# Either negative or no correlations between subjective effort surveys and objective directly-measured workloads in Hispanic migrant farmworkers

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Abstract

## 1. Introduction

Migrant farmworkers…

Relationship between subjective and objective measures has been studied.

The objective of this study was to find the correlations between the objective and subjective evaluation of the exertion at the overall level as well as at local body parts.

## 2. Methods

### 2.1 Participants

Twenty-four Hispanic male seasonal apple pickers participated in the study. The participants’ ages were on average 28.4 years (range 18-47 years). Their experience as farmworkers in the United States were on average 3.4 years (range 1-14 years). The participants were equally divided into three groups to perform different harvesting methods: 1.) picking apples at the lower level of the trees up to their reach distance overhead, denoted as “Ground”, 2.) using a ladder to pick apples from the full trees, denoted as “Ladder”, and 3.) picking apples at the upper level of the trees while standing on the semi-automated mobile orchard platform, denoted as “Platform”. All the participants worked in the same schedule from 7:00 to 15:30 with a break during 9:30-10:00.

The protocols for participant recruitment and data collection were approved by the university’s Human Subject’s Division Institutional Review Board. All the participants provided their informed consent.

### 2.2 Data collection

#### 2.2.1 Heart rate monitors

Participants’ heart rate in beats per minute were collected at 1 Hz throughout a full work day using a heart monitor *(Polar RS100CX; Polar Electro Inc., Lake Success, NY)*.

#### 2.2.2 Electromyography

Local muscle activity signal was collected from both left and right trapezius muscles at 1,000 Hz using single-use disposable pre-gelled electrodes (Blue Sensor N; Ambu; Ballerup, Denmark) connected with pre-amplifiers wires to a battery-powered portable data logger (Biomonitor ME6000; Mega Electronics Ltd.; Kuopio, Finland).

#### 2.2.3 Subjective ratings: Borg RPE, Omni RPE and Borg CR10

Borg RPE and Omni RPE were used as subjective measures of overall effort while Borg CR10 was used as a subjective measure of local discomfort. The Borg RPE and Borg CR10 translated into Spanish were previously validated in the field (Thamsuwan et al., 2019). In addition, the Omni RPE with pictures of human wearing an apple bag were included (Figure 1).

The measurement time points of the effort surveys were:

* T0: right before start the work shift
* T1: after working for 150 minutes since the beginning of the work shift
* T2: after taking a break for 30 minutes, immediately after the 150-minute work period
* T3: at the end of 8-hour work sift

### 2.3 Data processing

#### 2.3.1 Metabolic load: percent of heart rate reserve

Raw heart rate data were filtered using a 5-point moving median to eliminate measurement artifacts. The mean heart rate for each period of interest, i.e. corresponding to the effort survey, were extracted.

The metabolic load was calculated in terms of the percent of heart rate reserve during the work period based on the equations (i), (ii) and (iii) where is the maximal heart rate of an individual, is the heart rate measured while the participant was sitting before start working, is the heart rate measured while the participant was working, and is the resting heart rate of an individual.

Equation (i)

Equation (ii)

Equation (iii)

%HRR was square-root transformed to meet the assumption of normality and verified by Shapiro-Wilk test. Figure X shows the histograms and Q-Q plots of the data before and after the transformation.

#### 2.3.2 Muscle fatigue: EMG median power frequency

Raw EMG signal were filtered with a 20-450 Hz bandpass filter. By converting a time domain signal into frequency domain, median power frequency of the EMG was calculated for every 10 minutes. Then we conducted a linear regression of MPF on time for each trapezius side and each individual subject based on to the question (iv).

Equation (iv)

The slope of the time factor () from the equation (iv), which represented an increase or decrease in MPF over the work period, was used in the analysis to identify the association between muscle fatigue and the changes over time in the subject-reported local discomfort.

#### 2.3.3 Effort survey

The effort surveys including Borg RPE, Omni RPE and Borg CR10 at the specific time point were analyzed in terms of the increase or decrease as compared to the values at the beginning of the work shift.

