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Characterizing exposure to physical risk factors among reforestation hand planters in the Southeastern United States

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ABSTRACT

Low back and neck/shoulder pain are commonly reported among reforestation hand planters. While some studies have documented the intensive cardiovascular demands of hand planting, limited information is available regarding exposures to physical risk factors associated with the development of musculoskeletal disorders (MSDs) among hand planters. This study used surface electromyography (EMG) and inertial measurement units (IMUs) to characterize the muscle activation patterns, upper arm and trunk postures, movement velocities, and physical activity (PA) of fourteen Southeastern reforestation hand planters over one work shift. Results indicated that hand planters are exposed to physical risk factors such as extreme trunk postures (32.5% of time spent in ≥45° trunk flexion) and high effort muscle exertions (e.g., mean root-mean-square right upper trapezius amplitude of 54.1% reference voluntary exertion) that may place them at increased risk for developing MSDs. The findings indicate a need for continued field-based research among hand planters to identify and/or develop maximally effective interventions.

1. Introduction

Reforestation, or the intentional restocking of depleted forests, provides many valuable resources and amenities to our society including clean air and water, healthy habitats for wildlife, and recreational opportunities (USDA-FS, n.d.). Quality seedlings and plantings are a requirement for successful reforestation (South and Mexal, 1984). Planting quality is typically highest when performed by hand planters (Stjernberg, 2003).

Hand planters carry a large bag of seedlings over the shoulders and plant the seedlings one at a time at a desired spacing using a planting tool. Commonly used planting tools include a hoedad, which resembles an axe with a long blade, and a dibble bar, which is a narrow spade shovel (Fig. 1A). Typically, the planter forces the planting tool into the ground using the dominant arm and his or her foot to dig a hole for the seedling. He or she then reaches behind their back into the carried bag to remove a seedling, bends at the waist to place the seedling into the hole, and seals the hole with his or her hand or foot. Planting crews range in size depending on the size of the acreage to be planted (Fig. 1B). Despite being physically demanding work (Giguère et al., 1993; Hodges and Kennedy, 2011; Roberts, 2002; Robinson et al., 1993; Trites et al., 1993), hand planting has been observed to provide a yield of nearly 95% survival (Stjernberg, 2003). Another benefit of hand planting is the high rate of production that is possible regardless of terrain conditions. Hand planters of containerized seedlings in eastern and central Canada have been observed to average 11.7 s per planting (Stjernberg, 1988). In British Columbia, average production rates were above 1900 plantings per day or roughly 10 s per seedling (Stjernberg, 2003). Another survey of planters in Canada reported an average productivity of 1245 plantings per day (Giguère et al., 1993). McDonald et al. (2008) observed that hand planting of bareroot seedlings with a dibble bar took 7 s or less for 70% of plantings. Assuming 60% productive time, the planting rate would be about

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Fig. 1. (A) A hand planter using a 'T' handle dibble bar to plant a seedling. (B) A hand planting crew working in a forest in the Southeastern United States.

300 plantings per hour or 2400 plantings across an 8-h shift. For these reasons, hand planting has been reported on six times more acres than machine planting (Folegatti et al., 2007).

Hand planters are often compensated based upon production. This practice results in low job desirability and high turnover, and creates working conditions in which injuries and musculoskeletal pain may go unreported (Grzywacz et al., 2013; Hodges and Kennedy, 2011; McDaniel and Casanova, 2003). Workers in the U.S. Agriculture, Forestry, and Fishing (AFF) industry sector report among the highest rates of work-related musculoskeletal disorders (MSDs) across all industry sectors every year (BLS, 2014; BLS, 2015). The low back, neck, and shoulder are common sites for pain symptoms among hand planters (Hagen et al., 1998; Slot and Dumas, 2010).

Although several studies are available describing the main elements of the planting routine and the intensive cardiovascular demands of hand planting (Denbeigh et al., 2013; Giguère et al., 1993; Hodges and Kennedy, 2011; Slot, 2010; Slot et al., 2010; Upjohn et al., 2008), limited information is available regarding exposures to physical risk factors (e.g., sustained and/or non-neutral postures of the low back and upper arm, high movement velocities, and forceful muscular exertions; da Costa and Vieira, 2010) associated with the development of adverse musculoskeletal health outcomes among hand planters. The most comprehensive assessment to date was performed by Slot et al. (2010) and Upjohn et al. (2008) who evaluated the upper body and trunk postures of 14 tree planters working in Northern Ontario. Results of their work indicated that planters spent over 50% of the work day (4.3 h) with the trunk flexed >45° and that extreme shoulder postures (defined in the current study as elevation ≥60°) were required for particular aspects of the planting cycle. However, many common summary measures used to characterize and compare exposures among occupational groups such as percentiles of the amplitude probability distribution function (APDF; Jonsson, 1982) were not reported for the shoulder. Furthermore, the shoulder data were only collected in two, 15 min increments at the very beginning and very end of the work shift using observational methods. The study also did not involve any measurement of the muscle activity required during the planting tasks and the study sample only included Canadian tree planters using a different type of planting tool ('D' handle spade) that may not be representative of the exposures experienced by planters in the Southeastern United States.

Characterizations of exposures to physical risk factors among Southeastern forestry workers are needed to design tools and interventions capable of mitigating exposures and preventing the development of musculoskeletal conditions (Quandt et al., 2013). The objectives of this pilot study, therefore, were to (i) characterize the trunk and upper arm postures, movement velocities, and neck/shoulder muscle activation patterns of hand planters during full-shift work using direct measurement technologies, and (ii) compare these findings with data from other studies of occupational groups that commonly perform tasks associated with a high prevalence of musculoskeletal pain and symptoms in order to better understand the exposures to physical risk factors affecting hand planters.

2. Methods

2.1. Participants and study design

Fourteen male reforestation workers (mean age = 26.9 ± 6.0 years; mean body mass index = 24.8 ± 1.7 kg/m^2) were recruited from a reforestation contractor registered with the Alabama Forestry Commission for hand planting services. All of the participants enrolled in the study were compensated on an hourly basis by their employer. The participants were seasonal workers employed through H-2B visas. Participants self-reported: 1) no history of physician-diagnosed MSDs in the neck/shoulder or back regions, 2) no neck/shoulder or back pain two weeks prior to participation in the study, and 3) no history of neurodegenerative disease. All participants were right-hand dominant. Institutional Review Board approval of all study procedures was obtained from Auburn University prior to commencing study activities, and each participant provided informed consent.

2.2. Data collection procedures

Data were collected as participants performed hand planting tasks using direct measurement methods. The work location varied based on the planting schedule, but each participant started and ended the workday in the same forest stand. Each participant was observed for one full work shift during the prime planting season of January–February. The planting occurred when soil moisture conditions ranged from fresh to moist. The planting sites were within the coastal plain of Alabama and the soils are mostly free of stones in the surface horizons.

A research assistant shadowed each worker and recorded the time on a notepad (to the nearest minute) at which specific tasks began and ended. Observed tasks included, but were not limited to: 1) unloading boxes of tree seedlings from a refrigerated trailer, 2) loading seedlings into a bag for planting, and 3) the actual hand planting of the seedlings. The participants were provided all items necessary to complete their work by the contractor, and conducted their work as normal. The contractor reported an expected daily production rate of 2200 seedlings planted per day by each worker. Each participant used a dibble bar with a T-style handle as the