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Redesign of the Handle of the Painting Tool of Construction Painters.

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Abstract

This study explores the design of a handle for painting tools aimed at improving ergonomics and reducing physical strain on painters during wall painting tasks. Traditional straight handles often create an acute angle with the painter's wrist, leading to discomfort and excessive force application. In contrast, a bent handle aligns more naturally with the painter's forearm, thereby reducing wrist strain and improving overall comfort. The study finds that a bent handle creates a more favorable angle for applying force on the wall, making the painting process less physically demanding. Additionally, the bent design allows painters to work from a closer distance to the wall, particularly in confined spaces such as balconies of high-rise buildings. This design also enables painters to adjust handle length according to the height of the wall being painted, improving reach and efficiency. A survey of Indian painters indicated an average usable handle length of 4 feet 9 inches for optimal performance. The study further considers the dimensions and grip design to ensure the handle is ergonomic, with a diameter of 30 mm to 36 mm, consistent with industry standards for handheld tools. Overall, the bent handle design offers significant functional benefits, enhancing both comfort and efficiency for painters.

Keywords

construction painters, hand-held, handle, human factors, tool-design,

1. Introduction

Research on the well-being of construction finishing workers remains scarce, hindering progress toward achieving epistemic equality for this workforce (Ficker, 2015; Singh, 2017a). Construction workers are predominantly male due to shift timings that are often unsuitable for women. This challenge is further compounded by the physical demands of load-carrying tasks, which pose additional risks. (Singh, 2025 a, b). Age-related musculoskeletal degeneration and reduced agility are well-documented (Pykkoo, 1990). Ekpenyong and Inyang (2014) identified a direct link between work-related musculoskeletal disorders (WMSDs) and factors like age and body weight among physically active workers. With work experience often correlating with age, more seasoned workers face a heightened risk of WMSDs. Lokhart et al. (2005) also observed an increased likelihood of falls among older workers. Bamboo scaffolding poles, balconies, and projections often restrict workspace flexibility. To alleviate wrist strain, prioritizing ergonomic tool and equipment design is essential.

Utilizing user-centered design methods (Singh et al. 2022b) could address these issues effectively. Neglected groups like glass cleaners and wallpaper applicators in the construction industry often rely on improvised solutions and suboptimal tools (Jugaad, Singh et al., 2017c). For example, wooden sticks used to stir paint are repurposed to extend paint roller handles. Singh et al. (2019) emphasized that targeted product design interventions could significantly benefit such workers. Conducting ethnographic studies (Singh et al. 2017b) could provide deeper insights into the work systems and environments of these groups, while task analyses and shadowing techniques (Singh et al., 2022a) can help identify actionable improvements.

2. Handles of hand-held tools

The ergonomic design of hand-held construction tools has been widely studied to enhance user safety, comfort, and efficiency. Handle design plays a significant role in minimizing musculoskeletal strain and maximizing performance. Tichauer (1978) emphasized that the shape and material of tool handles directly affect grip comfort, force application, and the risk of strain-related injuries. Similarly, Grant et al. (1992) found that cylindrical handles with adequate diameter significantly reduced pressure on the palm and improved overall grip force, which is crucial for tasks requiring repetitive hand movements. Lindqvist et al. (1994) examined hand-held construction tools and discovered that improper handle design was linked to the development of carpal tunnel syndrome and other hand-wrist disorders.

