Final Progress Report

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List of Terms and Abbreviations

BIA:	Bioelectrical Impedance Analysis
BMI:	Body Mass Index
CESD:	Center for Epidemiological Studies Depression Scale
ECR:	Elder Care Responsibilities
FRT:	Functional Reach Test
HWSE:	Healthy Worker Survivor Effect
JCQ:	Job Content Questionnaire
MSH:	Musculoskeletal Health
MSD:	Musculoskeletal Disease
NCAAA:	North Central Area Agency on Aging
OA:	Osteo-arthritis
OHS:	Occupational Health and Safety
PAR:	Participatory Action Research
PATH:	Position Activity Tools and Handling
R2P:	Research to Practice
TWH:	Total Worker Health
VO2 MAX:	Maximum Oxygen Consumption
WAI:	Workability Index

Abstract

The University of Connecticut Study on Aging, Musculoskeletal Disorders and Work Capacity -- 2R01OH008929-06A1 (2017-2022), subsequently referred to as UConn-SAM, continued the work performed under 5R01OH008929 (2008-2014). 2R01OH008929-06A1 was extended for two additional years under a no cost extension through September 30, 2022. The two-year extension was the consequence of the barriers to field work imposed by COVID-19.

Viewed in its entirely, UConn-SAM has been the longest running cohort study that has been supported by NIOSH. In principle, longitudinal studies have been problematic in working cohorts because of interruptions in the inception group caused by job transfer and the complications of long-term follow-up once the place of employment is obviated. UConn-SAM was buffeted by two historical events – the Great Recession and COVID-19. This had effects on results and introduced new areas of inquiry that in most respects were more significant than the answers to the specific hypothesis. The pattern of not leaving work from 2008-13 was corrected in 2018 when turnover resumed in a historical pattern. The lack of association between health status, including musculoskeletal disease, and retiring or leaving work for other reasons was largely negative until 2022 when retirement and leaving work was explained by social and individual circumstances. Elder Care Responsibilities (ECR) were important study additions, and it was ECR providers who experienced the greatest degrees of health-related prevalent causes.

UConn-SAM had three aims. The first was the determination of whether the low drop-out and retirement rates (study endpoints) observed from 2008-2014 would persist a decade after the Great Recession. The second was whether surveys could be refined to capture more financial, retirement planning, and ECR components, and whether physical testing could be refined given the earlier failure of these measures to predict outcomes. The third component was a pilot introduction of an intervention, which had been stalled by the onset of COVID-19.

Key findings were identification of a restoration of historical retirement and dropout patterns by 2018. Surveys were refined and provided a more thorough window on ECR and the effects of social conditions on retirement planning. Also, the physical testing was refined to include more strenuous components for measuring physical fatigue and a more useful sub-maximal exercise test. At the conclusion of UConn-SAM, a pilot intervention was performed as planned with the North Central Area Agency on Aging (NCAAA).

SECTION 1

Significant or Key Findings

The University of Connecticut Study on Aging, Musculoskeletal Disorders and Work Capacity -- 2R01OH008929-06A1 (2017-2022), subsequently referred to as UConn-SAM, continued the work performed under 5R01OH008929 (2008-2014). 2R01OH008929-06A1 was extended for two additional years under a no cost extension through September 30, 2022. The two-year extension was the consequence of the barriers to field work imposed by COVID-19. Viewed in its entirety, 2R01OH008929-06A1 (2017-2022) was buffeted by two historical events – the Great Recession and COVID-19. This had effects on results and introduced new areas of inquiry that in most respects were more significant than the answers to the specific hypothesis.

The pattern of not leaving work from 2008-13 was corrected in 2018 when turnover resumed in a historical pattern. The lack of association between health status, including musculoskeletal disease, and retiring or leaving work for other reasons was largely negative until 2022 when retirement and leaving work was explained by social and individual circumstances.
Elder Care Responsibilities (ECR) were an important study addition, and it was ECR providers who experienced the greatest degrees of health-related prevalent causes.

Significant Findings Related to Specific Aims

SIGNIFICANT EFFECT	Aim
The frequency of remaining at work had returned to pre-recession levels at Time 4 (T4) (2018) without associated changes in health status.	1a.
There was an adverse response to working conditions in 2008-13, related to the Great Recession but the expected adverse response with aging was not recognized.	1b.
The prevalence of ECR was not associated with deferred retirement as hypothesized. Instead ECR remained consistent in prevalence and comparable to the prior study period.	1c.
The likelihood of age-related functional decrements and increasing difficulty with physical demands at work was not proven, but results were nuanced. Older workers wanted more job flexibility and time flexibility but did not site job difficulty as a major influence. There were expected age related performance declines, but these were not associated with work difficulties. This was true through T4 testing. However, at Time 5 (T5), job difficulty and physical health were cited as reasons for leaving. Perhaps increasing. *In Virus, Veritas?*	1d.
We hypothesized that gender differences would widen as retirement was delayed. This is a somewhat complex expectation, in that work characteristics were not directly observed in 2017-2022 and were not pertinent in the earlier period.	1e.
The hypothesis that COVID-19 would produce a distinctive pattern for leaving work or retiring was demonstrated as retirees reported more health problems and those leaving work but not retiring cited work-family tensions and scheduling difficulties.	1f.
Using workforce groups to inform the surveys for revision was useful particularly in delineating the prevalence of ECR and other resources as defined by managers and experienced by the workforce. There were clear advantages over some of the widely used 'validated instruments'. Enhanced retention techniques were successful in T5 maintenance of the workforce. Nevertheless, there were impediments to recontact	2a.

once workers had left facility employment. Also, employer contribution to testing on worktime was highly significant and a barrier when absent.	
Best physiological tests were tested in the laboratory. Sub-maximal exercise correlated to HR was superior to our original maximum exercise test. Extension of extinction/fatigue intervals from 20-30 sec. led to superior more differentiated results.	2b
A more reduced sensor load for actigraphy produced as good results as the 4-sensor model proposed in IMPACTO, which was our reference.	2c.
Focus Groups were useful in identifying intervention priorities. The interruptions of COVID-19 limited direct engagement until the final 3 months of the project.	3a.
ECR interventions were limited because of COVID-19. They ended with Area Committee on Aging following-up post study.	3b.
A Healthy Aging E-Tool with NIOSH is still in progress and proceeds with direct NIOSH funding.	3c.

Translation of Findings

UConn-SAM survey questions and approaches have been provided to NIOSH. Publications are listed elsewhere. The NIOSH E-Tool will enter the public domain.

Research Outcomes/Impact

The impacts of UConn-SAM are related to its unique nature as an occupational medicine longitudinal study. The findings significantly revise a good deal of conventional thinking in the field. The expected endpoints around the physical dimensions of work were not observed. Instead, the balance of threats to health rested on more complex work life or TWH type considerations. The impacts of ECR were important. Also, more flexibility at work overwhelmed the basic physical characteristics of the jobs. In terms of various hypotheses on maintaining an aging workforce at work, it was clear that flexibility around work schedules and life demands were more consequential than simple physical demands. It should be noted that in partially automated work where the most physically demanding components have been culled, the perspective on health and well-being seems more fitting.

There were good reasons to question standard survey instruments that were markedly inert to the influence of usually identified work factors. What was not inert was the powerful period effects of the Great Recession and COVID-19. The significant changes in work organization and ownership complicated entry by the study team, particularly with more offsite management. This will require careful planning by investigators.

The importance of period effects in the changing American work and social environment should not be underestimated. That, and some significant local changes in work organization, and more subjective factors, such as the effect of company success and hiring and workforce attitude, are also important considerations.

