and P90 data. All records were processed and analyzed in SPSS 23.0 (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.). Given the particular task, the study prioritized the body segments that fell out of the neutral ranges.

Results

Activity self-report

At the beginning of the workday, the discomfort was very low, except for in the knees, in which the discomfort was medium. The other two reports from the same workday showed an increase in discomfort due to exposure to the working conditions and the fatigue of the human body. The last report from the working day indicated in high discomfort, as shown in Figure 1.

Figure 1. Self discomfort report results

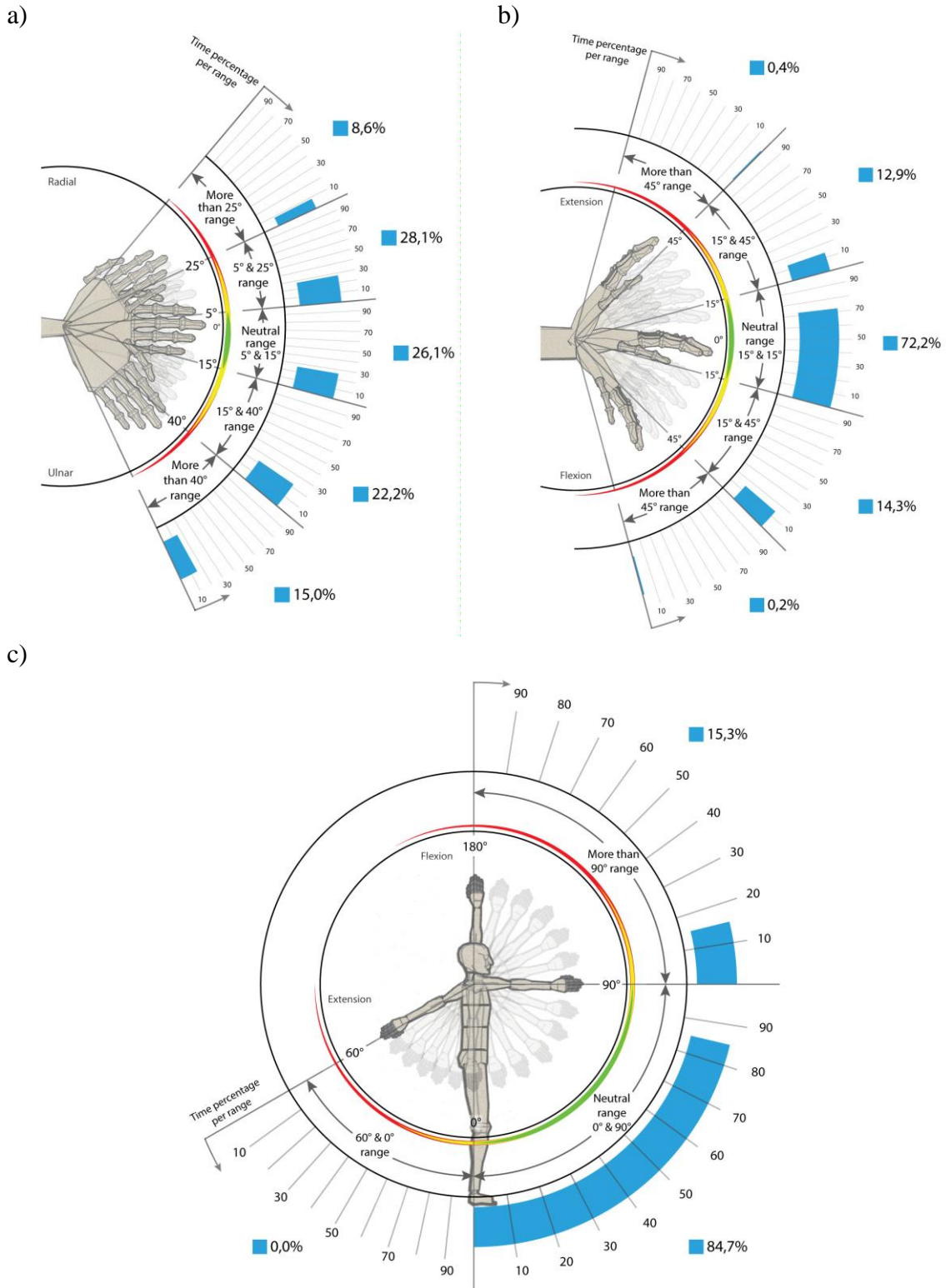


Source: Authors own elaboration.