Tools with textured, non-slip surfaces, as suggested by Nag and Nag (2004), were found to reduce slippage and improve grip stability, particularly in wet or dusty construction environments. Furthermore, Kong et al. (2007) highlighted that softer handle materials such as rubberized grips enhanced comfort and reduced vibration transmission to the hand, minimizing the risk of vibration-related disorders. In the case of paint roller handles, Johnson and Childress (2011) observed that an angled handle reduced wrist deviation during painting tasks, improving the ergonomic posture of the hand and arm. Additionally, Freivalds (1997) reported that tools designed to match the natural hand contour lowered fatigue levels and improved task performance over extended periods. Similar findings were supported by Hedge and Morimoto (1995), who concluded that ergonomically contoured handles, coupled with adjustable lengths, allowed workers of varying heights to perform tasks comfortably.
Studies on floor wipers and window-cleaning tools have also shown that handle length significantly impacts user posture. Chen et al. (2007) demonstrated that shorter handles forced users into awkward postures, increasing strain on the lower back and shoulders. In contrast, longer, telescopic handles enabled upright postures, reducing the risk of musculoskeletal injuries. Furthermore, Riley et al. (2006) investigated the effectiveness of grip diameter and found that an intermediate diameter (35–45 mm) reduced excessive grip force and enhanced operational efficiency. Handle orientation is another crucial ergonomic factor. Smith et al. (2010) found that angled or offset handles minimized ulnar deviation and wrist extension, which are common contributors to cumulative trauma disorders. This was corroborated by Seo and Armstrong (2009), who studied painting roller handles and concluded that adjustable and ergonomic handle designs improved force distribution, reducing pressure points and increasing operational precision (Singh et al, 2025 c).

The usability of hand-held construction tools is also influenced by tool weight and balance. According to Berqvist et al. (1995), lightweight tools with balanced weight distribution reduced forearm fatigue and encouraged prolonged usage without compromising efficiency. Takala et al. (1987) also highlighted that tool weight should not exceed 2 kg for repetitive tasks to avoid overloading the wrist and forearm muscles. Additionally, Kong and Lowe (2005) stressed the importance of user-centered design in construction tools, recommending that user feedback be incorporated into the development process to address specific ergonomic concerns. Jones et al. (2012) advocated for field testing prototypes to ensure tools meet ergonomic and functional requirements in real-world scenarios. These findings collectively underscore the importance of designing hand-held construction tools that prioritize user safety, comfort, and efficiency while reducing injury risks.

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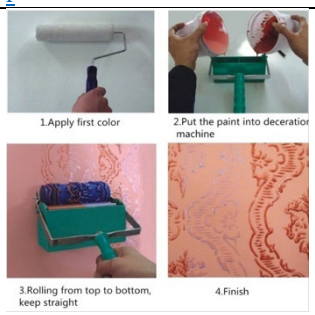
Conducting ethnographic studies (Singh et al., 2017b) could provide deeper insights into the work systems and environments of these groups, while task analyses and shadowing techniques (Singh et al., 2022a) can help identify actionable improvements. In this study, a user-centered design (UCD) approach (Singh et al., 2020, 2021) was implemented to address the specific needs, preferences, and challenges of construction painters. This methodology ensured the development of tools that reduced physical strain, enhanced comfort, and improved job site productivity. The study revealed that exterior wall painters face more dynamic and precarious physical movements compared to their interior counterparts, who work in relatively stable and spacious environments. Factors like height and weight further influence the balance and task performance of painters working in strained postures (Singh et al., 2019). Both groups report upper and lower body pain due to the repetitive and prolonged twisting, bending, and stretching of neck, back, and arm muscles (Singh et al., 2016). However, exterior wall painters face additional challenges, including carrying heavy materials and maintaining balance in precarious positions, leading to distinct physical strain patterns for interior and exterior wall painters.

3. Existing painting tools

Paint roller covers are made from three different materials. These are lamb's wool, synthetic fiber, and foam. Roller covers made of lamb's wool are ideal for oil-based paints and painting on any surface texture. Synthetic fabric covers are preferred for water-based paints and work for any surface textures. Foam covers work well with oil or high-gloss latex paints and work best for smooth or textured surfaces. The width of a paint roller ranges from 7 – 12 inches while some specialized rollers are available in the range of 2 – 18 inches. For convenience sake, the design and development of the new tool had used the commonly available 7" wide fabric rollers. Currently, different kinds of paint rollers are used in the industry. While some of them have a spray feature, others have small container attached. These painting tools are further discussed in detail in the following table 1.

Table 1. Existing Painting tools used in indoor painting.