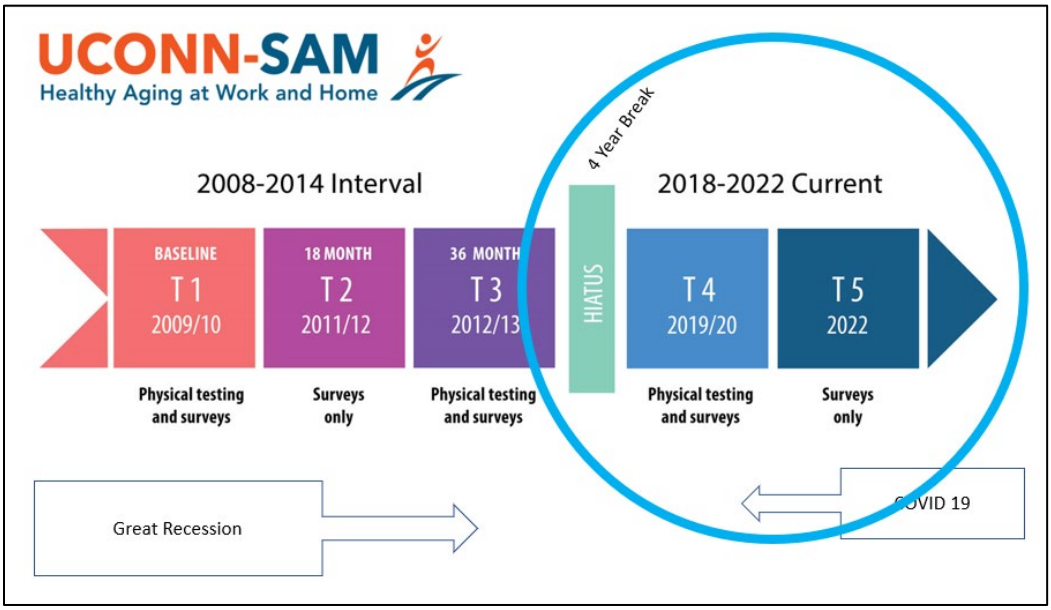
Finally, we did not satisfy our original expectation to validate the findings of the Finnish Municipal Workers Study. Physiological testing did not provide an authoritative platform for delineating likelihood of disability and leaving work. We did not show that Workability was a particularly useful measure. Overall, we have raised doubts about the suitability of complex physiological testing as conventionally formulated.

Section 2 - Scientific Report

Background

The University of Connecticut Study on Aging, Musculoskeletal Disorders and Work Capacity -- 2R01OH008929-06A1 (2017-2022), subsequently referred to as UConn-SAM, continued the work performed under 5R01OH008929 (2008-2014). 2R01OH008929-06A1 was extended for two additional years under a no cost extension through September 30, 2022. The two-year extension was the consequence of the barriers to field work imposed by COVID-19.

Viewed in its entirely, UConn-SAM has been the longest running cohort study that NIOSH has supported. In principle, longitudinal studies have been problematic in working cohorts because of interruptions in the inception group caused by job transfer and drop-out from the work force and because of the difficulties in long-term follow-up once the place of employment has been removed as a focus of participation. This longitudinal study of musculoskeletal health has extended continuously from 2008 to 2022, with multiple testing sequences. Because of funding interruptions there was a 3-year gap from 2014-2017. Because of a desynchrony between funding periods and field-based collection of data, that gap translated into a four-year interval from 2014-2018 when there was no data collection. There have been five sequences of survey-based data collection, Time 1 – Time 5 (T1 - T5) in 2008, 2011, 2013, 2019 and 2022, and four sequences of physiological testing. Complete physiological testing on the incumbent workforce was performed at T1 and T3, preceding the most recent funding interval. The T4 physiological testing was performed under this grant 2R01OH008929-06A1 (2017-2022). The study population at inception (N=776) was enlarged to 1000 at T2 to preserve adequate power because predicted endpoints, centered around leaving work, proved to be insufficiently populated during the Great Recession. UConn-SAM was based at 6 mid-size skilled manufacturing companies, characterized by their historical stability in workforce retention, and consistency of senior management and product lines. In addition, there were longstanding working relationships with the study team. A graphic sequence of timeline and testing is summarized in the following figure.



UConn-SAM was based on the premise that an extended period of observation (originally 5-6 years) would distinguish physiologic from premature aging of the musculoskeletal system, with functional status effecting "drop-out" from employment. A key objective was to examine the interplay between work and non-work factors, and to recognize better gender specific physiological, social, organizational, and environmental influences on the aging process and work. The combined focus on individual health, work organization, and psychosocial measures was already consistent with Total Worker Health™ (TWH) objectives before the TWH™ program was formally proposed.

UConn-SAM has proven to be exceptional in several ways. First, as introduced, it has been the longest cohort study supported by NIOSH. Second, the study was both intersected and circumscribed by two historical events: 1) the Great Recession, and 2) COVID-19. Third, it has proven to be a laboratory for assessing the stability and reliability of accepted, evidence-based survey and physiological metrics during a time of socio-demographic potential population effects. Fourth, it has been a platform for converting observational study results into targeted interventions. UConn-SAM proved to be an elemental barometer of social changes that we had not foreseen at initiation. As one example, entry criteria presumed stability of the participating companies, based on their historical record. Because of concerns with inter-cohort comparability and with maintaining a predictable retirement and transfer rate, plant selection criteria, based on historical performance, were as follows:

- Medium size employer historically known to the study staff.
- A broad age distribution centered around the late 5th or early 6th decade.
- A workforce engaged in light skilled manufacturing with high degrees of repetition
- No age specific or seniority policies leading to early or forced retirement.
- Exposure to global competitors.
- Capacity to document stable retention rates for established employees (more than 5-years at the job), during the 5-years preceding study inception.
- Successful demonstration in a pilot study that former employees could be reached and would respond.
- No current plans for major workforce downsizing during the lifetime of the study.

The intrusion of the Great Recession invalidated the presumption of stability. In addition, as will be explained below, there were also changes in the ownership and management of the previously stable participating companies that deviated from historical precedent.

The addition of Elder Care Responsibility (ECR) measures in T2 and T3 provided important new insights on health effects that were not anticipated at baseline in 2008.

Extension of the 2008-2014 Study

The original study of musculoskeletal disease and aging (2008-14) was designed to incorporate key outcomes within the proposed study lifetime: 1) physiological change and 2) dropping out from the inception working relationship. The decision to extend the study, as 2R01OH008929-06A1 (2017-22), was based on exceptional juxtaposition of the study interval through the heart of the Great Recession. A final report of the 2008-2014 study previously was submitted to NIOSH and this report is more confined to 2R01OH008929-06A1 (2017-22). However, because the accumulation longitudinal data provided an opportunity to trace participant response profiles back to 2008, there is considerable reference to the earlier work.

Study Aims

The three principle aims and the sub-aims (hypotheses) from the R01OH008929-06A1 application are listed below.

Aim 1. Characterize barriers to healthy workforce aging for both men and women, e.g.: retirement options, dissatisfaction with working conditions, and elder care burden, through extended observation of an older manufacturing workforce cohort.

Hypothesis 1a. Despite possible improvements in macro-economic conditions, continued national or local economic uncertainty will induce cohort members to continue to postpone retirement.

Hypothesis 1b. Adverse perceptions of working conditions due to work organizational factors will intensify for older workers as they age further.

Hypothesis 1c. Prevalence of Elder Care Responsibility (ECR) will increase for older workers who continue to work and postpone retirement, being especially salient for those in physically demanding jobs.

Hypothesis 1d. Probability of age-related functional decrements (on physiological testing) and adverse health outcomes will increase for older workers as they continue employment beyond planned retirement; both increases will be greater in high-risk sub-groups such as those with high ECR.

