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Human Factors: The Journal of the Human Factors and Ergonomics Society 2014 56: 143 originally published online 9 September 2013
DOI: 10.1177/0018720813502807

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What is This?

SPECIAL ISSUE: Epidemiological Studies of Workplace Musculoskeletal Disorders

The Impact of Posture on Wrist Tendinosis Among Blue-Collar Workers: The San Francisco Study

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Objective: The objective was to evaluate the effect of wrist posture on incidence of wrist tendinosis in a prospective cohort of blue-collar workers.

Background: Previous studies have identified awkward wrist posture as a risk factor for wrist tendinosis, though the magnitude of the relationship is unclear.

Method: Workers (*N* = 413) at four industries were followed for up to 28 months with questionnaires and physical examinations every 4 months. Individualized exposure assessments of wrist posture were based on video analysis to determine the wrist extension/flexion angle for up to four tasks. Posture measures were calculated while in "heavy pinch" (> 1 kg force), "heavy power grip" (> 4 kg force), and across "all grips." A proportional hazards model estimated the relationship between time-weighted average posture measures and incidence of dominant-side wrist tendinosis.

Results: In a model based on tertiles of exposure, adjusted for age, gender, hand force, and repetition of exertions, risk of tendinosis more than doubled in the highest category (HR = 2.69, 95% CI = 1.01–7.21) across all grips. The relative risk was highest during heavy pinch (HR = 5.03, 95% CI = 0.74–34.05), though not statistically significant. Increased median wrist extension while in heavy power grip was protective (HR = 0.24, 95% CI = 0.06–0.94).

Conclusion: In this study of production workers, median wrist flexion of more than 7°, across all grips, was associated with an increased risk of tendinosis. The protective findings on median wrist extension during power grip deserve further investigation. Work tasks and tools should be designed to prevent sustained wrist flexion, especially during tasks involving forceful pinch.

Keywords: wrist, tendinosis, tendinitis, tendonitis, tendonopathy, posture, prospective, exposure response, incidence

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HUMAN FACTORS
Vol. 56, No. 1, February 2014, pp. 143–150
DOI: 10.1177/0018720813502807
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INTRODUCTION

Work-related upper-extremity musculoskeletal disorders (MSDs) continue to be a problem in the U.S. workforce and contribute to pain, discomfort, loss of productivity, and disability (Martimo et al., 2009). Wrist flexor and extensor tendinopathies are common workplace overuse injuries from repeated forceful use of the hand (Armstrong, Fine, Goldstein, Lifshitz, & Silverstein, 1987; Descatha, Roquelaure, Evanoff, & Leclerc, 2007; Silverstein, Fine, & Armstrong, 1986). Wrist posture has been associated with upper extremity MSDs, including wrist tendinosis (Armstrong et al., 1987; Knox & Moore, 2001). Extreme wrist extension or flexion can put excessive passive loads on tendons and place muscles at nonoptimal lengths, resulting in decreased maximal force production capabilities. In addition, friction between tendons and adjacent bony or ligamentous structures may increase in certain extreme wrist postures. Kutsumi, Amadio, Zhao, Zobitz, and An (2005) found that wrist position significantly affected the tendon gliding resistance of the extensor pollicis brevis and likely contributed to the development of wrist extensor tendinosis.

We previously reported results on the relationship between incidence of wrist tendinosis and select measures of force and repetition in the workplace (Harris, Eisen, Goldberg, Krause, & Rempel, 2011). An exposure–response relationship for percent time in heavy pinch (>1 kg) and wrist tendinosis was observed. However, those exposed to high hand repetition rates, whether measured by observer-rated Hand Activity Level scale or video analysis, showed no increased risk of wrist tendinosis when adjusted for force. Although we have some understanding of the exposure–response relationship among force, repetition, and wrist tendinosis, there are limited data

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on the relationships between wrist posture and wrist tendinosis, especially during repetitive forceful exertions. The primary purpose of this study was to investigate whether an exposure–response relationship exists between nonneutral wrist postures and wrist tendinosis.

