

Occupational lifting and risk of hypertension, stratified by use of anti-hypertensives, physical activity and age - a prospective cohort study

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Abstract

Background Prevalence of hypertension varies across occupations, maybe due to differences in exposure to occupational lifting. This study investigated associations between occupational lifting and hypertension, stratified by use of anti-hypertensives, leisure time physical activity (LTPA), occupational physical activity (OPA) and age.

Methods Data from the Copenhagen General Population Study were included. The Copenhagen General Population Study was approved by the local ethical committee (H-KF-01-144/01), and all participation were conducted in accordance with the declaration of Helsinki. Multivariable logistic regression models, adjusted for sex, age, BMI, smoking, school education, mental stress and baseline blood pressure (BP), were applied to estimate: the (i) cross-sectional association (n=67,363) between occupational lifting and hypertension (using anti-hypertensives or BP $\geq 140/\geq 90$ mmHg), (ii) prospective association (n=7,020) between occupational lifting and risk of an above median change in systolic BP (baseline to follow-up) and/or a shift from no use to use of anti-hypertensives, among the included population and stratified by use of anti-hypertensives, LTPA, OPA and age.

Results Cross-sectionally, heavy occupational lifting lowered hypertension risk. Mean baseline BP, showed that the higher the level of LTPA the lower mean BP across all levels of OPA were, but only among those not using anti-hypertensives. The prospective analysis showed occupational lifting to increase the risk of hypertension, among workers aged ≥ 50 years, or reporting light to moderate LTPA.

Conclusions This study finds positive associations between occupational lifting and risk for hypertension among workers aged ≥ 50 years. Further research on the association between occupational lifting and precursors of cardiovascular disease are needed before recommendations for occupational lifting and cardiovascular health can be established.

Background

Hypertension increase risk for cardiovascular disease [1, 2]. Prevalence of hypertension vary across occupations and may be affected by the working environment, such as heavy lifting [3, 4]. Lifting heavy burdens acutely increases the blood pressure (BP) [5], and several hours of lifting can induce future increases in BP [6]. Previously, weak positive relations between occupational lifting and BP have been shown, especially among users of anti-hypertensives [7].

Leisure time physical activity (LTPA) and cardiorespiratory fitness, are known to affect the prevalence of hypertension [8–10]. Among occupational groups exposed to occupational lifting and high levels of occupational physical activity (OPA), a high level of cardiorespiratory fitness is suggested to lower the risk for cardiovascular mortality [11] by reducing the strain on the cardiovascular system [12]. Likewise, differences in ambulatory BP across sub-groups based on combinations of level of OPA and LTPA have been reported [6], possibility explained by the physical activity health paradox [13]. Thus, investigations of associations between occupational lifting and BP in subgroups on levels of LTPA and use of anti-hypertensives would be of interest for future guidelines for rehabilitation and preventive initiatives.

Furthermore, will rising age and hypertension stiffen the arteries contributing to endothelial damage, which may increase in the total peripheral resistance and thereby also BP [14, 15]. Thus, these two factors potentially increases vulnerability to hazardous effects on BP from exposure to occupational lifting. Hence, to verify previous results, and to additionally investigate the moderating effect from LTPA, we proposed this study aiming to explore cross-sectional and prospective associations between heavy occupational lifting and hypertension, stratified on use of anti-hypertensives, LTPA and age.

Methods

Data from the Copenhagen General Population Study was analyzed to replicate the previous results based on the Copenhagen City Heart Study [7], as previously described [16]. Baseline data was collected from 2003 to 2015, and holds information on health as well as a large variety of biological, environmental and lifestyle related factors from approximately 110,000 participants aged 20 to 98 years. In 2015 the follow-up data collection started, which is planned to terminate in 2025. The Copenhagen General Population Study was approved by the local ethical committee (H-KF-01-144/01), all participation were conducted in accordance with the declaration of Helsinki and all participants signed an informed consent to participate.