Hypothesis 1e. The observed gender differences in workplace exposures (see Progress Report) will widen as older employees work beyond planned retirement age

Aim 2. Refine methods to assess musculoskeletal outcomes, work ability, physical job demands, and other predictors and endpoints for healthy workforce aging:

Sub-aim 2a. Use of Participatory Action Research (PAR) methods, as well as surveys and qualitative measures to insure retention

Sub-aim 2b. Select the best predictive physiologic measures among the current and an upgraded proposed battery of tests for determining successful aging at work and intervention effectiveness.

Sub-aim 2c. Improve instrumented exposure monitoring for assessment of physical activity at work and out of work using actigraphy.

Aim 3. Developing and Piloting Several Worksite Interventions Using PAR Methods to Insure Intervention Effectiveness and Successful Aging at Work

Sub-aim 3a. Use of work environment assessment and qualitative data from focus groups to determine a set of possible worksite interventions to promote healthy aging at work.

Sub-aim 3b. Developing and piloting an eldercare intervention as both a discrete project and as a format for additional intervention projects.

These three aims in 2R01OH008929-06A1 were based on several provocative and unanswered questions which arose in the 2008-2014 study. They were: 1) resolving whether the economic fears and reluctance to leave employment was a period effect or a reflection of longer-term changes around finances and employment; 2) making more definitive determinations on survey content and physiological findings, given the non-conformity of our findings with the published literature; and (3) determining whether some of the unexpected findings, particularly around ECR could be actualized as pilot interventions. It will be noted that Aim 1 is specific to unresolved issues around core outcomes from the 2008-2014 study. The expected endpoints related to employment consequences of musculoskeletal health did not occur, as workers did not leave work or change jobs in patterns consistent with historical norms. Moreover, ECR had emerged as more important issue. This was due in part to the limited literature on ECR in hourly workers. In addition, our widely accepted and presumably validated survey instruments appeared to lose their discrete independence in the face of what appeared to be external economic events. We appreciated that we were observing a complex reality which was at least as important as the rationale for our original study.

We proposed to continue the study for 3 years with three new specific aims. These considerations supported the more technical considerations implicit in Aim 2. In the 2008-2014 period, we added modules on finances, ECR and family responsibilities, and retirement intentions. These were refined and tested in 2R01OH008929-06A1. We also elected to refine our physical assessment protocols by studying specific test alternatives in the laboratory. We had found that our maximum exercise test was insufficiently discriminatory, and we evaluated an alternative approach. We had also found that several of the mechanical tests to measure muscle group fatigue were insufficiently rigorous to introduce adequate between participation variation. Extended test intervals required laboratory evaluation and consistency with participant safety. Aim 3 is entirely new and unrelated to the 2008-2014 study.

The satisfaction of Aim 1 was based around a new survey round and the addition of a T4 observation point. The intent was to provide fuller assessment of the 50-69 age group where adverse health effects were concentrated. To summarize, Aim 2 addressed modifications and finalized research recommendations for the work-aging questionnaire, for physiologic testing, and for actigraphic measurement of movement. Aim 3, as noted, was a pilot intervention phase. We deviated from the original 2R01OH008929-06A1 proposal by introducing a 5th survey in 2022. As proposed, a 4th round of surveys was completed by January 2020, and although some physical testing was pending, we had essentially completed our tasks. Aim 2 was a legacy aim in that the rectifications in survey and physical testing were regarded as material for future studies and no longer applicable to this study. Aim 3 was underway and would have consumed the final 2020 year of the study. However, COVID-19 interfered with study completion. Aim 3 proved difficult to administer, despite variable efforts at online administration, because of the prohibition on field work. In fact, COVID-19 presented an unexpected opportunity. Since T4 surveys were completed just prior to the COVID-19 lock-downs, there was a strong interest in administering a T5 survey at the conclusion of the COVID-19 pandemic, to gauge health and personal planning effects in this historically followed cohort. The initiation of a final survey round can be regarded was a response to an unanticipated historic opportunity.

These aims and sub-aims differ in some substantial ways from those of the original 2008-2014. For point of reference, there were four initial substantive Aims:

1. Evaluate the effects of workplace exposure (including physical, psychosocial, and organizational factors) on normal, age-related changes in musculoskeletal health (MSH).

2. Evaluate the effects of work-family balance, non-work factors, and personal factors (such as health attitudes and leisure exercise) on normal, age-related changes in MSH.

3. Evaluate how workplace exposures and non-work influences differ between men and women engaged in similar employment, and how these gender-specific patterns of risk differentially affect the normal, age-related changes in MSH.

4. Identify factors that best predict higher or lower than normal rates of disability or retirement.

While the original study aims were addressed, the inception criteria presumed stable employment and predictable changes in industrial processes over the study's proposed duration. Instead, the study period of 2008-2014 coincided with an unprecedented period of economic instability in the manufacturing sector. There were dramatic changes in measures of psychological strain at work, quality of work life, and apprehension about family finances. These negative perceptions rose rapidly between 2009 and 2011 and did not recover in 2013, despite a reportedly more stable economy. The anticipated frequency of departure from the workforce due to changes in MSH was apparently obscured by macro-level factors. Perhaps the most important set of non-workplace factors influencing perceptions of work and health involved apprehensions over retirement. In all, 64% of workers surveyed in 2013 were considering or had already decided on delayed retirement due to changes in the economy. Perceived physical demand at work showed little change over time, but it appeared to affect MSH adversely in certain sub-groups, most notably members of the workforce with ECR.

We had expected extensive worker turnover and health related disability in this population and presumed that the principal barrier to effects measurement would be a healthy worker survivor effect (HWSE). However, we had projected the five-year turnover rate (retirements, voluntary and involuntary severance, disability, death) at 39%, but only 15% of the workforce left employment (Cherniack et al. 2014). There were, in addition, dramatic changes in perceptions of psychological demands, quality of work life, and apprehensions about family finances. These perceptions peaked in 2011, and they did not improve in 2013. The survey items were based on presumably validated and stable measures, so it became clear that expected phenomena and outcomes were likely presumptive. Hence, a baseline hypothesis that declining health, job dissatisfaction, and family demands would generate turnover was not confirmed. As anticipated, age-related declines in dynamic physical performance were observed, particularly after the age of 60 (Cote et al.2014). However, the impact on employment was not measurable since people did not leave work.

Status of Study Aims Completion from 2R01OH008929-06A1

The hypothesis tables and table keys below provide a status dashboard of aims and their completion.

√ indicates completion of sub-aim
√- indicates sub-aim in progress and near completion or significantly accomplished
-√ indicates that the task is largely incomplete

Hypothesis – Aim 1	Status	Observation
Hypothesis 1a. Despite possible improvements in macro-economic conditions, continued national or local economic uncertainty will induce cohort members to continue to postpone retirement.	√-	• Prior to COVID-19 levels of work termination had returned to pre-recession levels without change in health status.
Hypothesis 1b. Adverse perceptions of working conditions due to work organizational factors will intensify for older workers as they age further.	√	• It appears that perceptions do not change with age, but there are effects on leaving work.
Hypothesis 1c. Prevalence of Elder Care Responsibility (ECR) will increase for older workers who continue to work and postpone retirement, being especially salient for those in physically demanding jobs.	√	• Eldercare responsibilities (ECR) remain consistent. • >80% site with ECR cite major resource limitations and priority.
Hypothesis 1d. Probability of age-related functional decrements (on physiological testing) and adverse health outcomes will increase for older workers as they continue employment beyond planned retirement; both increases will be greater in high-risk sub-groups such as those with high ECR.	√-	• Physical job demands seem less limiting than time demands with aging. • Job flexibility emerging as major impediment to continuing work. • Physical health under evaluation, reduced testing in cohort*.
Hypothesis 1e. The observed gender differences in workplace exposures will widen as older employees work beyond planned retirement age.	√-	• Gender differences unclear with more complex demography than predicted.
Hypothesis 1f (new). COVID-19 will generate distinctive retention and retirement patterns	-√	• Younger workers with family demand more likely to change jobs • Older workers with morbidities more likely to retire