METHOD

This was a 28-month prospective study designed to assess incidence and predictive factors for work-related upper-extremity MSDs in manufacturing and production industries (concrete stones, office chairs, dairy, and mushrooms). The study has been previously described in detail (Harris et al., 2011). All 450 participants provided baseline information on medical conditions, discomfort, previous injuries, and psychosocial work environment using items from the Job Content Questionnaire (Karasek et al., 1998). A total of 413 individuals had follow-up data from questionnaires and physical examinations completed every 4 months for up to 28 months.

Health Outcome Assessment

A physical exam was triggered every 4 months for the hand/wrist region when the following criteria were met:

- Experienced pain in the hand/wrist region during the past 4 months which was thought by the participant to be work related AND
- A score of at least a 5 on a 0- to 10-point pain intensity scale in the past 7 days OR
- Consumed pain medication (including over-the-counter medication) for hand/wrist pain for 2 of the past 7 days

Maneuvers used to diagnose up to 11 hand/wrist tendinoses included eliciting pain over a specific tendon while loading the associated muscle (positive maneuver). Case criteria included a positive maneuver and the presence of one of five core signs (tenderness to palpation, redness, swelling, crepitance, or warmth).

Outcome Variables

The primary outcome was incident hand/wrist tendinosis of the dominant side. Participants became a case once they were diagnosed with any one of the possible 11 tendinoses of the hand and wrist (Harris et al., 2011). Once a participant was diagnosed with tendinosis, he or she was censored from the analysis.

Exposure Assessment

Approximately 10 min of video was recorded for each task of each participant and analyzed frame by frame using multivideo task analysis (MVTA; Yen, 1995). Force measurements and matching were used to classify the grip of the dominant hand in each frame (Bao & Silverstein, 2005). The three categories of grip evaluated in the posture analysis were "heavy pinch" (>1 kg force), "heavy power grip" (>4 kg force), and "other" (light pinch, light power grip, and no load). A pinch was defined as a load that was primarily applied to the fingers. A power grip was defined as a load that was evenly distributed between the palm and the fingers or primarily located on the palm.

By individual and task, 15 frames from each grip category were chosen at random for analysis of wrist angle (e.g., deviation from neutral; 0°) in flexion and extension. For frames taken from an orthogonal side with good viewing conditions, analysts used MVTA's built in angle measurement tool to superimpose two lines (midregion of the extensor surface of the forearm and the dorsal surface of the hand) onto the video image (Bao, Howard, Spielholz, & Silverstein, 2007). A good viewing condition was defined by both hand and distal portion of the forearm being visible. For frames with ambiguous viewing conditions or not viewed from an orthogonal side, adjacent frames (±5) were used to assess joint angle. If wrist posture was not visible or the wrist was obstructed, the measurement was recorded as missing data (3.2%). Wrist extension/flexion was recorded to a precision of 5°, an amount that differentiated most tasks in the study.

Job title and primary work tasks were assessed for all workers and confirmed during an in-depth individualized field exposure assessment. Individualized field exposure assessments and/or video recordings were completed for 295 of the 450 participants. For workers who did not have individualized exposure assessment data (n = 155), exposure levels for each task were

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imputed based on the median values from the participants who performed the same task and had video assessed posture data (n = 127). The remaining 28 participants, without video posture data, were eliminated from the analysis. A time-weighted average was calculated based on the average number of hours worked per week per task that each worker self-reported (Harris et al., 2011). Peak deviations were the posture with the largest deviation from neutral across all tasks in either flexion or extension.

Exposure Variables

Force and repetition measures included in this analysis were the percent time spent in heavy pinch and power grip and the total repetition rate (repetitions/min) across all grips in the dominant hand as measured by video analysis (Harris et al., 2011). The primary exposures of interest were dominant-side time-weighted average (TWA) values of median wrist flexion and extension while in heavy pinch, heavy grip, and all grips. A post hoc analysis of other posture measures included heavy pinch, heavy grip, and all grips of the TWA percent time in ≥30° of extension, the TWA percent time in ≥30° of flexion, and peak wrist deviation from neutral.

