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Effects of lifetime occupational pesticide exposure on postural control among farmworkers and non-farmworkers

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Abstract

Objective—Assess potential chronic effects of pesticide exposure on postural control, by examining postural balance of farmworkers and non-farmworkers diverse self-reported lifetime exposures.

Methods—Balance was assessed during quiet upright stance under four experimental conditions (2 visual $\times$ 2 cognitive difficulty).

Results—Significant differences in baseline balance performance (eyes open without cognitive task) between occupational groups were apparent in postural sway complexity. When adding a cognitive task to the eyes open condition, the influence of lifetime exposure on complexity ratios appeared different between occupational groups. Removing visual information revealed a negative association of lifetime exposure with complexity ratios.

Conclusions—Farmworkers and non-farmworkers may use different postural control strategies even when controlling for the level of lifetime pesticide exposure. Long-term exposure can affect somatosensory/vestibular sensory systems and the central processing of sensory information for postural control.

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Conflicts of interest:

All authors have none to declare.

Introduction

Occupational exposure to pesticides is an important health concern for US farmworkers. A recent report of pesticide use in US agriculture found that ~230 million kilograms of pesticides were used in 2008¹. Pesticides can be classified by chemical type, for example as organophosphates (OPs), carbamates, and pyrethroids. Acute exposure to these chemical compounds can lead to immediate toxicological symptoms, including dizziness, muscle ache, nausea, and seizures²⁻⁴. In addition, acute or repeated exposure has been associated with declines in cognitive/neurological function and neurobehavioral performance⁵⁻⁸, involving deficits in cognitive, somatosensory or psychomotor functions, and postural control. Evidence for such adverse health effects, however, is inconsistent for low and moderate levels of prolonged exposure^{6,9-11}.

Measuring postural sway during quiet upright stance (also known as static posturography) has been used in a few studies as a potentially sensitive, non-invasive approach to assess subclinical neurotoxic effects of pesticides^{7,8,12,13}, or other neurotoxins¹⁴⁻¹⁶, on functional aspects of the central nervous system (CNS). Maintaining postural balance is a complex motor skill/process, requiring CNS processing, integration of afferent input from multiple sensory systems (visual, vestibular, and somatosensory), and motor control^{17,18}. Neurotoxic effects of pesticides could adversely affect several of these and related pathways, and could manifest as postural control deficits.

Previous studies^{7,8,13} have indeed reported that agricultural workers (i.e., likely more frequently exposed to pesticides) exhibited lower postural balance performance compared to non-agricultural workers. Immediate adverse effects of recent OP pesticide exposure on postural balance also have been reported^{12,19}. In these studies, the exposed group was classified as an occupational group, with some consideration of job duration or pesticide metabolites. Yet, to examine the potential chronic health effects of pesticide exposure, the level of lifetime exposure is necessary^{6,20}, but has not been well considered in previous studies, particularly for vulnerable populations. Migrant farmworkers are a vulnerable population; most are immigrants, with low incomes, limited educational attainment, and limited access to health care, who experience high rates of occupational injury and illness²¹⁻²³. Further, farmworkers generally report having limited control of their workplace^{24,25}.

Understanding the dynamic structures of postural sway can provide distinct information on the adaptability and stability of postural control²⁶⁻²⁸. To characterize such structures, there has been growing emphasis on nonlinear analytical approaches (e.g., entropy- or fractal-based methods), complementary to conventional linear analytical methods typically used to assess and quantify postural sway (e.g., amplitude, velocity, or area). For example, postural sway complexity was negatively associated with frailty among older adults, while sway amplitude was not²⁹. Further, older adults who experienced a fall exhibited lower sway complexity than both young adults and older adults who had not fallen³⁰. Using nonlinear analytic approaches thus may be particularly important given that occupational falls accounted for ~30% of all lost workday cases among farmworkers reported in 2013³¹.

However, nonlinear analytical approaches have not been used to examine the relationships between pesticide exposure and postural control.