Hypotheses Aim 2	Status	Observation
Sub-aim 2a. Use PAR methods, as well as surveys and qualitative measures to insure retention.	-√	• Focus groups informed survey • Retention in study is problematic once employees have left work. • Conclusion that high participation is ***only*** possible as long as employed. • With changes in management, and lean production, less willingness for onsite testing.
Sub-aim 2b. Select the best predictive physiologic measures among the current and an upgraded proposed battery of tests for determining successful aging at work and intervention effectiveness.	-√	• Preferred tests identified. • Utility of further testing of this type appears unlikely to be accepted.
Sub-aim 2c. Improve instrumented exposure monitoring for assessment of physical activity at work and out of work using actigraphy.	√-	• Instrumentation dramatically improved. • Most of the work from another NIOSH-funded project.
General: placing methods tools and results in the public domain.	√	• Completed

Hypotheses – Aim 3	Status	Observation
Sub-aim 3a. Use of work environment assessment and qualitative data from focus groups to determine a set of possible worksite interventions to promote healthy aging at work.	-√	• Priorities selected but challenged by COVID-19 hiatus. • Task largely incomplete. • New priorities emerging due to COVID-19 and aging
Sub-aim 3b. Developing and piloting an eldercare intervention as both a discrete project and as a format for additional intervention projects.	√	• In final year, multi-site visits maintained
Other Sub-aims:		
Sub-aim 3c. Develop healthy aging E-Tool with NIOSH.	√-	• Continued by contract through 2022-23
Sub-sim 3d. Field work on chronic disease interventions.	√	• Site visits in final year of project.

Methods and Adaptations

Changes in the Study Population and Period Effects on Cohort Stability

The 408 active cohort members and a considerably large eligible follow-up group are a target for future studies. This is based on the observation that the post COVID-19 workforce will be significantly affected by the pandemic. In 2008-2013, there was resistance to retirement of changing employment, apparently due to fiscal reasons, as more normal work cycling and retirement patterns had returned by 2019, despite individual financial positions slightly declining. We anticipate major work organizational changes over the next several years, particularly on the older workforce, many of whom used PPP and sick leave resources to stay away from the workplace. If economic anxiety returns, the patterns will be important although not easily predicable at the time.

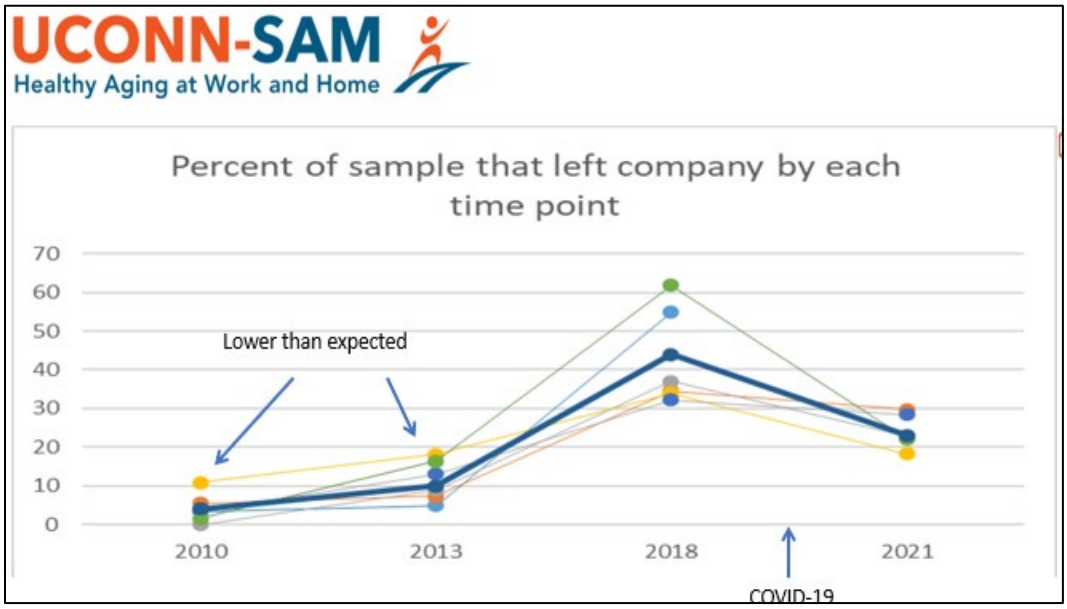
In Year 8, we added an additional aim (Aim 1f). Because of the delays introduced from COVID-19, we had extended the study beyond 2020. Although the interval was conceived as available for additional field interventions and data analysis, we elected to perform an additional round of surveys (T5) to utilize this unique opportunity to analyze workforce retirement and retention practices to just before and after Covid.

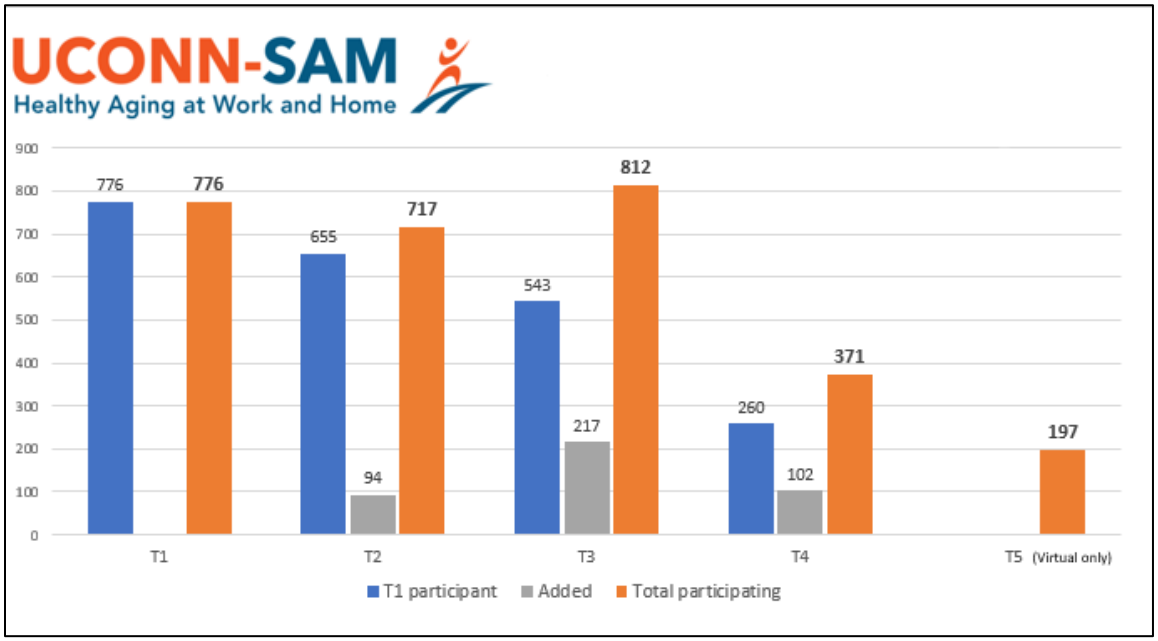
A new and unanticipated condition was reluctance to participate on the part of the workforce that was greater than expected from experience and earlier piloting. Focus groups identified heightened concerns over job security and disclosing health information. The experience with recruitment is summarized in the line and bar graphs shown below. Because participation rates were 27% lower than our precedent-based worst-case expectation, and plant populations were smaller, we were obligated to increase the number of sites from three to six. One consequence was a near doubling of the expected recruitment and baseline testing interval. Expansion of sites also introduced a new potential challenge to study power by introducing potential site-specific differences. The low participation rate (40%) resulted in a baseline cohort of 776, >10% below expectation, despite doubling the number of sites. A key adaptive decision was to proceed by emphasizing retention rather than by extending to an additional study site, since the latter course would have threatened study completion. The actual recruitment experience and temporal relationships in workforce continuity or leaving is represented in the following figures. The first represents annual leaving of employment at the host company. The second depicts the period cohort size and its maintenance through replacement.