1	 Source: https://odditymall.com/paint-runner	**Description:** A storage container is provided which is covered by a roller cover. Over time paint in small amounts is absorbed in the roller cover. **Advantage:** There is no need to go back for dips in the paint bucket. Though the container will require refilling at certain intervals. **Disadvantage:** As the level of the paint in the container falls, the roller cover absorbs lesser paint. The handle does not suit external wall painting as the painter performs the task from a distance.
2	 Source: https://www.familyhandyman.com/painting/techniques/paint-roller-techniques-and-tips/	**Description:** The paint roller has a long arm that facilitates hold for both hands. **Advantage:** The long handle of the paint roller equipment lets the painter reach higher and farther surfaces on the wall. **Disadvantage:** The painter has to apply larger pressure to press the neck of the roller as the roller is not very close to the body. The straight handle puts a strain on the painter's wrist. Does not fulfill the right angular painting.
3		**Description:** The paint roller gets a supply of paint from a pressure tank. A continuous inflow is supplied in the cavity of the roller entity. **Advantage**: A continuous inflow is supplied in the cavity of the roller entity. **Disadvantage:**: Perpendicular wall surfaces cannot be painted simultaneously. Contractors can not afford the expensive equipment in India.

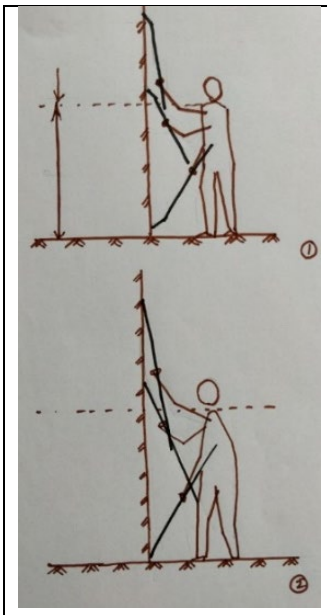
	Source: https://www.wagnerspraytech.com/products/paint-rollers/	The handle is not designed to paint farther surfaces hence not meant to paint external walls. Not suitable for painting external walls perched on scaffolding.
4	 Source: https://www.wigleydiy.co.uk/lgh-ult-sleeve-w-c-corner	**Description:** Special roller to paint the internal corners. **Demerit:** Paint roller used specifically to paint inside corners (90 degrees) only. It covers a relatively very smaller area.
5	 Source: https://paintsprayerjudge.com/electric-power-paint-roller-reviews/r	**Description:** The new design allows continuous refill in the roller cover for interior wall painting. **Advantage:** Reduces the no of refills from the paint bucket. **Disadvantage:** Does not support right angle painting. The wrists and shoulder experience strain as depicted in the figure. The additional weight of the paint chamber will put more strain on the hands of the painter and the painter is bound to use both hands to support the painting tool.
6	 Source: https://www.bukalapak.com/p/rumah-tangga/furniture-interior/dekorasi-rumah/e8jw7j-jual-wallpaper-paint-roller-002y-painting-roll-motif-tanpa-aplikator	**Description:** Used to paint textures on interior walls. **Advantage:** The attached container and the secondary roller allows a constant supply of paint in the active roller. It reduces no of refills from the paint bucket. **Disadvantage:** To reach farther areas in external wall painting the container may be extra weight. Handle and roller design does not satisfy external wall painting (for far reach and efficient painting of external walls)
7	 Source: https://paintedzone.com/how-to-paint-a-popcorn-ceiling/	**Description:** The new design allows continuous refill in the roller cover. **Advantage:** Reduces the no of refills from the paint bucket. **Disadvantage:** The wrists experience strain as depicted in the figure. The additional weight of the paint chamber will put more strain on the hands of the painter and the painter is bound to use both hands to support the painting tool. The spray may eventually use more amount of paint. The handle and nozzle work for only interior wall painting.

