Adoptability of Orchard Ladders with Shorter Rung Spacing

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Abstract

Falls from ladders continue to be a concern in orchard work. Standard ladder design per the American National Standards Institute utilizes a 30.5 cm (12-inch) rung spacing, which is the distance between steps along the rails. The European standard provides for a range of 25.0 to 30.0 cm (9.8 to 11.8 inches). This poster reports updates work on a laboratory study in which twelve human subjects climbed a standard ladder and four other ladders each with incrementally shorter spacing of 12.7 mm (0.5 inches). The ladders were positioned at 72 degrees, as well as shallower 68 and 64 degrees. No test subject chose the standard ladder at any angle. The average increased heart rate was lowest for the 10.5 inch ladder. Ultimately shorter steps may mean reduced fatigue, smaller maximum forces, and by extension increased stability of the worker on the ladder to help reduce falls.

Introduction

Approximately 50,000 workers tend to approximately 600K acres of orchard in California. AgSafe reported that tree crop worker injuries occur at a rate of 4.3/100 workers/year. A major insurance carrier indicated that falls account for 31% of the claims but 49% of costs. Falls from ladders are a common cause of injury.

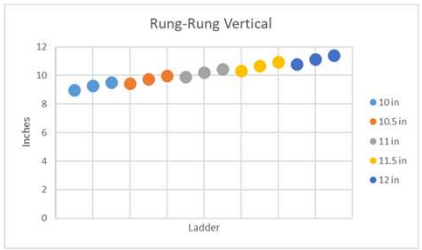
From a biomechanical perspective, a shorter person may be using a larger percentage of their range of motion, as well as their muscle contraction capability. This may contribute to fatigue, and it may contribute to the lower stability when the worker transfers all of their weight to one leg while pushing up with the other leg to reach the next rung.

Purpose: This study looked at several choices in rung spacing in a controlled laboratory environment. Other work in agricultural ergonomics has shown that smaller changes can make a big difference on various levels.



Methods

- Twelve subjects participated in this 5x3 (ladder x angle) within-subject design. An orchard ladder manufacturer (Strathmore) fabricated official ladders with the non-standard spacing of 25.4 cm, 26.7 cm, 27.9 cm, and 29.2 cm, and a standard 12-inch ladder. The ladders were secured at three different angles.
- Human subjects' anthropometry was recorded, and the subjects were fitted with a chest-strap heart rate monitor (Polar).
- Each subject ascended/descended five rungs five times on each of the five ladders positioned at three different angles, with three minutes rest between each of the trials.
- The rung/angle treatment was randomized, and when a ladder needed to be changed, rather than just the angle, all three minutes were required. The subjects' were asked to use the side rails rather than the rungs for hand support.
- At the conclusion of the fifteen trials, each subject was allowed as much time and assistance as they needed to try all of the ladders at any of the three angles to rank their five favorite rung/angle combinations.

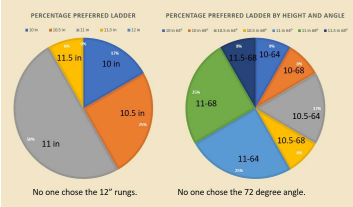


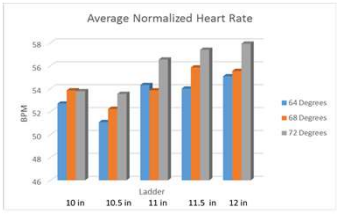
The vertical distance between rungs is dependent on both the rung spacing and the ladder angle. This chart shows these distances for each ladder at each angle. There is a general progression upwards, with a slight dip in distance between the one ladder at its steepest angle to the next larger-spaced ladder at its shallowest angle.