### 2.4 Statistical analysis

For the overall effort or full body exertion, we calculated a correlation between %HRR and Borg RPE, and a correlation between %HRR and Omni RPE. For the local discomfort or muscle fatigue, we calculated a correlation between muscle fatigue (EMG MPF) and Borg CR10.

Initially, Pearson’s correlations between the subjective and objective measures were calculated. Then we conducted linear regressions to adjust for known confounders; that is, the harvesting method and the time of measurement for the overall exertion, and the harvesting method and the side of trapezius (dominant and non-dominant) for the local discomfort.

As the dataset was fairly small, that is, 24 participants for overall effort and 20 participants for local discomfort due to EMG data lost, we set the level of statistical significance at 0.90. All the statistical analysis was conducted using R programming language.

## 3. Results

### 3.1 Overall effort: %HRR as metabolic load, Borg RPE and Omni RPE

Based on the Shapiro-Wilk test, initial %HRR was not normally distributed (p = 0.013). After the %HRR was square-root transformed, the data became normally distributed (p = 0.48). Figure 2 shows the histograms and the QQ-plots of data before and after the transformation.

The metabolic load, i.e. %HRR, among each group of workers at each time of measurement is shown in Figure 3. In general, %HRR was between 0.15 and 0.75 after the participants had worked for 90 minutes (T1). Then the %HRR significantly dropped after a 30-minute break (T2) and increased again at the end of the work shift (T3) (p-value < 0.0001). According to Figure 5, the %HRR in the Ladder workers were higher than the %HRR in the Ground and Platform groups at T1 and T3.

The increases in Borg RPE from the beginning of the work shift were greater at the end of the work shift (T3) as compared to the other time (p-value < 0.0001) as shown in Figure 4. However, the increases in Borg RPE over time were not significantly different across the harvesting methods.

The increases in Omni RPE from the beginning of the work shift were also greater at the end of the work shift (T3) as compared to the other time (p-value < 0.0001) as shown in Figure 5. Moreover, at T3, the increases in Omni RPE from the beginning of the shift were significantly smaller in the Ground workers than in the Ladder and Platform groups (p-value = 0.05).

### 3.2 Association between objective metabolic load and subjective overall effort

Without adjusting for neither work period (T1, T2 and T3) nor harvesting method (Ground, Ladder and Platform), the correlation coefficient between the %HRR and the Borg RPE difference was 0.152 with the statistically insignificant p-value of 0.20. Similarly, the correlation coefficient between the %HRR and the Omni RPE difference was 0.169 also with the statistically insignificant p-value of 0.16.

However, when adjusted for the work period and the harvesting method, which had significant effect on the %HRR, the correlation coefficient between the %HRR and the Borg RPE difference became -0.0063 with the p-value of 0.048. In the same way, the correlation coefficient between the %HRR and the Omni RPE difference became -0.0127 with the p-value of 0.027.

With the confounding effect, the analyses were further stratified by the harvesting method and by the work period. On one hand, when the analysis was stratified by the harvesting method and the effect of the work period was adjusted, significant correlations between the %HRR and the Borg RPE difference were found only in the Ground and Ladder groups (p-values = 0.072 and 0.044, respectively), and a significant correlation between the %HRR and the Omni RPE difference was found only in the Ladder group (p-value = 0.078).

On the other hand, when stratified by the work period, i.e. the time point of measurement, Figures 6 and 7 showed the negative correlations between the objective and subjective measures in all time points of measurement. Nevertheless, the correlations between the %HRR and the Borg RPE difference were found statistically significant only at T1 and T3 (both p-values were 0.087). Meanwhile, none of the correlation coefficients between the %HRR and the Omni RPE were statistically significant. Note that the reason might be due to the fact that stratification reduced the sample size and, consequently, there was not enough power to detect a significant correlation in each group.

### 3.3 Local discomfort: EMG MPF as muscle fatigue and Borg CR10

The EMG MDF in 10-minute windows of all participants had a bi-modal distribution (Figure 8) due to the difference between dominant and non-dominant muscle sides and the difference across harvesting methods as well as across the time of the day. These differences were adjusted using linear regression. After removing, i.e. adjusting for, the effects of muscle side () and the effects of the participants () who were different across the harvesting methods, the slope of the time variable () was used for analysis to find correlation between EMG MDF and Borg CR10. Figure 9 shows the distribution of the while the Shapiro-Wilk test indicated that the data could be normally distributed (p-value = 0.059).