4. Need for a bent handle

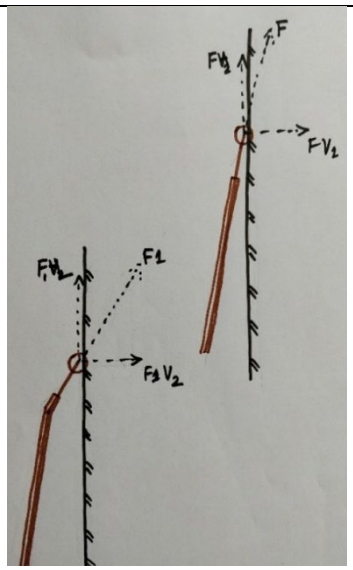
The design of the handle takes into account the alignment of the wrist of the painter with the handle. Walls are vertical surfaces that make an acute angle with the wrist of a painter. Like in hand-dills. The hand and drill bit are at 90 degrees to each other, the handle of the painting tool would be better for the grip. It will allow the reduction of strain on the wrist. It follows Bridger's idea (2011, pp196) that 'bending the handle instead of the wrist' is a better configuration. To reduce undesired fatigue and repetition of motion, the paint roller is expected to not slide away. The straight handle makes a very acute angle with the wall when the painting tool is rolled on farther surfaces or higher surface. However, in the new design, the angular handle helps the roller to be pressed on the wall surface (figure 1a). Due to the pressing force on the rollers, the fabric squeezes the paint out. With each stroke, the squeezing of the paint and the rolling action results in the spreading of the paint on the wall.

5. Functional benefits of bent handle

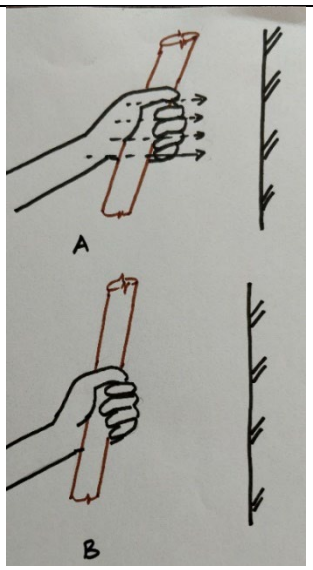
While painting a wall surface that is above the shoulder height of a painter, the straight handle makes a very acute, then the angle made on the wall by the bent handle (figure 1-b). The angular handle offers larger force F2V2 (figure 1-b) which is a reactionary component of the force applied by the painter on the painting handle and the roller. However, the straight handle offers a smaller reactionary component force FV1 on the wall. Additionally, the angled design helps reduce wrist flexion and extension for the painter (figure 1 d), making the bent handle less strenuous, minimizing hand fatigue. Hence the bent handle is better and makes the painting activity easier for the painter. Painting activity requires a certain push force for the roller fabric to squeeze and leave a small amount of paint on the wall surface. While doing vertical zig-zag motion the painting tool. This means the handle of the painting tool is to be held by the painter with just an amount of pressure to be applied on the roller so that the paint is released on the wall and strokes help spread the paint.



a



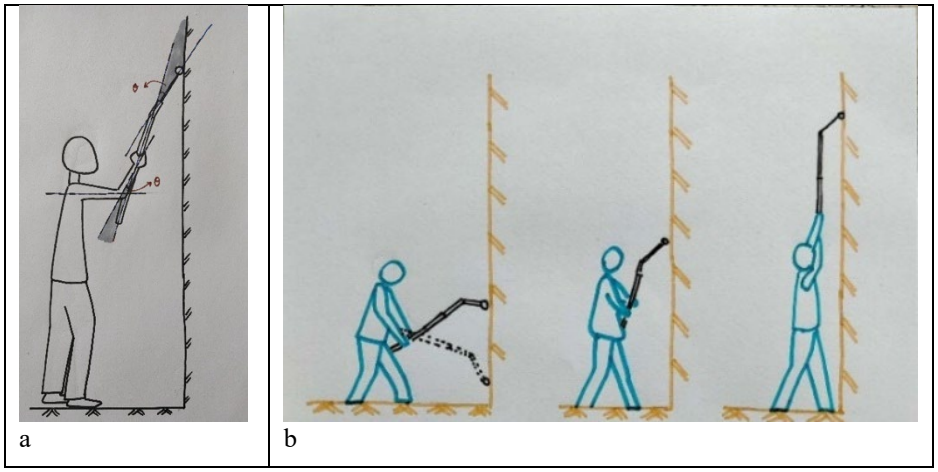
b. The bent handle makes a less acute angle with the wall