The pattern of remaining in current employment or leaving followed a similar pattern at all the participating sites. High level of resistance to leaving work were consistent at all sites through the Recession (T1). The recovery rate by 2018 (date of survey not administrative data) exceeds the historical norm and suggests a compensatory effect. Interestingly at T4, the pattern had replicated the historical norm. The data is entirely pre-COVID. Notably, the T5 data was collected by electronic survey only on the 197 respondents among 408 who were eligible.

The two companies that had larger than expected T3 turnover than their peers had interesting side stories. The highest turnover (green) was an employer with historically low rates of turnover and generally good employee relations. However, the PayScale was comparatively low. The other leaver (blue) was the company that dropped out and had fraught workforce relationships and general pessimism about corporate survivor.

Of the pre- and post-Covid workforce, 197 of 408 (48%) eligible participants completed remote electronic surveys. 118 workers had either left the workplace (n=75) or retired (n=43).





Site Retention and Administrative Changes

One of the most significant alterations between 2008-2014 and 2017-2022 was an extensive and almost universal pattern of changes in management and operations. The guiding entry assumption of a stable workplace was valid in 2008-2014, but there were profound changes in ownership, management, and product output by 2018. This is represented in the following table.

2018 Project Renewal -Status of Organizations Originally Part of Project

Manufacturer Status - 2018	1	2	3	4	5
Size of company	mid	large	mid	large	large
Mergers & Acquisitions	x	x		x	x
Name change	x	x		x	
Global expansion		x	x	x	x
Local plant increase in employees	x	x	x	x	x
Upper management change (CEO/GenM)	x	x		x	x
New key study contacts	x	x			x
Ease of re-engagement			x		
Left study in Fall 2018					
T3 participant count	115	147	104	298	132

One consequence was that the introduction of new and often offsite management and HR was associated with greater resistance to onsite research and less interest in long-term health effects in the workforces. An interesting observation is that the retractions and scaling back with the Great Recession was reversed and all the facilities had undergone expansion. It should be noted that there were no significant changes in hourly wages, and benefits were either stable or mildly reversed.

Site retention was more challenging than foreseen and considerably more difficult than was the case a decade ago. However, both the study team and the internal environmental health and safety groups encountered previously unrealized barriers around allocating on-site staff time. As indicated in previous reports, there were profound management changes at 5 of the 6 sites, with changes in corporate form and the farming out of key resources, such as HR. The study team appreciated that all the sites were at risk of withdrawing from ongoing participation due to changed ownership, managerial turnover, concerns with loss worktime and a harsher work climate. At 4 of the 6 sites ownership management had changed at least once since 2014, and at a 5th site there had been a complete change in local management. In three cases, due to ownership changes, there was no longer local management and HR, as their functions had been taken over by a distant corporate entity. This necessitated a series of survey changes with separate themes to workers leaving the workforce for differing reasons and with a reliance on automated formats. It also meant a fundamental reassignment of staff to maintain site adherence.

Realizing the new and likely future challenges of retention there have been ongoing events to familiarize the site leaders with interventions, to hold seminars on a variety of topics and to begin the intervention planning process. These steps have included the following:

1. Establishment of a study site newsletter.
2. Conduct of health fairs.
3. Assistance through TURI and our own industrial hygiene (IH) with alternative use of production chemicals.
4. Site specific IH and ergonomic consultation as part of study participation.

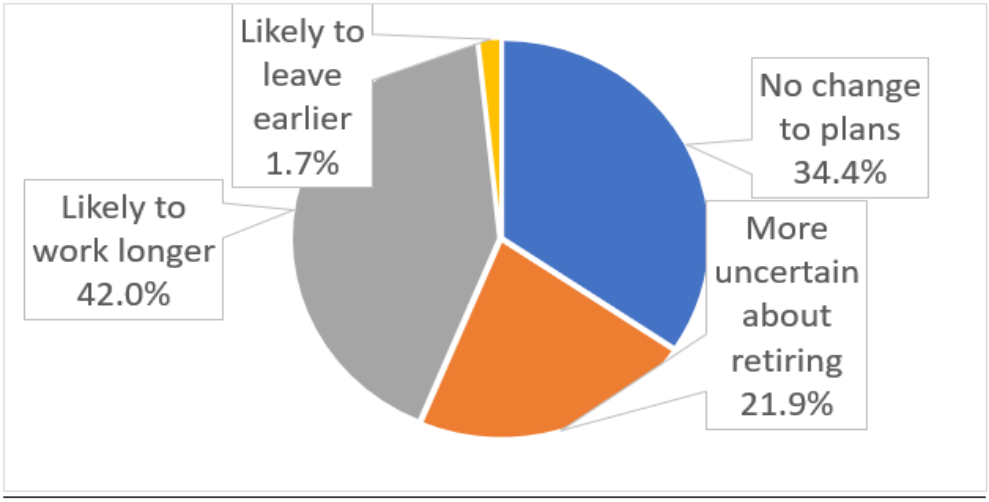
5. Workshops held at the university on age-friendly workplace design, elder care utilization, and retirement and planning in the older working group.

We have concluded that these types of exceptional efforts would be essential to future long-term cohort studies, given the changes in the manufacturing workplace. At least in New England manufacturing, the sealing off of the worksite from outside investigation was an unanticipated barrier. It raises a question of whether multi-site cohort studies in manufacturing are possible given the changes in management and, just as important, the churning of Environmental, Health, & Safety (EH&S) personnel.

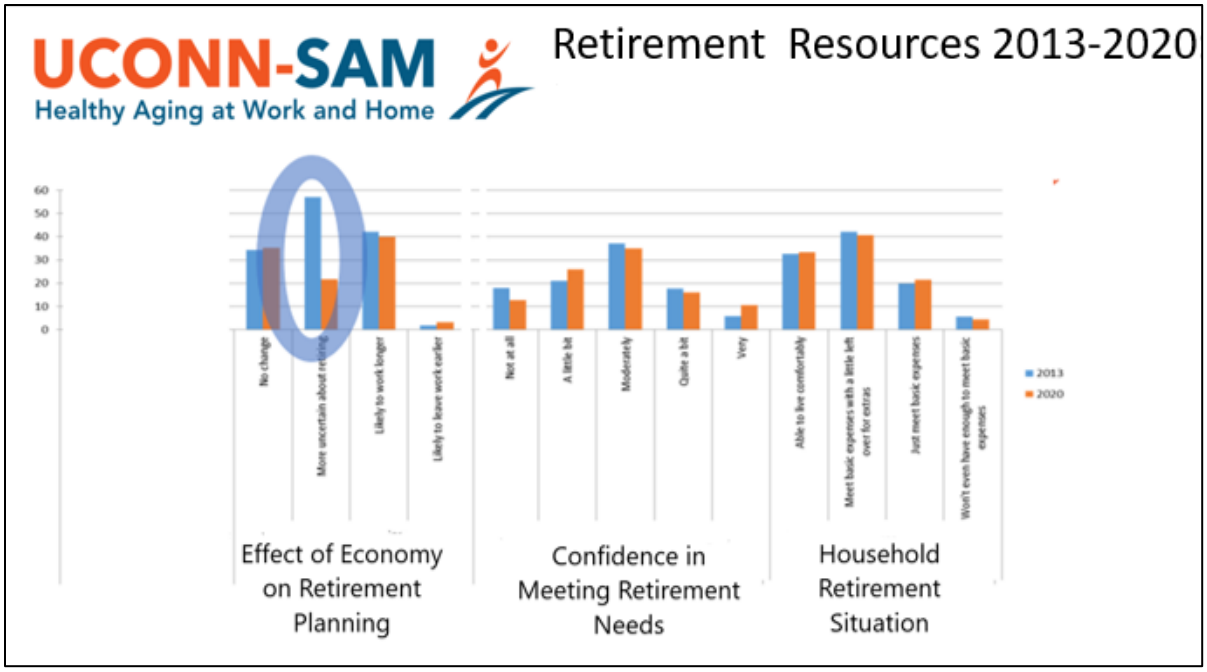
Key Results

Economic and Other Impacts on Employment

One of the unanticipated and most drastic observations during the 2008-2014 study period involved effects on retirement expectations, confidence in financial resources and plans to remain at work. The following pie chart originated from the T3 assessment indicates pessimism and uncertainty about personal retirement resources.