Statistical Analysis

Survival analysis was performed using the Cox proportional hazards model with robust confidence intervals to estimate hazard ratios. To estimate an exposure–response relationship, measures of median extension or flexion were split into tertiles based on an equal number of cases in all three groups. Potential confounders were included in each model and sequentially removed and replaced. Variables that changed the primary exposure effect measure >10% were retained in the final model. Although only gender consistently met this criterion, all models included adjustment for age, gender, force (percent time in heavy pinch and grip), and repetition rate (repetitions/min in all grip types).

RESULTS

The study population included 37% women, and approximately half were over the age of 40 years (Harris et al., 2011). In all, 9% had a medical condition that included diabetes, lupus, rheumatoid arthritis, or gout and 34% were considered obese (BMI ≥ 30). Of participants, 4% were left hand dominant. Low job strain identified by high job demand and low control based on median subscale splits (Karasek et al., 1998) was reported in 72% of the participants, and 58% had worked at their job for more than 5 years.

There were 481.4 person-years and 26 incident cases of dominant-side wrist tendinosis, for an incidence of 5.4 cases per 100 person-years. Tendinosis of the dominant hand first dorsal compartment (de Quervain's disease) had the highest overall incidence, at 2.7 cases per 100 person-years (n = 13).

There was a low correlation between repetition rate and force as quantified by the percent time spent in heavy pinch and grip (r^2 = .21). Both variables had correlations less than .36 with all median wrist flexion and extension measures. There were moderate correlations between the percent time spent in more than 30° flexion or extension and repetition rate ($r^2 \leq .32$) and the percent time in heavy pinch or grip ($r^2 \leq .44$). There was a low negative correlation between peak deviation measures and both repetition rate ($r^2 \leq -.14$) and the percent time in heavy pinch and grip ($r^2 \leq -.25$).

The initial a priori analyses for median wrist posture in flexion or extension and incident wrist tendinosis were adjusted for age, gender, force, and repetition (Table 1). To assess trends between increased exposure and risk of wrist tendinosis while in different grips, exposures were split into tertiles by cases for each posture category, including all grips, heavy pinch, and heavy grip. For the all grips category there was an increase in risk of wrist tendinosis at 7° of wrist flexion (HR = 2.69, 95% CI = 1.01–7.21). Median wrist extension greater than 16° also doubled risk, though the findings were not significant (HR = 1.93, 95% CI = 0.68–5.49). When median wrist extension and flexion while in heavy pinch were assessed, there were also increases in risk that did not reach statistical significance. Risk for wrist tendinosis increased five-fold for those exposed to high median wrist flexion postures (>20°) while in heavy pinch

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TABLE 1: A Priori Analysis of Median Wrist Extension and Flexion on Risk of Hand/Wrist Tendinosis While in Different Grip Postures, Adjusted for Force (% time in heavy pinch and grip), Repetition (total reps/min), Gender, and Age

	N (total)	Cases	Controls	Cutoff Values	HR	Lower 95% CI	Upper 95% CI	*p* Value
Time-weighted average median wrist extension								
Across all hand postures	365	25	340					
Low	200	9	191	≤16.6°	1.00			
Medium	68	8	60	>16.6° & ≤21.7°	1.93	0.68	5.49	.22
High	97	8	89	>21.7°	1.03	0.34	3.13	.96
While in heavy pinch	351	25	326					
Low	114	9	105	≤16.9°	1.00			
Medium	116	8	108	>16.9° & ≤20.7°	0.92	0.34	2.53	.88
High	121	8	113	>20.7°	1.48	0.37	5.93	.58
While in heavy power grip	324	22	302					
Low	54	8	46	≤20.0°	1.00			
Medium	98	8	90	>20.0° & ≤43.3°	0.55	0.12	2.51	.44
High	172	6	166	>43.3°	0.24	0.06	0.94	.04
Time-weighted average median wrist flexion								
Across all hand postures	358	25	333					
Low	157	9	148	≤2.8°	1.00			
Medium	167	8	159	>2.8° & ≤7.1°	0.95	0.34	2.67	.93
High	34	8	26	>7.1°	2.69	1.01	7.21	.05
While in heavy pinch	323	23	300					
Low	130	8	122	≤5.6°	1.00			
Medium	176	9	167	>5.6° & ≤20.0°	1.21	0.40	3.61	.74
High	17	6	11	>20.0°	5.03	0.74	34.05	.10
While in heavy power grip	196	8	188					
Low	74	3	71	≤8.6°	1.00			
Medium	99	3	96	>8.6° & ≤11.3°	0.67	0.14	3.13	.61
High	23	2	21	>11.3°	1.25	0.13	12.41	.85