The purpose of this study was to assess the effects of occupational pesticide exposure on postural control, considering the level of lifetime exposure. We further examined whether such effects differentially affected the postural control of migrant Latino farmworkers vs. non-farmworker Latino immigrants (who have not been employed in occupations involving frequent pesticide exposure). This research is a part of a larger ongoing effort to address the health of Latino farmworkers in eastern North Carolina, through which postural balance and questionnaire-based lifetime pesticide exposure data were obtained from a large sample of Latino immigrants. Here, postural balance was assessed based on measures of sway, obtained under several conditions designed to highlight select aspects of the postural control system, and using both conventional and contemporary (nonlinear) analytical approaches.

METHODS

Overview

The data for this analysis were collected as part a research supplement to PACE4^{see 20 for more details}, a community-based participatory research project examining pesticide exposure and neurological outcomes for Latino farmworkers, with a comparison group of non-farmworkers. Community partners were the North Carolina Farmworkers Project (Benson, NC), which serves farmworkers in eastern North Carolina, and El Buen Pastor Latino Community Services (Winston-Salem, NC), which serves Latino immigrant families in Winston-Salem, NC. The study protocol was reviewed and approved by the Wake Forest School of Medicine and the Virginia Tech IRBs, and all participants provided signed informed consent. PACE4 data collection spanned three years (2012–2014). In May–June 2012, participants completed a baseline questionnaire that contained items to construct measures of personal characteristics (e.g., age, education, current occupation), and to construct measures of lifetime pesticide exposure using items adapted from the National Institute of Neurological Disorders and Stroke (NINDS) Common Data Elements³². Participants completed up to four follow-up contacts at monthly intervals in 2012; in 2013, they completed up to four follow-up contacts at monthly intervals beginning in June for farmworkers and July for non-farmworkers; and in 2014, participants completed a single follow-up contact. Data used in this analysis were collected as part of the 2013 follow-up contacts.

Participants

To be included in the larger PACE4 study, participants had to be aged 30 to 70 years, and without physician-diagnosed diabetes. Farmworkers had to be currently employed in agriculture and have done so for at least three consecutive years. Non-farmworkers could not have been employed for the past 3 years in jobs that expose workers to pesticides, including farm work, forestry, landscaping, grounds keeping, lawn maintenance, and pest control. All participants self-identified as Latino or Hispanic, and almost all spoke Spanish as their primary language. Participants were recruited with the assistance of the community partner organizations, with 235 farmworkers and 212 non-farmworkers completing the

baseline interview in 2012. For 2013, 108 farmworkers and 68 non-farmworkers were located. Reasons for attrition included a high rate of migration for work, farmworkers not returning to the farms for which they had been workers, and changes to contact information (e.g., phone number, address) precluding reminder.

A total of 77 farmworkers and 59 non-farmworkers completed this postural control component of the study; all were male. All PACE4 participants were eligible to complete postural control testing (see below) if they reported no musculoskeletal injuries that could affect postural control and no experience of dizziness or vertigo during their daily life. Additionally, farmworker participants generally engaged in tobacco production, and so might have been affected by nicotine poisoning, Green Tobacco Sickness. Its symptoms include nausea, dizziness, and headache, and which are typically of short duration and relieved without medication^{33,34}. Given these potential influence of such symptoms on balance, we thus ensured that farmworker participants did not work in tobacco production one or two days prior to balance testing, and that they did not show any relevant symptoms on the day of balance data collection. All participants who met the inclusion criteria were asked to participate in this study component; all agreed to participate and were included if time were available. Data from two non-farmworkers were removed from statistical analyses, as these individuals previously did farm work for many years, and they exhibited extreme values in the level of lifetime exposure and balance measures relative to the remaining group of non-farmworkers.

Farmworker and non-farmworker participants were similar in terms of age and the time of day when balance measurements were conducted. Group differences in body mass and stature approached significance with farmworkers being somewhat heavier and taller on average (Table 1). They did not differ in BMI, self-reported back pain, or self-reported neck pain. They differed in mean sleep duration, with farmworkers reporting more sleep hours. Measures of historical pesticide exposure were derived from self-reported data collected during the baseline interview, and which are described in detail elsewhere²⁰. Briefly, lifetime pesticide exposure was the sum of age periods over which participants were exposed to residential and occupational pesticides. Years of occupational pesticide exposure was the total number of years that participants held jobs in which they mixed, applied, or were exposed in some other way to pesticides. Farmworkers had greater lifetime pesticide exposure and years of occupational pesticide exposure.