When the workforce was resurveyed at T4, a very different picture emerged. The surveys required detailed characterization of expected retirement resources and primary sources, i.e., social security defined benefit or defined contribution plans, IRAs, etc. These results had not changed appreciably but confidence did change in the aftermath of the Recession, as presented in the following chart.



There had been no significant change regarding the extant resources or financial needs. There was, however, a dramatic change in confidence about proceeding towards retirement. This is once again strong evidence for a period effect during the Great Recession which left a clear imprint on many survey findings.

Reasons for Retiring and Leaving Employment

Although there was a strong implication that extrinsic economic factors effected confidence and caution about retirement and differentiated the post- Recession period from its temporal precursor, we were unable to identify health or other considerations that motivated leaving the workforce. In the following table, a comparison is provided between workers studied at T3 who remained at their jobs at T4 (n=371) and those who left between T3 and T4 (n=319).

Demographic Characteristics or Stayers and Leavers at T4								
	Male	White	Age Years	Felt Age Years	Tenure Years	Owning Home	Living with Partner	Hourly Pay
Stayers n=371	73%	85%	46	40	14	80%	73%	63%
Leavers n=319	71%	82%	49	43	17	81%	71%	51%

The only substantial difference between the two populations was the higher % of workers receiving hourly compensation rather than a salary.

In the following table, these comparisons between stayers and leavers are extended by comparing key health and psychosocial characteristics between the two groups. There were no significant differences at T3 that differentiated the T3 workforce that left from the T3 workforce that remained into T4.

There were no identifiable factors that differentiated between the two populations. The result is interesting for another reason. Psychosocial measures appeared to reflect secular period changes in these groups.

	Present T3/T4 (N = 371)		Present T3/ Left T4 (N = 319)	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
SF-12	2.54	0.73	2.58	0.78
CES-D	4.60	3.64	4.57	3.63
Pain	0.55	0.79	0.54	0.72
Workability	9.54	1.02	9.48	1.06
Health Problem Limiting Work	1.23	0.40	1.29	0.49
Health Problem Limiting Sleep	1.13	0.35	1.18	0.42
Work-Family Conflict	1.84	0.59	1.77	0.53
Family-Work Conflict	1.60	0.54	1.51	0.51
Burnout	2.66	0.77	2.60	0.79
Job Insecurity	1.62	0.69	1.63	0.69
Job Satisfaction	3.55	0.89	3.53	0.93
Intent to Turnover	2.06	0.98	2.13	0.99

Burnout, for example, rose systemically for all six cites during the period of the Great Recession from T1-T3. The notable exception is Employer 5. Unlike its peers, Employer 5 underwent a massive hiring influx, following an SEC mandated change of ownership. Employer 1 is an apparent anomaly because of the elevated level of reported burnout. Between T2 and T3, the employer introduced a Walmart-like JIT notification policy where workers were provided schedules at the beginning of each week. This was in an older and workforce whose hours and pay had historically been stable. It is also of interest that Employer 6 had shut down its other in-state facilities and the threat of closure seemed imminent. At T4, the company had been sold and expanded, and the anomalous feature receded. This brief explication of external events may not be sufficiently explanatory, but it does suggest that some of the psychosocial measures show considerable variability and appear to detect discrete response patterns within specific populations. It makes the uniformity of responses between stayers and leavers more striking.

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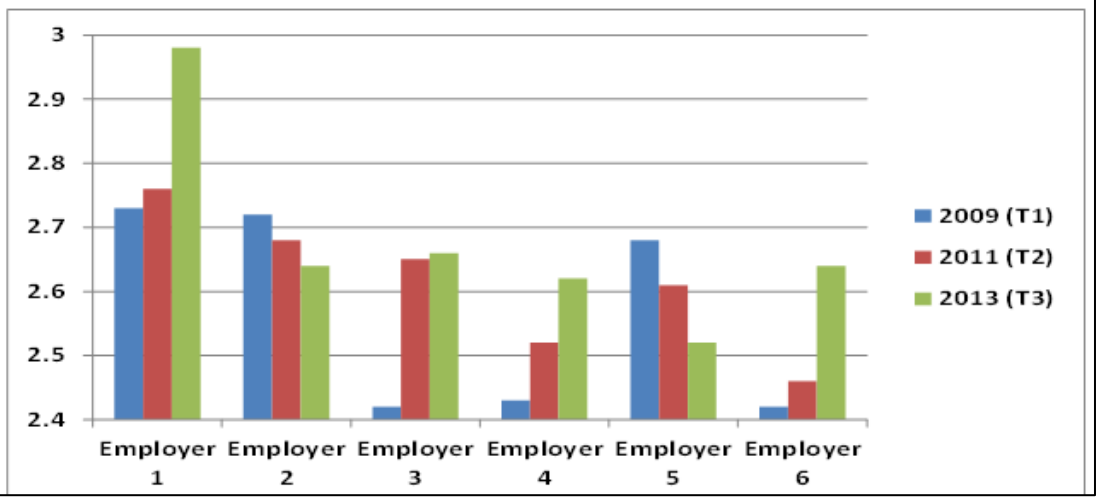
Example:
Trends in Burnout 2008-2013



Did COVID-19 Generate a Specific Response Pattern?

Through T4 the patterns implicit to staying or leaving the place of employment seemed to be remarkably resistant to anticipated explanatory variables. This duplicates a pattern seen for physical testing at T3 where the age expected declines in physical performance did occur as expected (Cote et al. 2014), but there were too few instances of leaving work to generate useful attribution. We were able, however, to look at other presumably intermediate endpoints such as workability.

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Physical performance testing regressed on Work Ability dimensions (regression coefficients)

	Overall WA	Physical WA	Mental WA	Interpersonal WA
Systolic BP	-.327	ns	ns	-.366*
Diastolic BP	ns	ns	ns	-.269
Hypertension	ns	ns	ns	ns
Rt leg power	.063	ns	.060	ns
Rt leg strength	.059	ns	ns	ns
BMI	ns	ns	ns	ns
% body fat	ns	-.056	ns	ns

However, as was the case with survey data, physical performance data was not particularly discriminatory in gauging self-reported work capacity.

The T5 data from COVID-19 suggest a different and highly interesting response pattern. For the first time, there were significant pattens for those leaving work and retiring which suggested both age and family responsibility associative patterns. Among those leaving work and not retiring, male gender, difficult working hours, children, and job satisfaction all were associated, although somewhat short of statistical significance, with leaving work. These work life factors were less important for workers who retired.