Muscle fatigue, i.e. the EMG MPF, reduced over time as shown by the negative slope ( = -0.0056) in the regression equation (iv) (p-value < 0.0001). This is in accordance to the results of muscle activity from the previous study (Thamsuwan and Johnson, 2022).

The Borg CR10 difference between the beginning and the end of work shift by each harvesting method is shown in Figure 10. The increases in Borg CR10 from the beginning to the end of the work shift was higher in the Platform group than in the Ground and Ladder groups. According to the Kruskal-Wallis tests for nonparametric data, the harvesting method had a statistically significant effect on the Borg CR10 increase over time (p-value = 0.013) but the side of trapezius did not (p-value = 0.51).

### 3.4 Association between objective muscle fatigue and subjective local discomfort

Regardless of whether we accounted for the muscle side, work period or harvesting method, there was no correlation between the slope in the equation (iv) and the Borg CR10 difference. That is, there was no relationship between the EMG mean power frequency representing muscle fatigue and the Borg CR10 increases or decreases over the work period. Figure 11 shows the scatter plot between the on the y-axis and the Borg CR10 difference between the start and the end of work shift.

## 4. Discussions

There were negative correlations between the objective and subjective measures of overall effort.

There was no correlation between the objective and subjective measures of local discomfort.

Despite being translated and adapted to the culture, the subjective effort surveys, namely Omni RPE, Borg RPE and Borg CR10, may not be suitable for this population. Therefore, they should not replace the objective direct-measured ergonomic assessment.