(HR = 5.03, 95% CI = 0.74–34.05) and by 50% for those exposed to high median wrist extension postures (>20°) while in heavy pinch (HR = 1.48, 95% CI = 0.37–5.93). Wrist extension (> 43°) during heavy grip was protective (HR = 0.24, 95% CI = 0.06–0.94), whereas a nonsignificant increase in risk (HR = 1.25, 95% CI = 0.13–12.41) was observed for wrist flexion during heavy grip (>11°).

The post hoc analyses indicated that the percent time spent in wrist extension ≥30° while in all grips increased risk beyond 18° and while in heavy pinch beyond 10° (Table 2). Wrist extension ≥30° of extension while in heavy grip was protective. For wrist flexion ≥30°, the all grips category was protective (HR = 0.24, 95% CI = 0.08–0.73), whereas the percent time spent in ≥30° flexion while in heavy grip more than doubled the risk (HR = 2.47, 95% CI = 0.81–7.52). Similarly, though statistically nonsignificant, peak deviation in all grips and heavy pinch tended to reduce risk of developing wrist tendinosis, whereas peak deviation in heavy grip appeared to increase risk.

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TABLE 2: Post Hoc Analysis of Time-Weighted Average Posture Measures and Risk of Hand/Wrist Tendinosis, Adjusted for Force (% time in heavy pinch and grip), Repetition (total reps/min), Gender, and Age

	N (total)	Cases	Controls	Cutoff Values	HR	Lower 95% CI	Upper 95% CI	*p* Value
Time-weighted average percent time in ≥30° wrist extension								
Across all hand postures	365	25	340					
Low	195	9	186	≤18.8%	1.00			
Medium	60	8	52	>18.8% & ≤30.1%	1.90	0.65	5.52	.24
High	110	8	102	>30.1%	0.86	0.31	2.40	.77
While in heavy pinch	351	25	326					
Low	129	9	120	≤5.0%	1.00			
Medium	177	8	169	>5.0% & ≤10.5%	0.78	0.30	2.07	.63
High	45	8	37	>10.5%	3.03	0.81	11.25	.10
While in heavy power grip	328	22	306					
Low	33	8	25	≤0.4%	1.00			
Medium	157	10	147	>0.4% & ≤2.0%	0.36	0.10	1.31	.12
High	138	4	134	>2.0%	0.07	0.02	0.28	.00
Time-weighted average percent time in ≥30° wrist flexion								
Across all hand postures	365	25	340					
Low	104	12	92	≤0.1%	1.00			
Medium	182	5	177	>0.1% & ≤0.6%	0.24	0.08	0.73	.01
High	79	8	71	>0.6%	0.65	0.25	1.73	.39
While in heavy pinch	351	25	326					
Low	129	11	118	≤0%	1.00			
Medium	98	6	92	>0% & ≤0.1%	0.67	0.24	1.86	.44
High	124	8	116	>0.1%	0.73	0.30	1.79	.50
While in heavy power grip	328	22	306					
Low	287	16	271	≤0.0%	1.00			
High	41	6	35	>0.0%	2.47	0.81	7.52	.11
Peak deviation across all tasks (flexion or extension)								
Across all hand postures	365	25	340					
Low	74	9	65	≤42°	1.00			
Medium	222	10	212	>42° & ≤56.9°	0.54	0.19	1.52	.24
High	69	6	63	>56.9°	0.70	0.23	2.12	.53
While in heavy pinch	365	25	340					
Low	120	9	111	≤34.8°	1.00			
Medium	108	9	99	>34.8° & ≤40.0°	0.81	0.32	2.08	.67
High	137	7	130	>40.0°	0.43	0.17	1.12	.08
While in heavy power grip	354	23	331					
Low	110	8	102	≤40°	1.00			
Medium	191	10	181	>40.0° & ≤54.4°	1.09	0.35	3.36	.88
High	53	5	48	>54.4°	1.35	0.38	4.88	.64

