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Women in the Construction Industry: Can Assistive Robotic Technologies Help to Close Employment and Pay Gaps?

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Introduction

- Women's share of U.S. construction trade jobs has remained stubbornly low in past two decades
  - Risen from just 2.5% to 4.2%
- Numerous barriers faced by women in construction:
  - harassment
  - discrimination
  - feelings of isolation on the job
  - inadequate jobsite sanitation
  - low participation in apprenticeship programs
  - insufficient access to leadership positions
  - reputation of construction as a "macho" industry
  - emphasis on upper-body strength requirements
- Construction has one of the highest levels of occupational segregation among all industries

Introduction

- The U.S. construction industry cannot afford to have these barriers to entry and retention facing women workers.
- Chronic shortages of skilled workers since the 1980s; projected to continue in the coming decade. Main reasons:
  - high workplace injuries
  - high turnover
  - early retirements
  - difficulties attracting and retaining young workers
- Potential solution to address the labor shortage and underrepresentation of women is to leverage wearable assistive robots
  - Often called exoskeletons or exosuits
  - Designed to reduce strain and increase strength through mechanical interaction with the body

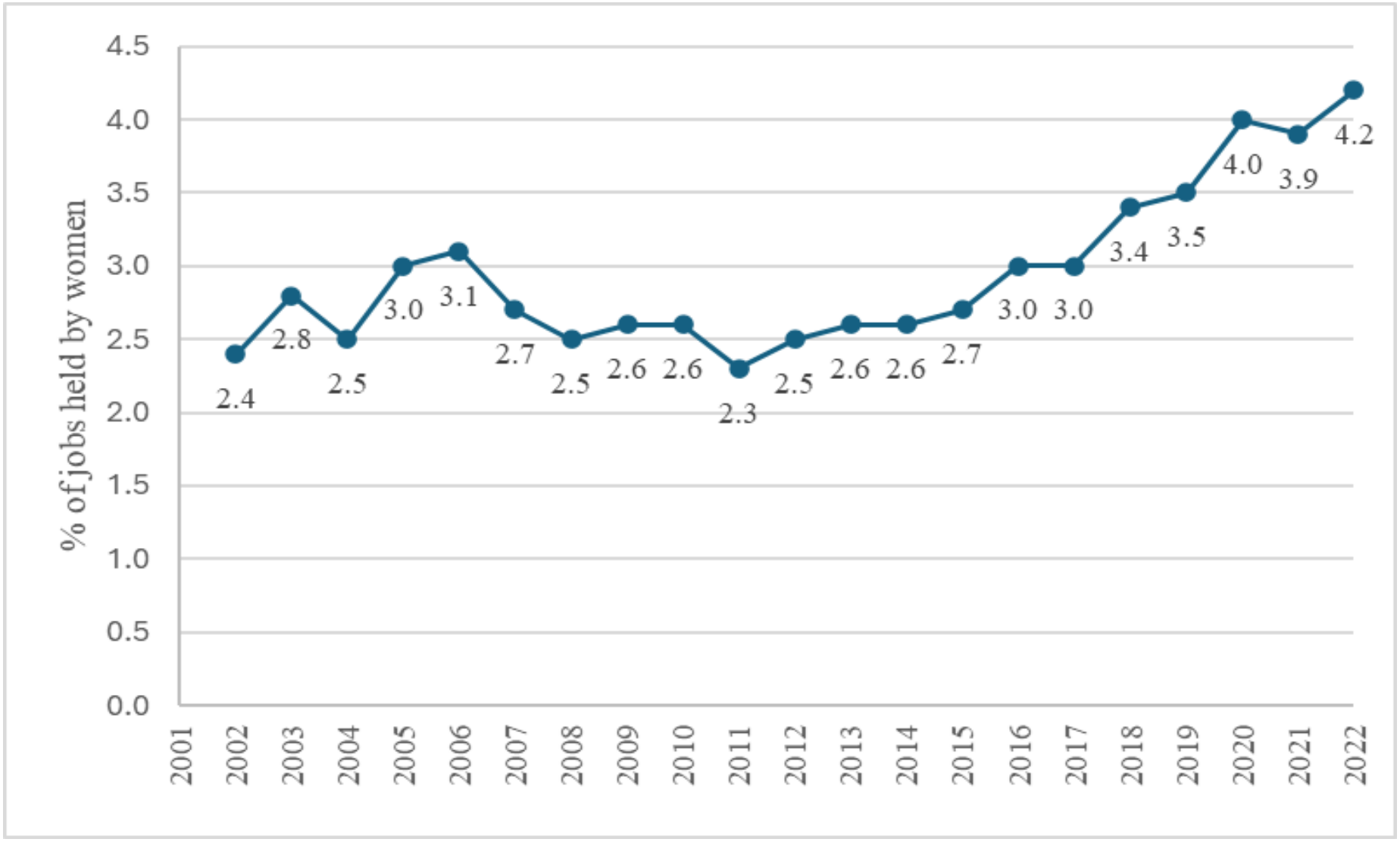
Introduction

- What does scholarship show? Most studies on workplace automation and robotics center on displacement of human workers by machines
  - Less known about economic benefits of human-robot collaboration
- Mixed evidence on impact of new technologies on women's employment and pay in occupations dominated by men
  - Less known about wearable devices and their gendered effects
- This study explores the potential of wearable robot technologies to reduce gender disparities in employment and wages in the construction industry
  - Also explores extent to which ability requirements related to strength and mobility hinder women's entry into construction

Background

- Lots of construction jobs so many women work in construction, but as a share of all construction workers their representation remains below 5%
- Within construction, fewer women in production-oriented occupations, more in clerical and support
- Construction industry is notoriously dangerous
  - accounts for nearly one in five workplace fatalities
- Gender differences in physical strength: women have 52% the upper body strength of men and 66% the lower body strength of men (Miller et al. 1993)
- Also endemic: injuries affecting muscles, tendons, joints, and nerves, including sprains, strains, nerve compression, and herniated discs.
- Advancements in wearable technology can help to transition towards proactive safety strategies

Percentage of Construction Jobs Held by Women