Experimental Design and Procedures

A repeated measures design was used, with participants completing two trials of quiet, upright stance under each of four experimental conditions (all combinations of 2 visual $\times$ 2 cognitive difficulty). The cognitive difficulty conditions were with and without a concurrent cognitive task, while the visual conditions were eyes-closed (EC) and eyes-open (EO). The cognitive task required verbally counting backward by one from a randomly selected three-digit number³⁵; this was done in the participants self-selected language. Note that adding a concurrent cognitive task competes with central processing resources for postural control, while removing vision increases reliance on somatosensory and vestibular information^{17,35}.

Thus, the set of four conditions was intended to challenge different systems involved in postural control.

For the stance trials, participants stood barefoot on a force platform (AccuGait, AMTI™, Watertown, MA) in a quiet room. Each trial lasted 60 seconds, during which participants were asked to stand as still as possible, with arms at their sides, feet together, and head pointed straight ahead. For the EO condition, participants were asked to stare at a cross mark placed 1 m anterior to and at the vertical level of their eyes. The presentation order of experimental conditions was fully randomized, and a 1-min rest period was given between trials. For each participant, a custom Labview™ (National Instruments, Austin, TX) program was used to generate the presentation order and three-digit numbers for the cognitive task, as well as auditory tones to control the beginning and ending of standing trials and rest periods. Prior to data collection, participants completed several practice trials for familiarization.

Data Processing

Tri-axial ground reaction forces and moments were sampled at 100 Hz using the force platform. Subsequently, these measures were low-pass filtered (Butterworth, 18 Hz cut-off frequency, 4th order, bi-directional) and transformed to derive center-of-pressure (COP) time series in the antero-posterior (AP) and medial-lateral (ML) directions using standard methods³⁶. Mean COP velocity (MV) and area have relatively good reliability among conventional COP-based measures of postural sway^{37,38}, so MV in the AP and ML directions and 95% prediction ellipse area (PEA) were computed for each standing trial, as defined in Prieto et al.³⁹ and Schubert & Kirchner⁴⁰, respectively.

The complexity of each COP time series was estimated in the AP and ML directions, using the multiscale entropy (MSE) algorithm (see Costa et al.²⁶ for mathematical details) implemented in the Physiologon toolkit software⁴¹. MSE calculates sample entropies over predefined multiple time scales (t_s), to account for multiple time scale structures of a physiologic signal. MSE yields a complexity index (CI) as an outcome measure, by integrating entropy values over the timescales. Thus, given two time series, high entropy values over a wider range of time scales (i.e., high CI value) indicate higher complexity. To minimize temporal correlation and non-stationarity⁴², we calculated CI values with $t_s = 8$ from differenced AP and ML COP time series, and required parameters for the MSE (length $m = 4$, and specific tolerance $r = 0.15$) were set following the procedures of Ramdani et al.⁴². All data processing was completed using Matlab 7 (Mathworks™ Inc., Natick, MA).

Statistical Analyses

Baseline postural balance performance (i.e., COP-based measures from two replications of the EO condition without the cognitive task) was first compared between the occupational groups (farmworkers vs. non-farmworkers), using a linear mixed model⁴³. Conventional COP-based measures (MV_{AP} , MV_{ML} , and PEA) were log-transformed to achieve normally-distributed residuals. To assess whether farmworkers (vs. non-farmworkers) performed differently with the presence of the additional cognitive task or the removal of vision, separate linear mixed models were fitted using ratios of COP-based measures from the two

replications of each of the remaining three conditions divided by respective mean baseline COP-based measures. Estimates of historical pesticide exposure levels were available from two measures: lifetime exposure and years of occupational exposure. As these were highly correlated ($r = \sim 0.7$), only the latter was included as a covariate. In all statistical tests, we included years of occupational exposure and its interaction with occupational group (i.e., different exposure characteristics), to examine whether relationships between the level of lifetime pesticide exposure and balance performance were consistent across the occupational groups.