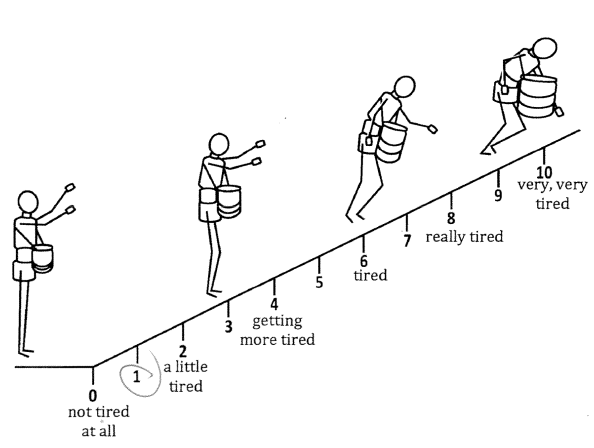


Figure 1. Omni RPE used in this study

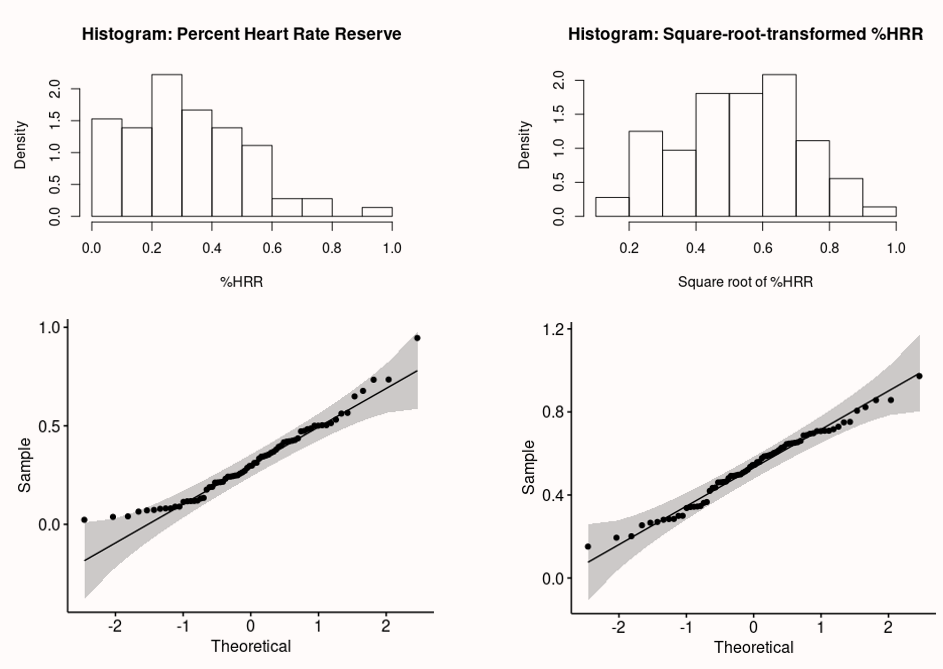


Figure 2. Histograms and Q-Q plots of the %HRR before and after square-root transformed

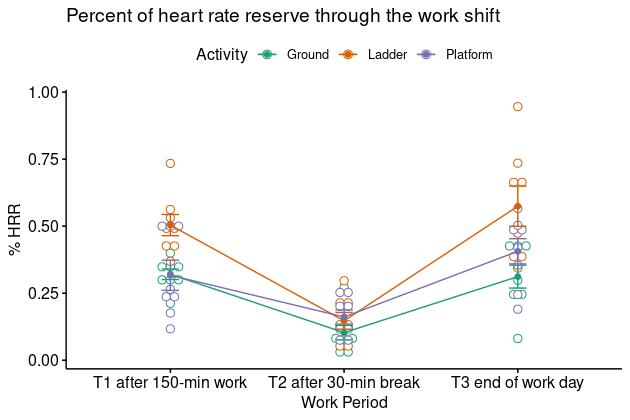


Figure 3. %HRR measured among each group of workers at each work period

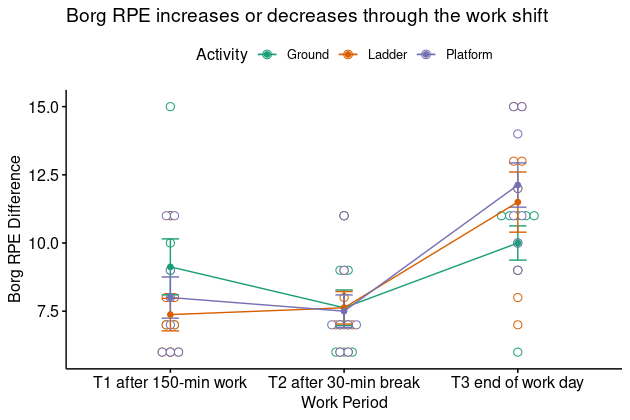


Figure 4. The difference in Borg RPE from the beginning of work reported by each group of workers at each work period

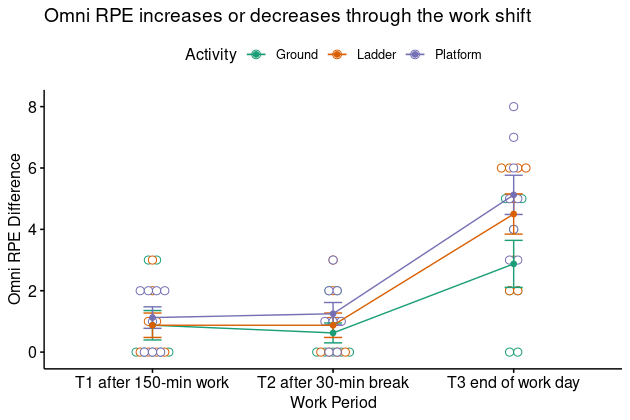


Figure 5. The difference in Omni RPE from the beginning of work reported by each group of workers at each work period

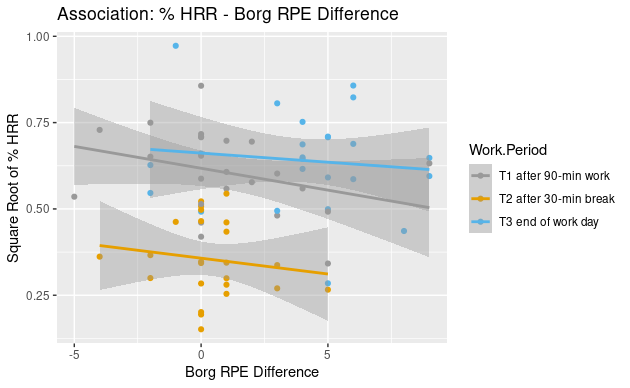


Figure 6. The association between %HRR and Borg RPE difference from the beginning of work shift