Predictors of Quitting or Retirement T4→T5

	Quitting Work (n=75) vs Staying			Retiring (n=43) vs. Staying	
	Unadjusted Prevalence Ratio	p-value		Unadjusted Prevalence Ratio	*p-value*
Male Gender	0.55	0.08		0.61	0.34
Childcare Responsibilities	**1.93**	**0.04**		0.26	0.07
Adult Care Responsibilities	0.80	0.56		0.79	0.68
Worse Health in General	0.87	0.51		**1.92**	**0.04**
Poor Fit of Working Hours	**1.58**	**0.04**		No convergence	
Family Work Conflict	1.30	0.32		0.89	0.79
Job Satisfaction	2.08	0.06		0.72	0.20

The implication is that quality of life issues, particularly around family responsibilities, appear to predict leaving the workplace prior to retirement. Health issues appear important for retirees.

The separation of post-COVID responses (T5) from precedent responses (T4) is also expressed in the following table, which compares responses of T5 workers with their pre-COVID responses. Except for the articulated intention to quit, responses did not vary significantly. The implications are unexpected, and they offer a further perspective on the relative relationships in terms of leaving work between individual health factors, narrowly defined working conditions, family and personal demands and extrinsic period inducing effects. Of the three factors, working conditions defined narrowly as events occurring on the job appear less prominent than other non-work factors. That, of course, depends on this narrow definition of job content. Working hours and conflicts with family responsibilities are usually put into the non-worktime bin, but there is certainly association with the demands of a 40+ hour working week.

Response Differences at T4 and T5

	2019 (n=197)	2022 (n=176)	
	Mean (SD)	**Mean (SD)**	**p-value**
Schedule Control	2.62 (0.81)	2.64 (0.87)	NS
Intention to quit	2.19 (1.06)	2.44 (1.18)	**0.03**
Intention to look for new job	*2.07 (1.10)*	*2.23 (1.21)*	NS
Job Satisfaction	3.77 (0.87)	3.75 (0.92)	NS
Stress in General	1.93 (0.93)	1.90 (0.96)	NS

Eldercare Responsibilities (ECR) and Leaving Work

A different and somewhat contradictory conclusion arises from the ECR responses.

Eldercare and Health 2020	
% with eldercare responsibilities	14.6%
% male	62%
Average AGE (SD)	49.8 (12.7)
Reduced sleep quality	p=0.04
More pain interference at home and work	P=0.02
More pain in past week	P=0.01

For almost any measure, members of the workforce with ECR had markedly worse parameters than their peers without ECR, thus suggesting a measurable ecologic effect. This finding complements the T3 data, which suggests that ECR was the major identifiable factor leading to leaving work.

In the following table, a variety of health indicators for workers with ECR are divided into those providing chronic, those newly started in ECR and those who had stopped providing care in the inter-survey period. The implication is that recent assumption of responsibilities carries the highest risk profile for adverse health effects.

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	None	Stopped	Newly Started	Chronic/Ongoing
MENTAL HEALTH	--			
DEPRESSIVE SYMPTOMS* **	--	↑↑	↑↑↑	↑
SLEEP QUALITY**	--	↓	↓	→
FAMILY-WORK CONFLICT* **	--	↑	↑	↑↑
WORK STRESS* **	--	↑↑	→	↑↑
JOB PERFORMANCE	--	→	→	→

[a] Sample sizes vary due to missing data; Row percentages compared
* p< .05, ** p < .01, *** p < .001 per ANOVA analysis

Implications should not be over drawn, given the limited scope of the data. The following table which covers the interest in ECR materials and support for workers with current or past ECR suggests that the workplace and discrete social services may be consequential.

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Healthy Aging at Work and Home

Interest in Eldercare Resources

	Does your workplace provide?				Do you currently use OR would you be likely to use such a service?	
	Don't Know		No		Yes	
	Overall	*>55*	*Overall*	*>55*	*Overall*	*>55*
On-site counseling regarding eldercare	38%	38%	56%	63%	45%	39%
Off-site counseling regarding eldercare	45%	50%	42%	38%	38%	35%
Flexible work hours	17%	9%	48%	56%	68%	65%
On-site presentations on eldercare	32%	17%	64%	83%	52%	83%
In-home care support services (e.g., a visiting nurse)	32%	29%	61%	71%	49%	57%
Out-of-home support services (e.g., adult day care)	30%	25%	63%	75%	40%	48%
Paid time off/work leave	20%	13%	41%	45%	67%	64%

(Total N = 67, >55 N = 24)

The implication is that more flexible work arrangements would be valued. Paid leave and flexibility of work hours was also cited as highly desirable by older workers considering retirement.

T1 – T3 Aging Changes to the Cohort

Aim 1. The following analyses pertain to T1→T3 longitudinal data (2008→2013). There is a potential selection bias on outcomes since there were relatively few changes in employment status between 2008 and 2013. Because there was no systemic physiological testing at T4, the inferences cannot be extended fully. Other than BP, there were no remarkable age specific changes in the cohort.

	Time 1		Time 3	
	Mean	SE	Mean	SE
Body Mass Index	29.1	0.24	29.1	0.24
Waist Circumference	95.9	0.59	96.7	0.6
Body Fat	29.7	0.3	29.3	0.32
Systolic Blood Pressure	122.9	0.71	130.6	0.78
Diastolic Blood Pressure	79	0.45	82.8	0.5

We also had measured several health variables relating to body mass (fat free muscle mass by BIA), as well as BMI were measured. Age and female gender were associated with body mass increases, as expected. Work demands did not affect the physical parameters, but leisure exercise was associated with diminished body mass. The relative effectiveness of leisure exercise versus work exertion is an interesting finding. Pertinent to UConn-SAM, the age-related changes over 5 observational years were modest, and were affected by gender and leisure exercise.

		Body Mass Index			Body Fat		
		Beta	SE	p-value	Beta	SE	p-value
Study Time	2013	0.05	0.09	0.62	-0.28	0.20	0.17
	2008 (ref)	-	-		-	-	
Exercise	1-3 hours/week	**0.00**	**0.19**	**0.01**	**-0.41**	**0.36**	**<0.01**
	>3 hours/week	**-0.53**	**0.23**		**-1.79**	**0.41**	
	0 hours/week (ref)	-	-		-	-	
Physical Job Demands	High	0.14	0.20	0.49	0.36	0.37	0.33
	Low (ref)	-	-		-	-	
Age		**0.05**	**0.02**	**<0.01**	**0.05**	**0.02**	**0.01**
Gender	Female	-0.55	0.43	0.2	**11.05**	**0.51**	**<0.01**
	Male (ref)	-	-		-	-	
Job Type	Hourly	**0.87**	**0.31**	**<0.01**	**0.93**	**0.46**	**0.04**
	Salaried (ref)	-	-		-	-	

Dynamic physiologic responses were also catalogued. In this case, spine flexion, grip strength and leg power were also examined.

		Spine Flexion			Right Hand Grip Strength			Leg Max		
		Beta	SE	p-value	Beta	SE	p-value	Beta	SE	p-value
Study Time	2013	0.73	0.27	<0.01	-4.10	0.32	<0.01	-0.80	0.94	0.4
	2008 (ref)	-	-		-	-		-	-	
Exercise	1-3 hours/week	-0.31	0.51	<0.01	-0.63	0.54	0.12	0.71	1.40	<0.01
	>3 hours/week	1.66	0.59		0.41	0.59		6.57	1.46	
	0 hours/week (ref)	-	-		-	-		-	-	
Physical Job Demands	High	0.01	0.52	0.98	1.10	0.55	0.04	-0.56	1.39	0.69
	Low (ref)	-	-		-	-		-	-	
Age		-0.09	0.03	<0.01	-0.17	0.03	<0.01	-0.52	0.06	<0.01
Gender	Female	3.51	0.78	<0.01	-18.67	0.64	<0.01	-14.80	1.41	<0.01
	Male (ref)	-	-		-	-		-	-	
Job Type	Hourly	1.38	0.67	0.04	-0.81	0.61	0.19	-0.44	1.43	0.76
	Salaried (ref)	-	-		-	-		-	-	

The importance of age, gender and leisure exercise replicated the body mass findings. Although physical effort at work apparently did not improve body mass measures, there was an increase in grip strength. In summary, the findings reported in the 2008-2014 final report were reconfirmed. Aging effects were observed as expected in the cohort, but they did not appear to affect job performance capacity, workability, or leaving the workforce.