Postural load of the studied corporal segments

The results from the corporal segments showed that during coffee harvesting activities, the flexion and extension of the wrist was in a neutral posture 72.2% of the time. The ulnar deviations of the wrist in the neutral range represented 37.2% of the time. However, the deviation presented out of the range was divided into two ranges: 15% of the ulnar deviation was greater than 40°, and 22.2% of the time in ulnar deviation was between 15° and 40°. In addition, the radial deviation was out of the neutral range 36.7% of the time. Finally, shoulder flexion and extension were in the neutral range 84.7% of the time, and only 15.3% of the time did the work involve flexion greater than 90° (Figure 2 and Table 3).

Figure 2. Corporal segments: a) wrist deviation, b) wrist flexion and extension, and c) shoulder flexion and extension



Source: Authors own elaboration.

Table 3. Statistics of the GNM analysis

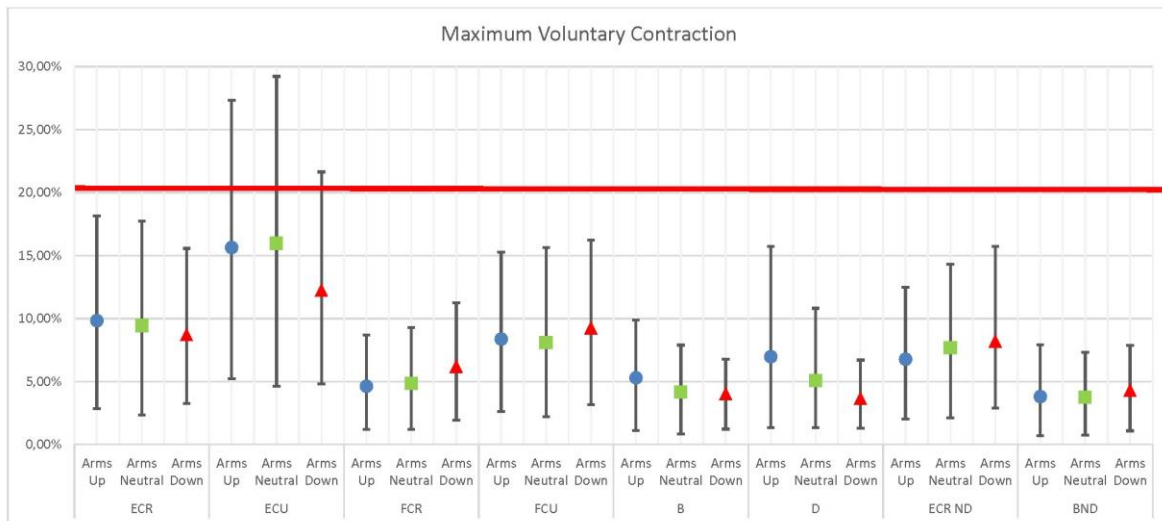
Statistics				
		Wrist_Flex_Ext	Deviation_Rad_Uln	Shoulder_Flex_Ext
N	Valid	248288	248288	248288
	Missing	0	0	0
Mean		0,7304	-7,9352	-20,5978
Standard Error		0,02914	,05473	,03650
Median		1,6000	-3,7000	-21,6000
Mode		0,00	14,80	4,80
Std. Deviation		14,51926	27,27167	18,18870
Variance		210,809	743,744	330,829
Range		128,20	174,90	118,30
Percentiles	10	-17,7000	-46,6000	-44,6000
	50	1,6000	-3,7000	-21,6000
	90	18,1000	23,1000	4,4000

Source: Authors own elaboration.