c. The wrist applies more force on the wall with a straight handle

d. Source: https://www.familyhandyman.com/list/paint-roller-techniques-tips/

Figure 1. Bent handle versus straight handle



a b

Figure 2. The angle of the bent handle

The acute angle in the case of the straight handle of the existing painting tool makes the painter apply more force on the handle which in turns result in clutching of the fingers on the handle (figure 1-c). Along with this the wrist and arms press more on the handle in the activity of painting (A). The bent angle facilitates a less acute angle or straighter position for the wall. this allows less pressure to be put on the handle and the roller but enough to paint the surface. Another benefit of the bent handle is that the balconies in metropolitan cities have high rise residential buildings with compact spaces. The balconies are not wide enough to allow the painter to stand much farther from the wall. As shown in figure 1-c more acute angles (A) of the handle with the wall means that the painter needs to stand farther away from the wall while the straighter angle (B) means the painter can paint from a closer distance from the wall.

The angle at which the forearm of the painter as observed at the time of testing was found to be 20 degrees. Thus, as the inclination of the bend is parallel to the angle of the elbow with the handle the angle theta is equal to 20 degrees (figure 2-a). The length of the handle can also be designed such that the painter can paint a reasonably large surface area. The painter stands about 45 to 60 cm away from the painting surface. For the comfort of putting force on the wall with the handle so that the paint roller sticks on the wall surface, the painter cannot stand very close to the wall as shown in figure 2-b. This means that the painter needs a handle length that will allow him to paint higher surfaces to the extent that the roller does not slide away on the wall. The average height of Indian painters in the survey that was conducted suggests that the average height of the painters is 5’5 1/2” (figure 3; ‘descriptive statistics).

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Group	117	1	4	2.15	.988
Experience	117	1	25	6.20	4.188
Age	117	17	50	28.07	6.717
Villvisit	117	1	3	1.56	.594
Weight	117	52	68	60.36	3.768
Height	117	160	176	166.32	3.664
Fatigue	117	1	3	1.91	.682
Headache	117	1	3	1.39	.601
Neck	117	1	3	1.88	.756
Shoulder	117	1	3	1.53	.749
Uback	117	1	3	1.44	.621
Lback	117	1	3	1.65	.758
Wristhand	117	1	3	1.35	.530
Thighbuttocks	117	1	3	1.49	.690
AnkleFeet	117	1	3	1.82	.651
Valid N (listwise)	117				

Figure 3. Descriptive statistics of the data of 117 wall-finishing construction workers.

An average painter reportedly paints not more than 10 feet height of walls while being in a balcony or scaffolding of the buildings. Thus, the maximum height to be painted is 10 feet.

The shoulder height of 6 feet painter was 60 inches (5 feet)
The shoulder height of the painter of height 5 feet 6 inches was 54 inches (4 feet 6 inches)
The shoulder height of the painter of height 5 feet 3 inches was 51 inches (4 feet 3 inches)
Distance between the roller and the hand (when holding the painting tool at the nearest position to the handle is 12 inches)
Thus, the usable length of the paint roller tool = 10 feet – 4 feet3 inches – 12 inches
=4 feet 9 inches

A PVC prototype was tested with a painter (figure 4). The after REBA analysis was based on his posture during a maintenance painting activity on a portion of the exterior façade of Raheja Vistas in Powai, Mumbai. His posture analysis was performed on the postures when he painted a perpendicular column (90 degrees and 270 degrees), and a flat surface.