Postural balance performance has been found to be associated, though to varying extents, with age⁴⁴, stature, and body mass^{45,46}, low back and neck pain^{47,48}, time of day for balance measurement^{49,50}, and sleep deprivation⁵¹. Given this, measures of each noted potential influence were initially included as covariates. Age, stature, and body mass were included as continuous variables. Low back and neck pain frequencies were included as categorical variables: 0 = none in the past three months; 1 = at least once in the past three months; 2 = every month; 3 = every week; and, 4 = every day. The time of day for balance measurement was included as a categorical variable (before 3 pm and after 3 pm). Lastly, for sleep deprivation, reported sleep hours per night was included as a continuous variable. Covariates retained in the final models – based on Akaike information criterion values, statistical significance, and practical relevance – were age, stature, body mass, and self-reported neck pain and back pain frequencies. All analyses were completed using R statistical software⁵², and statistical significance was determined at $p < 0.05$.

RESULTS

Baseline Postural Balance Performance

A summary of baseline COP measures is provided in Table 2. The conventional COP-based measures did not significantly differ between occupational groups and were not associated with years of occupational exposure (Table 3). Similarly, no covariates were associated with conventional COP-based measures, except for a significant positive association between MV_{ML} and stature. However, sway complexity (CI_{AP} and CI_{ML}) did significantly differ between occupational groups, with farmworkers having higher values. CI was also significantly negatively associated with body mass and self-reported neck pain frequency.

Changes in Postural Balance with Cognitive Task and Removal of Vision

For the EO plus cognitive task condition, no significant association was found between any predictors and the COP-based ratio measures (with respect to baseline measures). Yet, occupational group and its interaction with years of occupational exposure (Figure 1) had rather strong effects on the CI_{ML} ratio (rCI_{ML}) that approached significance ($p = 0.066$). For the EC without cognitive task condition, COP-based ratio measures were not significantly associated with predictors with two exceptions. First, there was a negative association between rMV_{ML} and self-reported low back pain frequency ($p = 0.03$); model coefficient (95% Confidence Interval) = -0.046 (-0.088 , -0.005). Second, there was a similar negative association between rCI_{AP} and years of occupational exposure ($p = 0.038$); model coefficient (95% Confidence Interval) = -0.0042 (-0.008 , -0.0002). For the EC plus

cognitive task condition, farmworkers had significantly lower rMV_{ML} and larger rCI_{ML} values. Mean (95% Confidence Interval) values of rMV_{ML} and rCI_{ML} were, respectively, 1.48 (1.4, 1.56) and 0.86 (0.84, 0.88) for farmworkers, and 1.72 (1.57, 1.89) and 0.81 (0.77, 0.84) for non-farmworkers. rCI_{AP} values were significantly negatively associated with years of occupational exposure. Further, although only approaching significance ($p = 0.056$), there was an interaction effect of occupational group and years of occupational exposure (Figure 2). In addition, $rPEA$ exhibited a significantly positive association with body mass and years of occupational exposure.

DISCUSSION

This study examined postural control in Latino farmworkers and non-farmworkers and evaluated the effects of estimated lifetime occupational exposure to pesticides. A difference in baseline balance performance between farmworkers and non-farmworkers was apparent only with postural sway complexity, in that farmworkers exhibited greater complexity in postural sway. Having participants close their eyes to remove visual cues revealed a negative association of years of occupational exposure with rCI_{AP} , independent of occupational group. Yet, specific to the EO plus cognitive task condition, there was a rather strong interaction effect of occupational group and years of occupational exposure on rCI_{AP} . The results of this study thus suggest, first, that farmworkers and non-farmworkers may use different postural control strategies, and, second, that long-term pesticide exposure may affect sensory systems or central processing of sensory information for postural control.

