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Effects of prone position on physiological and biomechanical parameters in healthy adults

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1. Introduction

In the agricultural sector, especially in organic farming, work tasks such as planting, harvesting, and soil treatment activities can pose significant health risks to individuals due to repetitive movements and prolonged periods of standing or bending. To improve working conditions, innovative machinery such as bed weeders have been designed to perform these tasks in a prone position. However, to date, no studies have investigated the potential advantages or risks associated with this prone position among healthy subjects in occupational settings. Research in pathological subjects has demonstrated the benefits of prone positioning on respiratory function (Malbuisson et al., 2000), oxygenation, and cardiac function (Hering et al., 2001). Nevertheless, prolonged use of this position can lead to decreased thoracolumbar muscle elasticity and the development of oedema or pressure ulcers (Patton et al., 2022). In healthy individuals, a positive effect on pulmonary ventilation distribution has been observed (Paupy et al., 2014), as well as beneficial changes in cardiac function (Pump et al., 2001). A positive effect on back curvature compared to standing has been described (Hausler et al., 2020), as well as a reduction in subjects' discomfort (Meyer et al., 2007).

The objective of this study was to assess the impact of the supine position during work on physiological and biomechanical parameters. To approximate different work setups —one rudimentary setup that could be assembled by the farmer themselves, and a more advanced and elaborated setup generally offered by manufacturers— two laboratory conditions were compared: the first condition (C1) employed a simple weight bench, while the second condition (C2) used a wide massage bed equipped with head, shoulder, and foot supports (Figure 1). It is presumed that the measured parameters will be better in condition 2.

2. Methods

2.1 Protocol

Fifteen healthy subjects (25.7 ± 9.2 years; 64.8 ± 16.3 kg; 1.69 ± 0.10 m), volunteered to participate. A treadmill was used to simulate ground movement, polystyrene balls were placed on it and scrolled at 1.5 km/h. Subjects were asked to sort them according to color. The measurement protocol lasted 10 minutes in each condition with 5 min of rest.

2.2 Data Acquisition

To measure back curvature and range of motion, 37 markers were fixed on the subject and tracked (Vicon Syt. Ltd). 10 electrodes (Pico, Cometa) were used to measure the EMG of the biceps, triceps, infraspinatus, deltoid, trapezius, neck extensors, brachioradialis, wrist extensors, and latissimus dorsi muscles. A metabolic analyser (K5, Cosmed) coupled with an optical heart rate monitor (Polar Verity Sense) allowed measurement of cardiorespiratory activity. A pressure mat (Tekscan, model 5310) measured thoracoabdominal external pressure. A perceived effort questionnaire based on

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the Borg scale was also handed to each subject after completing each condition.

2.3 Data Processing

The EMG data were filtered using a Butterworth band-pass filter with a range of 20-450 Hz and a sliding RMS window of 25 ms. A Shapiro-Wilk test indicated that all the data were non-parametric. Thus, non-parametric Wilcoxon tests were performed to compare the results. The data between the two conditions were compared, as well as between rest and activity phases.

3. Results and discussion

Table 1. Summary of data comparing C1 and C2 in activity (median ± interquartile range/2)

	C1	C2	p
Covered Area (dm2)	14 ± 2	7.9 ± 1.8	***
EMG Back and Neck (RMS: µV)	27 ± 11	14 ± 4	**
Heart Rate (bpm)	80 ± 6	73 ± 7	*
Respiratory Rate (cycles/min)	24 ± 3	24 ± 2	
Perceived Discomfort (CR10)	3.7 ± 1.1	1.0 ± 0.5	**
Thoraco-Abdominal Pressure (N/kg)	16 ± 2	15 ± 2	

* means p<0.05, ** p<0.01 and *** p<0.001

Table 1 shows differences between the two conditions. Motion capture showed a greater range of motion in C1. This may suggest greater freedom of movement but could also imply a tendency to get ahead and take breaks instead of maintaining a smooth workflow.

Back curvature and neck angle did not significantly differ between the two conditions. However, the study of muscle activity revealed that the muscles of the back and the neck were more engaged in C1 than in C2, where the muscles were nearly inactive. This increased engagement in C1 contributed to the discomfort and perceived pain by the subjects, as observed by Meyer et al. (2007). Results also showed that the brachioradialis muscle was significantly more activated in C1, confirmed by motion capture showing greater elbow flexion.

Cardiopulmonary parameters showed higher cardiac activity in C1 at the beginning of the activity. No significant difference was observed in the C2 condition between the rest and activity phases. The study of respiratory system variables showed no significant difference in either condition. A decrease in respiratory rate and pulmonary ventilation highlights a physiological adaptation of the body to the effort. The task was of low intensity, constant, and in a lying position, thus not straining the cardiorespiratory system, allowing for this adaptation to be observed. The results from the pressure mat showed thoracoabdominal pressure in C1 was higher during activity than at rest, which seems logical given the movements performed by the upper limbs. However, this higher-pressure during activity than at rest was not observed in C2, which is consistent with the lesser range of motion and the unchanged muscle activity at this level.

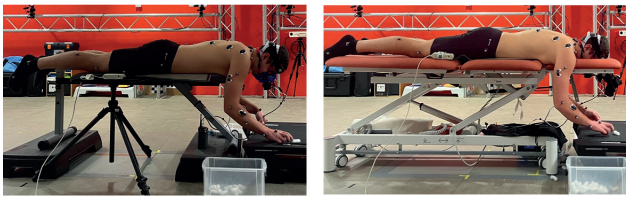

Figure 1. Prone position (C1); Prone position support with headrest (C2)

4. Conclusion

This study uncovered disparities between the two prone conditions in terms of physiological and biomechanical parameters. The C1 allows for a wider range of motion but may cause muscle discomfort, tension, and increased cardiorespiratory engagement despite being less comfortable.

In this preliminary study, the use of tables as weeding beds and treadmills to simulate displacement may not reflect real-world conditions. Additionally, it is important to consider outdoor conditions as they can influence the results. It would also be valuable to examine how different weeding machine designs impact musculoskeletal loading and fatigue by taking longer measurements. This line of inquiry could provide important insights to inform the ergonomic design of weeding equipment and mitigate the risk of work-related injuries among users.

Conflict of interest statement

I declare that there are no conflicts of interest regarding the publication of this research article. All authors have disclosed any financial or personal relationships with individuals or organizations that could potentially influence the work presented in this paper.

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