Muscular activity of the upper limbs

The extensor carpi ulnaris was the most strained muscle in the static level (P10) with an MVC of 4.6% and a dynamic level (P90) of 29.3% of the MVC. This was the highest level reached during the neutral posture of the arms activity. In addition, it was identified that the biceps muscle of the nondominant arm had less muscle activity, as shown in Figure 3 and Table 4.

Figure 3. Maximum Voluntary Contraction by arm positions



Source: Authors own elaboration.

Table 4. EMG analysis (percent)

		Mean	Percentile 10	Percentile 90
ECR	Arms Up	9.84	2.84	18.15
	Arms Neutral	9.45	2.35	17.74
	Arms Down	8.72	3.26	15.57
ECU	Arms Up	15.64	5.23	27.34
	Arms Neutral	15.99	4.63	29.23
	Arms Down	12.25	4.82	21.65
FCR	Arms Up	4.63	1.20	8.70
	Arms Neutral	4.86	1.20	9.27
	Arms Down	6.19	1.95	11.27
FCU	Arms Up	8.38	2.63	15.28
	Arms Neutral	8.12	2.22	15.64
	Arms Down	9.25	3.18	16.23
Biceps (B)	Arms Up	5.32	1.12	9.88
	Arms Neutral	4.19	0.82	7.90
	Arms Down	4.04	1.23	6.77
Deltoids (D)	Arms Up	6.98	1.33	15.73
	Arms Neutral	5.11	1.34	10.82
	Arms Down	3.66	1.28	6.71
ECR ND	Arms Up	6.79	2.03	12.49
	Arms Neutral	7.69	2.12	14.30
	Arms Down	8.19	2.88	15.73
BND	Arms Up	3.82	0.72	7.90
	Arms Neutral	3.76	0.74	7.31
	Arms Down	4.30	1.09	7.86

Source: Authors own elaboration.

Discussion

In this case study, a methodology was established to determine the actual working conditions of the Colombian coffee sector, specifically during the manual coffee harvest, and the hope is that this study will serve as a starting point for future research. This case study also attempted to identify risk factors in manual coffee harvesting from the perspective of the worker and to measure muscle activity and study angular segments, in which the risk of injuring the extensor carpi ulnaris increases.

This case study only focused on the main activity in coffee harvesting; it was necessary to evaluate the tools and how those tools affected the human body. A similar study was conducted in Nicaragua [12], in which they had a basket instead of a bag. We also followed an experimental design used for flowering crops that was developed in Colombia [9].

It is also known that the risks will not disappear; rather, the risk will probably be transferred to another region of the body, and it is necessary to use different working methods or technology to improve the performance of the activity in different working conditions. Additionally, it is necessary to realize that in Colombia, the topography will affect the task conditions, and it will probably also affect human body postures. It is known that different kinds of mechanization will improve production [11], but it is necessary to evaluate that technology in Colombia.

Conclusions

In summary, this case study shows that throughout the workday, there is fatigue that is evident with a high level of discomfort, especially in the lower limbs, in which the workers reported the most distress. Nevertheless, after performing an evaluation of muscular exposure on workers, this study found that the upper limbs are the area that needs to be evaluated, especially in the case of the extensor carpi radialis (ECR), which contracted at 20% the MVC in the three positions studied. Additionally, the results of the body segment evaluation indicated that most of the time segments were in neutral ranges, except for the wrist, which deviated the combination of risk factors in the muscles and body movements could generate carpal tunnel syndrome over time.

For future research, it is necessary to analyze the lower limbs, including but not limited to the back, using electromyography and electrogoniometry and to determine the impact that the worker experiences due to the load from the collector bucket during manual coffee harvesting activities.

Acknowledgements

The purpose of this case study was to diagnosis the working conditions present in coffee harvesting activities in Quindío, Colombia. This research was part of a project developed within the Colciencias Young Researcher program and the Centro de Estudios de Ergonomía from the Pontificia Universidad Javeriana.

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