Does baseline static balance performance suggest that farmworkers have relatively poorer balance control? There was no substantial difference in the conventional COP-based measures between the occupational groups (Table 3), yet sway area (i.e., PEA) tended to be slightly smaller ($p = 0.083$). This is interesting since a larger sway area is often interpreted to mean less stable postural control or inferior postural performance^{39,53–55}. Farmworkers also had higher values of sway complexity, and which may suggest more adaptive or efficient postural control^{30,56}. Our results thus appear to indicate that farmworkers have better postural balance control. However, and similar to our results, a study on Florida farmworkers⁷ reported that long-term farm work experience is negatively associated with sway area ($p < 0.1$) and some neurobehavioral performance measures. Additionally, older individuals with diabetes showed relatively smaller sway area and higher sway complexity before an exercise intervention⁵⁷, suggesting that there is not a simple, unidirectional relationship between sway measures (i.e., area and complexity) and postural control performance^{58,59}. It should be pointed out, though, that earlier work found a positive association between sway area and current exposure levels to Chlorpyrifos (based on a urinary metabolite; 5,6-trichloro-2-pyridinol)¹⁹¹². Overall, our results on baseline static postural balance do not seem to clarify whether farmworkers exposed to pesticides have poorer (or better) balance performance, but suggest more that occupational (i.e., likely low-level and frequent) pesticide exposure common in farmworkers may induce changes in the postural control systems. Further, these changes may be different from the effects of acute pesticide exposure.

Occupational pesticide exposure can affect the somatosensory and vestibular systems, both of which, along with visual input, are the primary subsystems involved in postural control. Removing visual information here, without an additional cognitive task, revealed an association of years of occupational exposure with rCI_{AP} . A decrease in CI_{AP} ratio values (relative to the baseline) was found, and this decrease was greater with increasing years of occupational exposure in both occupational groups. This outcome suggests that with more years of occupational exposure, a lack of visual information was less effectively compensated by the somatosensory or vestibular systems. Previous studies have similarly reported adverse effects of pesticide exposure on those sensory systems^{7,8,12,60}. A recent study further found a strong association between long-term exposure to OP pesticides and abnormal toe proprioception⁶¹.

Does occupational pesticide exposure affect central processing of sensory information for postural control? Here, an inconsistent influence of additional cognitive demand on sway complexity was found, depending on the occupational group and vision condition. Specifically, in the EO plus additional cognitive task condition (Figure 1) a negative association was found between years of occupational exposure and rCI_{ML} for farmworkers, versus a positive association for non-farmworkers. In the EC plus additional cognitive task condition (Figure 2), there was a negative association between years of occupational exposure and rCI_{AP} that was limited to non-farmworkers. Further, and interestingly, farmworkers (vs. non-farmworkers) showed smaller changes in MV, CI_{AP} , and CI_{ML} values relative to their baselines (i.e., ratio values closer to 1). It is rather unclear what these inconsistent effects of additional cognitive demand on sway complexity indicate. Yet, a previous study on sway complexity²⁹ found that frail individuals (vs. healthy individuals) exhibited a smaller decrease in sway complexity with the additional cognitive task, though frail individuals had relatively lower baseline sway complexity. A potential explanation of our results for the most challenging condition (i.e., EC plus additional cognitive task) may thus be that farmworkers prioritized maintaining postural balance with the presence of additional cognitive demand^{62,63}. That is, a negative association between rCI_{AP} and years of occupational exposure that was observed for both occupational groups in the EC condition was not present for farmworkers when the experimental condition became more challenging (i.e., increasing a cognitive demand). This postulate is also supported by the fact that cognitive performance is negatively associated with OP exposures^{7,64}. The cognitive task used in the current study was rather simple, and future studies may benefit from using more demanding cognitive tasks to assess the trade-off between postural balance control and cognitive task accuracy.