Data and methodology

- Use worker-level data from the 2014 U.S. Survey of Income and Program Participation (SIPP)
  - Only wave of SIPP to contain detailed information about mobility and strength impairments
  - Has 9 indicators of difficulty with physical activities (climbing stairs, walking, standing, sitting, kneeling, reaching overhead, lifting, grasping, and pushing/pulling large objects)
  - Sample size 20,146
    - 6,554 not employed; 13,592 employed
    - 1,001 employed in construction; 12,591 in non-construction
- Use linear probability models to predict employment, and use a Heckman selection model to predict natural log of hourly earnings.

Data and methodology

- Next step: compile occupational-level data in construction industry by merging O*NET data from BLS with public-use microdata from the American Community Survey

- Use merged data to examine employment composition, physical skill requirements, and earnings across detailed construction occupations

Sample means

- Women make up half of all non-construction jobs, they constitute just 8.3% of workers in construction
- 7 out of 9 impairments are associated with lower employment shares in construction compared to non-construction jobs.
  - Individuals with any of the 9 impairments are more likely to be out of the labor force than employed

Sample Means by Employment Status, SIPP Data

	Not Employed	Construction	Non-Construction
Woman	0.601	0.083	0.499
Mobility/strength impairments			
Climb 10 stairs	0.207	0.016	0.031
Walk 3 blocks	0.227	0.026	0.031
Stand 1 hour	0.264	0.050	0.047
Sit 1 hour	0.167	0.030	0.029
Stoop/crouch/kneel	0.287	0.074	0.077
Reach overhead	0.152	0.020	0.024
Lift/carry 10 pounds	0.195	0.018	0.023
Grasp small objects	0.109	0.017	0.019
Push/pull large objects	0.246	0.036	0.045

Regression results

- Being a woman is associated with a substantial employment gap in construction
  - 24.9 percentage points lower probability compared to men
  - None of the other explanatory variables in the employment estimation are as large
- Employment gap associated with being a woman is much smaller in non-construction jobs (7.9 percentage gaps)
- Individuals with four different types of mobility/strength impairments experience employment gaps in construction:
  - walking
  - standing
  - stooping/crouching/kneeling
  - pushing/pulling large objects

Regression results

- Being a woman is associated with a substantial earnings penalty in construction
  - Being a woman associated with 0.356 log point earnings penalty compared to being a man in construction, compared to 0.231 log points for non-construction jobs.
- Among the mobility/strength impairments, only difficulty with stooping/crouching/kneeling is associated with a statistically significant earnings penalty in construction jobs
  - Earnings premium for people with walking impairment; could be sorting into desk jobs that pay more