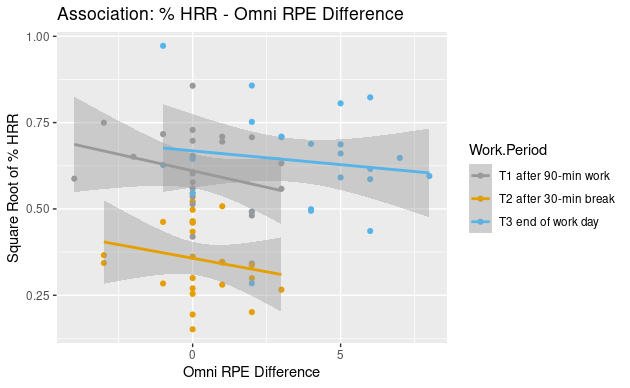


Figure 7. The association between %HRR and Omni RPE difference from the beginning of work shift

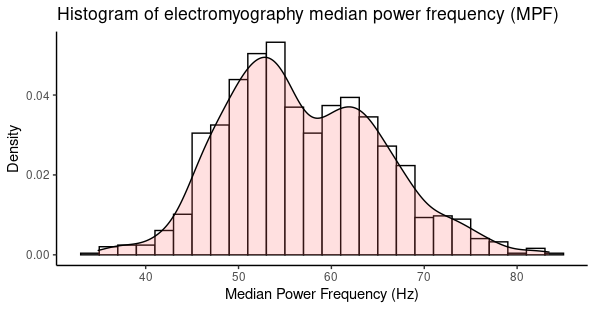


Figure 8. The histogram showing bi-modal distribution of EMG median power frequency

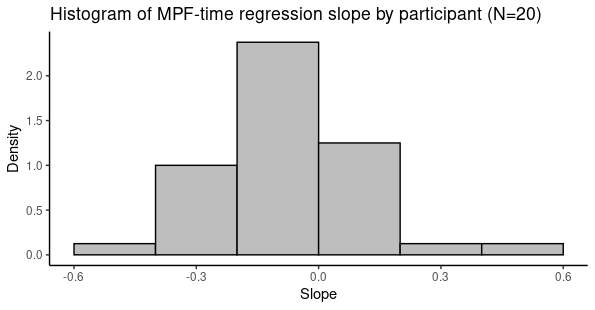


Figure 9. The histogram of the EMG median power frequency regression slope ()

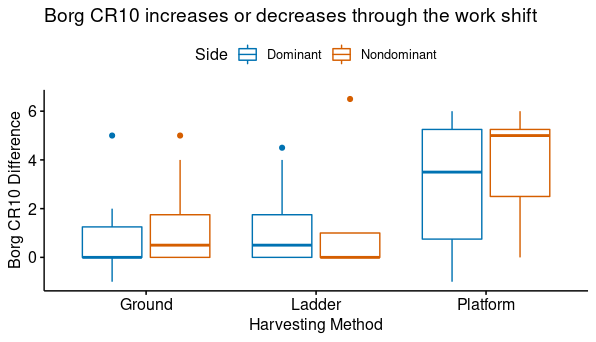


Figure 10. Borg CR10 difference between the beginning and the end of work shift by harvesting method and muscle side

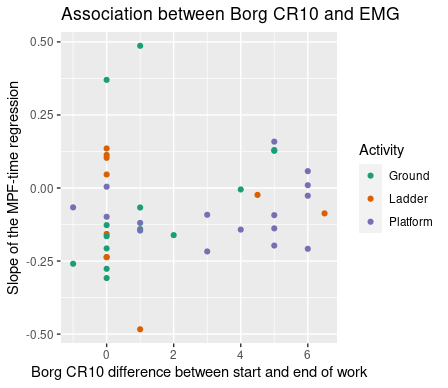


Figure 11. The scatter plot of Borg CR10 difference on x-axis and the on y-axis