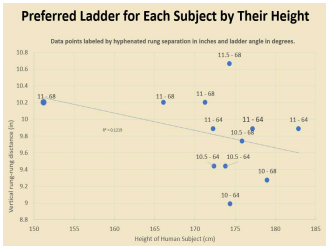
Results

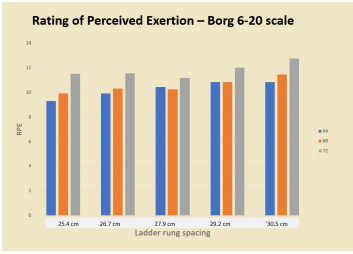
Subjects' basic anthropometric data (N = 13; 9 male, 3 female)

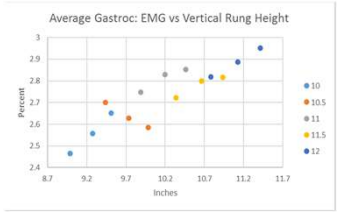
	Mean	Median	STDEV	Min	Max
Age	29.0	26.0	9.7	19	56
Height (cm)	172.6		7.6	151.2	182.9
Weight (kg)	77.0		11.8	54.5	95.6

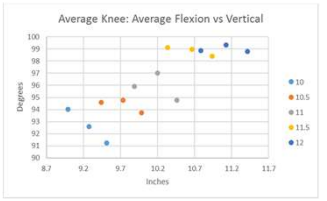












Discussion

- The subjects' preferred ladder rung spacing and angle included no instances of the standard ladder spacing of 30.5 cm (12 inches). One half of the subjects' favorite rung spacing was 27.9 cm (11 inches), with that group split in half with respect to the 64 and 68 degrees. On quarter of the subject preferred the 26.7 cm (10.5 inch) spacing. Although the designed angle is 72 degrees, in actual field use the ladders are infrequently positioned at such an angle, in part to have room for the picking sack or basket. However, considering that a shallower angle results in a smaller rung-rung vertical spacing, it is not surprising that shallower angles are preferred.
- Heart rate increase from resting was lowest for the 26.7 cm (10.5 inch) spacing. This was true for each ladder angle. The 27.9 cm (11.0 inch) spacing was the only instance where the intermediate angle (68 degrees) had a lower heart rate increase than the shallower or steeper angles.
- One objective of shorter rungs is reduced fatigue, which can provide a worker with improved ability to successfully recover from a slip, loss of balance, or other action that can lead to a fall. However, it is critical to note that the amount of work performed by the subjects in each of the trials was different due to the ultimate vertical height reached in each ascent. This can help explain the higher increases in heart rate for the larger rung spacing.
- The Rating of Perceived Exertion data suggest that for all five rung spacings, the 72 degree angle is rated higher than either the 64 or 68 angles that are relatively close to each other.
- The subjects' height, or other anthropometric measures such as knee height, hip height and weight, did not seem to provide any definitive suggestion of relationship to their preferred rung or angle.
- For purposes of this poster, only the gastrocnemius muscle electromyography (EMG) is presented. The data show a progressive increase except for the 26.7 cm (10.5 cm) rung spacing where the EMG lowers as the ladder's angle increases.
- For purposes of this poster, only the knee flexion data is presented. The data suggest progressively increasing flexion with increasing rung spacing, but decreasing with respect to increasing ladder angle for each ladder.
- This study suggests that small changes in work tools can make a difference to workers. Some manufacturers of Special Purpose ladders, a category into which 3-legged orchard ladders belong, have been willing to make ladders with custom spacing. There is some concern that ladders with different rung spacing designs might contribute to a fall caused unexpected rung location.
- As labor shortage increases, and as the workforce ages, improved or better fitting tools may have various benefits. Although automation is increasing, ladders are likely to continue to find application in agriculture.
- Especially in light of the European standard for rung spacing, there is a need to continue to understand whether the "one-foot" (12 inch; 30.5 cm) standard should be reconsidered.

Conclusions

- There was strong preference for ladders with shorter than standard 12-inch spacing and shallower than 72-degree angle.
- Trends suggest that heart rate rises with increased rung spacing and with increased ladder angle.
- Height, lower extremity anthropometry, and weight did not influence preferred ladder rung angle.
- Overall, the electromyography and motion results favor shorter rung spacing.
- The standard "one-foot" ladder should be reconsidered.

Acknowledgements

- Western Center for Agricultural Health and Safety (NIOSH grant 5U54OH007550-11)
- NIOSH Cooperative Agreement U05/CCU911435 ("Ergonomics Partnership to Address Treefruit Worker Injury")
- Strathmore Ladder Company (Strathmore, CA)
- Stokes Ladders, Inc. (Kelseyville, CA)

2019 Western Agricultural Safety and Health Conference – Cultivating Collaborations
University of Washington campus, Seattle, WA August 7-9, 2019