Regression results

	Employment		Earnings	
	Model 1: Construction	Model 2: Non-Construction	Model 3: Construction	Model 4: Non-Construction
Woman	-0.249***	-0.079***	-0.356***	-0.231***
	(0.009)	(0.007)	(0.118)	(0.014)
Mobility/strength impairments				
Climb 10 stairs	-0.022	-0.035*	0.110	(0.069)
	(0.014)	(0.020)	-0.178	-0.049
Walk 3 blocks	-0.055***	-0.128***	0.442***	-0.095*
	(0.014)	(0.021)	-0.153	-0.058
Stand 1 hour	-0.048***	-0.145***	(0.163)	0.052
	(0.017)	(0.020)	-0.157	-0.041
Sit 1 hour	0.002	0.009	0.095	0.025
	(0.012)	(0.018)	-0.264	-0.048
Stoop/crouch/kneel	-0.040**	-0.032**	-0.277**	(0.029)
	(0.016)	(0.015)	-0.121	-0.031
Reach overhead	-0.003	-0.032*	0.095	(0.002)
	(0.011)	(0.018)	-0.139	-0.051
Lift/carry 10 pounds	0.011	-0.104***	0.031	0.013
	(0.015)	(0.021)	-0.224	-0.057
Grasp small objects	-0.005	-0.014	(0.063)	-0.101*
	(0.012)	(0.019)	-0.239	-0.054
Push/pull large objects	-0.036***	-0.092***	0.077	(0.016)
	(0.013)	(0.018)	-0.142	-0.043

Ability and pay for detailed occupations

- Women most likely to be hazardous materials removal workers, inspectors, painters, and paper hangers.
- Men highly represented among higher pay occupations, such as elevator installers, derrick and rotary drill operators, mining machine operators, and steel workers
- Occupations with higher percentages of women workers have a lower level of income (r=-0.413) and lower ability levels (r=-0.331).

Women cluster in lower-pay, less physical occupations

Six-digit Occupations	Percent Female	Physical Level	Annual Income
Hazardous materials removal workers	22.52	2.21	47,255
Construction and building inspectors	11.03	1.47	66,697
Painters and paperhangers	9.09	2.35	37,701
Explosives workers, ordnance handling experts, and blasters	7.07	2.20	55,750
Helpers, construction trades	6.35	2.65	29,509
Sheet metal workers	4.84	2.40	53,131
First-line supervisors of construction and extraction workers	4.18	1.84	76,052
Other construction and related workers	4.16	2.25	44,635
Construction labourers	4.10	2.78	39,797
Solar photovoltaic installers	3.94	2.25	43,244
Insulation workers	3.71	2.44	51,741
Drywall installers, ceiling tile installers, and tapers	3.48	2.46	40,986
Carpet, floor, and tile installers and finishers	3.28	2.41	42,980

Men cluster in higher-pay, more physical occupations

Six-digit Occupations	Percent Female	Physical Level	Annual Income
Rail-track laying and maintenance equipment operators	2.67	2.63	65,682
Construction equipment operators	2.65	2.04	59,131
Carpenters	2.49	2.69	46,153
Electricians	2.48	2.67	64,052
Boilermakers	2.33	2.32	69,704
Fence erectors	2.21	2.75	37,402
Plumbers, pipefitters, and steamfitters	2.02	2.60	59,937
Glaziers	1.82	2.18	51,626
Structural iron and steel workers	1.72	3.13	60,882
Surface mining machine operators and earth drillers	1.70	1.93	62,836
Pipelayers	1.63	2.35	52,292
Plasterers and stucco masons	1.44	2.69	42,009
Derrick, rotary drill, and service unit operators	1.41	2.40	73,838
Elevator installers and repairers	1.37	2.03	99,999
Brick masons and reinforcing iron and rebar workers	1.33	2.51	45,662
Cement masons, concrete finishers, and terrazzo workers	0.98	2.81	47,508

Examples of wearable assistive robots

Case 1: HeroWear Apex Back Exosuit

Case 2: Hilti EXO Shoulder Exoskeleton

Case 3: Ekso EVO Exoskeleton

Conclusion

- Being a woman is associated with a substantial employment gap and an earnings penalty in construction
- Individuals with four different types of mobility/strength impairments experience employment gaps in construction:
  - walking
  - standing
  - stooping/crouching/kneeling
  - pushing/pulling large objects
- Difficulty with stooping/crouching/kneeling also associated with an earnings penalty in construction jobs
- Occupations with higher percentages of women workers have a lower level of income and lower ability levels

Conclusion

- Technologies that enhance women's manual dexterity, balance, and strength may improve their representation in some of the higher-paying occupations in construction
- Increased participation of women in construction jobs, facilitated by adoption of wearable assistive robots, may help to mitigate persistent labor shortages
- Challenges:
  - Wearable assistive robots tested primarily on men
  - Prototypes are bulky and intimidating, so not scalable
  - Actual tasks at construction sites are more varied and complex than simulated tasks in research labs.
  - Relatively high purchase and maintenance costs: do workers or employers bear these costs?