Limitations of the study should be acknowledged. First, lifetime pesticide exposure levels were limited to self-reported information, relying on recall. Any errors in lifetime exposure levels could be expected to make it more difficult to detect lifetime exposure-related associations (i.e., bias to the null hypotheses of no associations). Second, recent pesticide exposure levels were not considered. Any observed differences between occupational groups here could thus be attributed, to some extent, to differences of recent exposure levels between the groups. However, our results on sway area are consistent with an earlier study on occupational exposure⁷. Stephens et al.⁶⁵ further reported no association between acute and chronic effects of OP exposure. Third, the range of pesticide exposure levels overlapped

between the two current occupational groups (Table 1), and while non-farmers were expected to have no or minimal exposures, and thereby serve as a control group, this was not the case. To delineate the influence of lifetime pesticide exposure and occupational groups on postural control, we thus included years of occupational exposure and its interaction with occupational group. However, further study is merited, using a population with minimal or no occupational pesticide exposure. A prolonged longitudinal study that documents exposure over an extended period, though costly and difficult to perform, would be ideal for accurately assessing the effects of long-term exposures. Fourth, the presence of any pathological conditions or disorders (e.g., in the ear, nose, and throat regions) as well as nutritional status can be confounding or moderating influences on balance performance. Future consideration of such factors will help to better assess and isolate the effects of long-term exposures.

CONCLUSIONS

Static postural balance performance of farmworkers and non-farmworkers was examined to understand the effects of occupational pesticide exposure. Farmworkers had smaller baseline sway area and substantially higher baseline sway complexity, and which suggests that occupational pesticide exposure in this group induced changes in postural control systems. More specific analyses of sway complexity suggested that occupational pesticide exposure could affect the somatosensory and vestibular systems, as well as central processing of sensory information for postural control. Specifically, with longer years of occupational exposure, removal of visual information appeared less effectively compensated by the somatosensory or vestibular systems. Farmworkers appeared to prioritize maintaining postural balance when challenged with an additional cognitive demand. To further understand potential underlying causes of our findings, and to advance the use of static posturography as a subclinical assessment tool, future studies are needed to examine in more detail how the central processing of postural control is affected by occupational pesticide exposure, for example, by incorporating more demanding or different types of cognitive tasks (e.g., verbal vs. non-verbal, phonological loop vs. visual sketchpad), and also accounting for individual differences (e.g., fitness, health, and nutritional status).

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Figure 1.

Relationships between years of occupational pesticide exposure and complexity index (CI) ratio in the medial-lateral direction (rCI_{ML}) for the two worker groups in the eyes open plus additional cognitive task condition. Note that rCI_{ML} is the ratio of CI obtained in this condition, relative to the baseline condition (eyes open with no additional cognitive task). Lines are drawn over the range of years of pesticide exposure reported for each occupational group; dotted lines indicate 95% Confidence Intervals.

Figure 2.

Relationships between years of occupational pesticide exposure and CI ratio in the antero-posterior direction (rCI_{AP}) for the two workers groups in the eyes closed plus additional cognitive task condition. Note that rCI_{ML} is the ratio of CI obtained in this condition, relative to the baseline condition (eyes open with no additional cognitive task). Lines are drawn over the range of year of pesticide exposure reported for each occupational group; dotted lines indicate 95% Confidence Intervals.

Table 1

Summary of farmworker and non-farmworker characteristics. Values are mean (min., max.) for Age, Body mass, Stature, and BMI; and median (min., max.) otherwise. Comparisons between occupational groups done using independent sample *t* tests for Age, body mass, Stature, and BMI; and Kruskal Wallis tests otherwise. Significant differences between groups are highlighted with bold text.

	Farmworker (<i>n</i> = 77)	Non Farmworker (<i>n</i> = 57)	<i>p</i> value
Age	38.9 (30, 57)	40.2 (30, 70)	0.2
Body mass (kg)	84.1 (53.8, 140.7)	80.5 (58.2, 155.1)	0.059
Stature (m)	1.69 (1.5, 1.79)	1.66 (1.51, 1.9)	0.074
BMI (kg/m ²)	29.6 (20.9, 49.0)	29.0 (19.4, 52.9)	0.38
Self-reported neck pain frequency in past 3 months	0 (0, 2)	0 (0, 4)	0.67
Self-reported back pain frequency in past 3 months	0 (0, 4)	0 (0, 4)	0.67
Sleep duration (hours)	7 (4, 10)	6.2 (3, 9.5)	<0.0001
Time of day for balance measurement (24-h format)	15 (12, 21)	15 (11, 20)	0.96
Lifetime pesticide exposure (years)	12.8 (4, 33)	6.1 (0, 22)	<0.0001
Years of occupational pesticide exposure (years)	15.2 (3, 35)	4.2 (0, 17)	<0.0001

• Self-reported neck and back pain frequencies were assessed categorically. The four categories are described in the Statistical Analyses section.