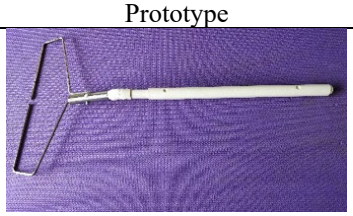
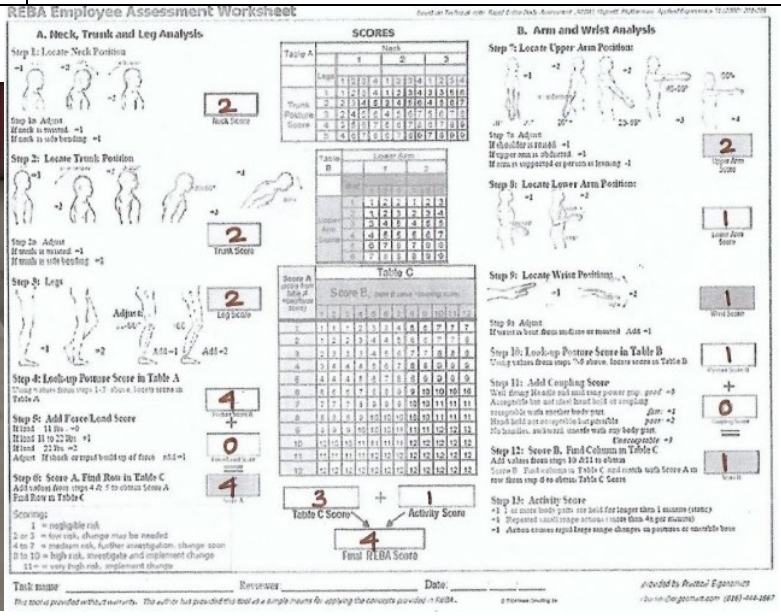
Prototype	Physical features
 a	• The handle is bent at 15 degrees. • PVC pipes are 2 mm thick • The prototype is heavier than the stainless-steel prototype. • The rollers can be removed and replaced if needed. • The product can be dismantled in three pieces which allow compact storage.
 b	 c

Figure 4. Posture analysis of the painter using the bent handle of the painting tool.

Figure 4 (c) shows a REBA score of 4 for posture (figure 4 (b)) which is borderline ‘medium risk’ as opposed to the ‘high risk’ score of 8 that were found in the previous painting postures (Singh et al, 2024 (SSRN)) .

6. Conclusion

The length of 4’9” is the total usable length of the handle when the painter reaches the 10-feett-high wall patch. At other times the painter does not need this length and works suitably with a shorter handle. Thus, a telescopic handle is needed which will allow the painter to adjust the length of the handle according to his requirement based on how far or near the wall surface is at a particular time. According to OSHA and Accessible and Usable Buildings and Facilities, ICC A117.1-2009 the handrail diameter should be 1 ¼” – 2” which is 31 mm to 50 mm. Since the painting tool handle is expected to provide a good grip while it serves as a handheld tool, an outer pipe with a diameter of 30 mm was used with a grip sheath which was 3 mm thick to provide another 6 mm in the total diameter of the handle. Future tool designs should focus on several key areas to enhance usability, safety, and performance. Adjustability and customization are essential, allowing handles to be tailored to the user’s hand size, grip strength, and preferences, thereby reducing strain. Modular designs could further enable users to configure

tools for specific tasks. Integrating smart technology, such as sensors to monitor grip force, vibration exposure, or fatigue levels, can enhance safety and performance by providing real-time data for feedback and design improvements.

The use of advanced materials like carbon fiber composites or biodegradable polymers could enhance ergonomics while addressing environmental concerns, and 3D printing could enable rapid prototyping and customizations. Emphasizing posture and task efficiency, tools should be designed to promote neutral postures, reduce awkward movements, and improve task efficiency through features like ergonomic angles and telescopic handles. Inclusivity should also be prioritized, ensuring tools are suitable for diverse users, including left-handed individuals, those with disabilities, and people of varying genders and ages, broadening market appeal. Safety features, such as anti-slip coatings and vibration-dampening mechanisms, should be incorporated to prevent accidents. Lastly, comprehensive ergonomic testing that considers physical, cognitive, and environmental factors will ensure tools are optimized for all aspects of worker safety and comfort.

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