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DISCUSSION

The incidence of dominant-side wrist tendinosis in this cohort was 5.4 per 11 person-years, with the highest number of cases having de Quervain's disease. This study assessed the association of wrist posture and the incidence of wrist tendinosis with more individual exposure detail than most previous studies. Based on these findings, there was increased risk above 7° of TWA median wrist flexion in all grips; although there was a trend of increased risk with TWA median wrist extension greater than 16°, it was not significant. A trend of increased risk of wrist tendinosis with median wrist flexion or extension greater than 20° during heavy pinch was also seen, though findings were not significant. Findings were less consistent while in heavy grip, with TWA median flexion showing an increased risk and TWA median wrist extension showing reduced risk.

Roquelaure, Corinne, Gaétan, Serge, and Fontbonne (2002) defined an extreme awkward posture being greater than 50% to 60% of total joint range and a moderate awkward posture being greater than 20% to 40% of total joint range. Based on this definition, wrist flexion greater than 40° and wrist extension greater than 35° are considered extreme. Similarly, wrist flexion between 24° and 40° and wrist extension between 21° and 35° are considered moderate deviations. Our results indicate that during heavy pinch, ergonomists, health care workers, and engineers should be looking for moderate (in addition to extreme) deviations in wrist flexion and extension as a posture that may increase risk of wrist tendinosis.

The increased risk for incident wrist tendinosis from awkward postures during heavy pinch may be related to the high incidence of de Quervain's disease in this cohort. This is consistent with findings from a cross-sectional study by Petie Le Manac'h et al. (2011), who found a two-fold increase in risk for those with de Quervain's disease from repeated or sustained wrist deviation in extreme posture. The extensor pollicis brevis (EPB) and abductor pollicis longus (APL) are affected in de Quervain's disease, both of which are active during pinch. Awkward wrist postures may place APL and EPB in less optimal length for generating force, thereby requiring greater muscle activity to achieve the same applied force. It is also possible that there is an increase in friction of the EPB and APL tendons as the wrist moves into flexion or extension. Regardless of the reason for the increase, based on these and previous findings, it is clear that pinch of more than 1 kg force should be minimized and, when needed, the wrist should be in a neutral posture.

Unlike the study by Petie Le Manac'h et al. (2011), who found a three-fold increase in risk of de Quervain's disease from repetitive use of twisting or driving of screws, our results indicate that there may be a difference between increased wrist flexion versus extension during heavy power grip. Median extension was actually protective, even beyond 43°, whereas median wrist flexion showed an increase in risk beyond 11°, though statistically nonsignificant. During power grip, a flexed wrist reduced maximum grip force by 40% to 50% (Mogk & Keir, 2003). For a task requiring a power grip, performing the task with wrist extension may require less muscle activity than performing the same task in wrist flexion, thereby reducing the loads on wrist tendons. The percent time spent in greater than 30° of wrist flexion was not useful for risk assessment in this cohort; workers spent little time in moderate flexion. In fact, cutoffs between exposure groups were so close together that the findings were not particularly useful. The analysis for the percent time spent in greater than 30° of wrist extension was more meaningful since workers spent more time in this position while in all grips or heavy pinch. The three-fold increase in risk during heavy pinch, although not significant ($p = .10$), deserves further investigation.