Table 2

Summary of COP-based measures obtained from linear mixed model results for the baseline testing condition (eyes open without cognitive task). Values are least-square means (95% Confidence Intervals).

	Farmworkers	Non-Farmworkers
MV_{AP} (cm/s)	0.80 (0.73, 0.87)	0.76 (0.66, 0.88)
MV_{ML} (cm/s)	0.76 (0.71, 0.82)	0.73 (0.64, 0.82)
PEA (cm²)	3.96 (3.47, 4.53)	4.07 (3.26, 5.1)
CI_{AP}	12.56 (12.16, 12.97)	11.59 (10.91, 12.27)
CI_{ML}	14.41 (14.01, 14.81)	13.37 (12.71, 14.03)

Table 3

Summary of linear mixed model results for the baseline testing condition (i.e., eyes open without cognitive task). Values are regression model coefficients (95% Confidence Intervals; *p* value), and significant effects are highlighted with bold text.

	MV _{AP}	MV _{ML}	PEA	CI _{AP}	CI _{ML}
OG	0.087 (-0.09, 0.26; 0.33)	-0.069 (-0.27, 0.13; 0.5)	-0.28 (-0.6, 0.037; 0.083)	1.00 (0.064, 1.94; 0.037)	1.52 (0.56, 2.48; 0.0022)
Age	0.0051 (-0.0012, 0.011; 0.11)	-0.0056 (-0.0016, 0.013; 0.13)	0.0042 (-0.0072, 0.016; 0.46)	0.0032 (-0.03, 0.037; 0.85)	0.0067 (-0.028, 0.041; 0.7)
BMI	0.0025 (-0.001, 0.006; 0.15)	-0.0017 (-0.006, 0.0023; 0.41)	-0.0011 (-0.0073, 0.016; 0.74)	-0.047 (-0.065, -0.03; <0.0001)	-0.034 (-0.052, -0.015; 0.006)
Stature	0.36 (-0.47, 1.19; 0.39)	0.99 (0.031, 1.94; 0.043)	1.25 (-0.25, 2.75; 0.1)	-1.38 (-5.8, 3.05; 0.54)	-2.66 (-7.18, 1.86; 0.25)
NP	0.0008 (-0.075, 0.077; 0.98)	0.0061 (-0.081, 0.093; 0.89)	0.08 (-0.056, 0.22; 0.25)	-0.53 (-0.93, -0.12; 0.011)	-0.53 (-0.95, -0.12; 0.013)
LBP	0.012 (-0.041, 0.066; 0.65)	0.018 (-0.043, 0.079; 0.56)	-0.022 (-0.047, 0.009; 0.66)	0.22 (-0.064, 0.5; 0.13)	0.089 (-0.2, 0.38; 0.55)
YE	0.0027 (-0.013, 0.018; 0.74)	-0.013 (-0.031, 0.005; 0.16)	-0.019 (-0.047, 0.009; 0.19)	-0.022 (-0.11, 0.06; 0.61)	0.026 (-0.06, 0.11; 0.56)
OG × YE	-0.0038 (-0.022, 0.014; 0.68)	0.011 (-0.01, 0.032; 0.3)	0.024 (-0.009, 0.057; 0.15)	0.0037 (-0.093, 0.1; 0.94)	-0.051 (-0.15, 0.047; 0.3)

• MV = mean center of pressure (COP) velocity; PEA = 95% prediction ellipse area; CI = complexity index.

• Subscripts, AP = antero-posterior and ML = medio-lateral direction.

• OG = occupational group; NP = neck pain frequency; LBP = low back pain frequency; YE = years of occupational pesticide exposure.