Aim 2. Under Sub-aim 2b, new testing protocols have been studied in the lab and revisions made. Part of the formative logic was to make a definitive recommendation on best testing in the aging workforce. We did extensive laboratory comparison of sub-maximal and short-term maximal exercise testing and have demonstrated the superiority of sub-maximal HR contoured testing. It will replace our current protocol and we will provide rational and evidence in the literature. We also revised the cumulative exercise repetition protocol for the trunk and upper extremity, consistent with laboratory findings. Under Sub-aim 2b, new testing protocols were studied in the lab and revisions made. Part of the formative logic was to make a definitive recommendation on best testing in the aging workforce. We did extensive laboratory comparison of sub-maximal and short-term maximal exercise testing and have demonstrated the superiority of sub-maximal HR contoured testing. We also revised the cumulative exercise repetition protocol for the trunk and upper extremity, consistent with laboratory findings. Beyond survey modification represented in the 2014 Final Report, among the Aim 2 'technical' revisions, there were several survey and survey collection additions. The core aging and work survey was extensively modified and edited. Changes were both advised and vetted through focus groups with older workers, including study participants. The economic and retirement modules was more detailed. These include questions on personal finances and longer-term employment expectations. There are additional questions on caregiving, directed in part to area resources. There was a new and more detailed module in impacts of shift and overtime work. There was extensive vetting of past survey items that had generated little significance and variance in past administrations. At T4, new survey modules were also developed around retirement resources and around company policies and programs that would encourage remaining within the workforce and would facilitate work satisfaction. These included programs in flexible time, elder care assistance, and improving physical health. These modules were accompanied by extended queries on ECR and the adequacy of financial resources.

In order to improve on the historically poor response rate among former employees, an electronic survey/app was added to facilitate response. At T5, because of changed management, four of the companies were no longer providing work-time access for survey distribution and completion with study personnel. Accordingly, the entire post-Covid survey adapted to multi-site and multi population online status.

Under Sub-aim 2c, we opted against use of the DPHACTO study design for use of actigraphy, as proposed 2R01OH008929-06A1 (2017-2022). It was our expectation to use their protocol with 4 accelerometers, but the data was unconvincing.

Aim 3. As mentioned, Aim 3 was complicated through 2022 because COVID-19 interfered with in-person and in-facility access and training. A list of the completed outreach activities is included as Appendix A.

Conclusions 2017-2022

The most consequential findings from 2R01OH008929-06A1 (2017-2022) pertain to Aim 1 and its sub-aims, those being directed to questions around musculoskeletal and leaving place of employment that could not be sufficiently answered in 2008-2014 due to an absence of workforce 'churning' and insufficient endpoints. In addition, the earlier findings on the import of ECR and its apparent adverse health outcomes affected the new queries in the follow-up T4 and T5 surveys. In addition, as noted, the changes in financial expectations following the Great Recession had raised new questions on perceptions of financial stability and ability to leave work. These were also emphases of the current study.

Citations within the Scientific Report

Cote MP, Kenny A, Dussetschleger J, Farr D, Chaurasia A, Cherniack M: [2014] Reference Values for Physical Performance Measures in the Aging Working Population, Human Factors 56:228-242.

Cherniack M, Dussetschleger J, Farr D, Dugan A; CPH-NEW Team: [2015] Workplace Cohort Studies in Times of Economic Instability, American Journal Industrial Medicine 58(2):138-151.

Publications

Journal Articles

Garza JL, Cavallari JM, Cherniack MG: [2022] Associations Between Observed Time Sitting at Work and Musculoskeletal Symptoms: A Repeated-measures Study of Manufacturing Workers. International Journal of Occupational Safety and Ergonomics.

Dugan, AG, Laguerre, RA, Barnes-Farrell, JL, Cavallari, JM, Garza, JL, Graham, LA, Petery, GA, Warren, N, & Cherniack, MG: [2021] Musculoskeletal Health and Perceived Work Ability in a Manufacturing Workforce. Occupational Health Science 6(1):73-110.

Garza JL, Wu HZ, Singh M, Cherniack MG: [2021] Comparison of the Wrist-Worn Fitbit Charge 2 and the Waist-Worn Actigraph GTX3 for Measuring, Steps Taken in Occupational Settings. Annals of Work Exposures and Health 66(2):281-284.

Dugan AG, Barnes-Farrell JL, Fortinsky RH, Cherniack MG: [2020] Acquired and Persistent Eldercare Demands: Impact on Worker Well-Being. Journal of Applied Gerontology 3994:357-367.

UConn-SAM, 2019-2021

Appendix A.: NCAAA Aging Collaborations/Interventions

January – March 2021	**Live Well Chronic Conditions Workshop Offered to Manufacturing Workers for Better Health.** A six-week telephonic program is based on an evidenced-based program for older adults. UConn tested to see if it can be applied to manufacturing workplace. 4 people committed. 1 retiree remained and gave it praise. NCAAA willing to offer the workshop again during better times.  CDSMP Info Session Flyer4.JCC.p
October 1, 2020	Our third scheduled virtual EHS/HR Covid-19 group meeting featured the non-profit agency **NCAAA. Maureen McIntyre, Executive Director** presented support services for older adults and programing offered to help the workers and their families. Jill Fabian responded with interest.
May 2020	**NCAAA Free Food flyer** distributed by email to salaried and posted for hourly Stanley workers. Area food distributors donated food to NCAAA and their volunteers made deliveries to shut ins.  NCAAA.Concept-1c.pdf
April 27, 2020	First WebEx Forum, Covid-19 to UConn-SAM with guest host Elise Gauthier, Plant Manager, StanleyBlack&Decker, New Britain Hand Tools Plant
March 2020	All field work ceased due to pandemic.
January - February 2020	UConn and Siemon Company was in the process of setting up **lunch n learn sessions** for employees through **Western CT Area Agency on Aging** before pandemic. First session is an overview of services. Next session, based on caregiving needs of the workers, set to focus on topics such as: Understanding Social Security, Dementia, long-term care, social services, food assistance programs and over 26 subjects and listings of free benefits to the area elderly.
January – February 5, 2020	Physical testing at Stanley Tools
January 13-14, 2020	**NCAAA at Stanley Tool with UConn-SAM** during consent and recruitment phase at plant. NCAAA attended two mornings to dispense brochures and to talk about community support services to workers. It was superseded by CIGNA health coach, Suzanne Standish LifeCare and Cigna EAP, campaigned for an annual weight loss incentive plan at the same time UConn consented participants. Break time and lunch times seemed too short with three activities taking floor space.

Cumulative Inclusion Enrollment Report

This report format should NOT be used for collecting data from study participants.

Study Title: University of Connecticut Study on Aging, Musculoskeletal Disorders and Worker Capacity (UConn-SAM)

Comments:

Racial Categories	Ethnic Categories									Total
	Not Hispanic or Latino			Hispanic or Latino			Unknown/Not Reported Ethnicity			
	Female	Male	Unknown/ Not Reported	Female	Male	Unknown/ Not Reported	Female	Male	Unknown/ Not Reported	
American Indian/ Alaska Native								3		**3**
Asian							1	9	2	**12**
Native Hawaiian or Other Pacific Islander										**0**
Black or African American							4	5	1	**10**
White							45	86	2	**133**
More Than One Race							9	7	1	**17**
Unknown or Not Reported							120	139	4	**263**
Total	**0**	**0**	**0**	**0**	**0**	**0**	**179**	**249**	**10**	**438**