Assessing wrist posture during production work can be difficult due to rapid arm motions and the variety of tasks performed. Some risk assessment tools simplify exposure assessment for posture by utilizing a peak awkward posture for the assessment. Results from this study indicate that, at least for production work, a single large peak angle deviation measure was not associated with increased risk of wrist tendinosis but appeared protective. It is possible that tasks involving high force require a more neutral joint position to maximize strength capabilities. Therefore, tasks with large peak deviations from neutral may be tasks

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that require low hand force and are, therefore, lower risk. Overall muscle and tendon loads would be expected to be higher with sustained awkward postures compared to single large deviations. Indeed, across all grip types, there was an inverse correlation between peak wrist deviation and median wrist flexion ($r = -.21$).

LIMITATIONS

As previously described, the strengths of this study lie in its prospective design, the observer blinded assessments of exposure and outcome measures, and exposure measured at the individual level (Harris et al., 2011). However, there are some limitations that may have contributed to reduced precision in the reported associations. First, the relatively low number of cases limited our power to detect differences in some exposure categories. To account for the relatively low number of cases, exposure categories were based on equalizing the number of cases in each group. The drawback to this approach is that the cut points between exposure groups are not strategically made based on clinical or design specific importance. In addition, for some of the adjusted models, groupings could not be split evenly thereby leaving disproportionately fewer cases in one group. Robust confidence intervals were used to increase confidence in statistically significant findings but caution should still be taken when interpreting the findings. Third, wrist posture measures were extracted from a 10-min video of each task of a worker. Although most of these production work tasks were repetitive with short cycle times, uncommon parts of the tasks would have been missed. In addition, the use of self-reported estimates of time on task per week may have caused some nondifferential exposure misclassification and biased results toward the null. Finally, a healthy worker survivor effect in this cohort may have contributed to an underestimate of associations (Harris et al., 2011).

CONCLUSION

Risk of wrist tendinosis approximately doubled for those with TWA median wrist flexion postures greater than 7°. A similar trend was observed for TWA median wrist extension postures greater than 16°, but it did not reach statistical significance. A trend of increased risk of wrist tendinosis and TWA median wrist flexion or extension greater than 20° while in heavy pinch (> 1 kg force) was observed. The use of peak wrist deviation or the percent time spent in extreme flexion or extension while in all grips or heavy pinch was actually protective and was not an effective method to quantify risk in this study. Overall, the findings suggest that among production workers it is important to identify and modify tasks with wrist flexion especially during episodes of heavy pinch (> 1 kg force). It appears that task and tool design should favor a wrist posture of neutral to slight wrist extension especially with high force power grip (> 4 kg force). In addition, in keeping with recommendations from the previous analysis of the same dataset (Harris et al., 2011), tasks should be designed to reduce the duration of episodes of heavy pinch.

ACKNOWLEDGMENTS

This study was funded by a grant from the National Institute for Occupational Safety and Health (NIOSH; R01-OH007914), but the findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the NIOSH. We would like to acknowledge Estie Hudes for her support with the statistical analysis and Ira Janowitz, Betsy Llosa, Chih Ming Hsieh, Kimmy Yung, Denny Yu, Ed Young, Mike Lopez, and Monica Garcia for their assistance with data collection and video analysis. Finally, the authors would like to thank the study participants and their employers for their time and willingness to participate in this study.

KEY POINTS

- Among production workers, a time-weighted average median wrist flexion greater than 7°, across all grip types, approximately doubled the risk of wrist tendinosis.
- A statistically nonsignificant trend was identified for median wrist deviation in extension or flexion while in heavy pinch (> 1 kg force).
- Increased median wrist extension while in heavy power grip (> 4 kg force) was protective, a finding that deserves further investigation.
- A single measure of peak wrist deviation in extension or flexion, during all grips and heavy pinch, was protective and was not an effective method to quantify risk in this study.

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Date received: December 7, 2012
Date accepted: July 15, 2013

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