The null-hypothesis was no associations between heavy occupational lifting and prevalence of hypertension. Secondary, interactions between LTPA, use of anti-hypertensives, age and occupational lifting were planned. Confidence intervals of 99% were chosen due to the multiple hypotheses tested.

Inclusion criteria

Cross-sectional, participants were included by having data on BP, level of OPA (including heavy lifting), use of anti-hypertensives, and being aged ≤ 70 years old. Prospectively, participants were included by being normotensive at baseline, having data on level of OPA at baseline, and data on BP and use of anti-hypertensives at baseline and follow-up.

Assessment of exposure

Level of OPA was obtained by use of the question: “Please describe your level of OPA within the past year” with the following response categories: “1) predominantly sedentary; 2) sitting or standing, some walking; 3) walking, some handling of material; 4) heavy manual work”. By answering 3 or 4, an additional question regarding heavy occupational lifting; “Do you lift heavy burdens?” with the response categories: “1) yes; 2) no”, was applied. Participants were classified as exposed to heavy occupational lifting by answering “yes” to this question, by answering “no” participants were assigned to the reference group. Stability of exposure was evaluated by Cohen’s kappa by baseline cross tabulated with follow-up, showing moderate agreement (0.48).

Assessment of outcome

Primary outcomes were hypertension and SBP (mmHg). Hypertension was classified as using anti-hypertensives and/or SBP \geq 140 mmHg or DBP \geq 90 mmHg at baseline examination. For the prospective analysis hypertension was classified as the shift from normotensive not using anti-hypertensives to use of anti-hypertensives or above median delta value of SBP (follow-up – baseline).

Moreover, secondary analyses were conducted to evaluate associations between occupational lifting on pulse pressure (SBP – DBP), mean arterial pressure ($2*DBP + SBP/3$) and mid BP ($\frac{1}{2} SBP + \frac{1}{2} DBP$).

BP was measured on one arm while sitting, after 5 minutes of rest, using an automated apparatus (BPA3plus, Microlife, Switzerland). The technicians were specially trained and the instruction was the same at both data collection time points.

Assessment of covariates

Various factors are shown to relate to both occupational workload (including lifting) and BP. Thus, those factors were included as covariates: sex (male/female) [17]; age (categories of < 40; 40–49; 50–59; 60–70 years) [18]; body mass index (BMI) (categories of < 18.5; 18.5–24.9; 25.0–29.9; \geq 30 kg/m²) [19]; smoking (categories of nonsmoking; currently smoking) [20]; level of LTPA (categories of *mainly sedentary* “you spend most of your leisure time performing sedentary tasks”; *light physical active* “you go for a walk, use your bicycle a little or perform activity for at least 4 hours per week”; *moderate physical active* “you are an active athlete, for at least 3 hours/week”; *strenuous physical active* “you take part in competitive sports, or perform moderate to vigorous activity (MVPA) more than 4 hours/week”) [21], mental stress (“are you often feeling nervous or stressed?” yes/no) [22], and length of school education in total years [23].

Criteria for statistical significance

The overall level of statistical significance was set at 0.05, secondary a Bonferroni correction was applied, thus the primary hypotheses were tested at a significance level of 0.01. All exploratory secondary analyses were evaluated by the 99% confidence interval (CI).

Statistical analyses

All statistical analyses were performed in the statistical software SAS, version 9.4 (SAS Institute, Cary, NC, USA).

1. Primary analysis

In the cross-sectional analysis the odds ratio (OR) for being hypertensive, and in the prospective analysis, the odds of becoming a SBP case, as a function of occupational lifting, were estimated by use of a logistic regression in a generalized estimating equation (GEE) model. Observations from the same person were treated as repeated measurements. A first order autoregressive correlation structure was assumed. The cross-sectional analysis was controlled for sex, age, BMI, smoking, LTPA, mental stress, school education. No exposure for occupational lifting was reference. Additionally, the prospective analysis was adjusted for BP at baseline.

Furthermore, the differences in resting BP across participants exposed and non-exposed to occupational lifting were analyzed by linear regressions both cross-sectional and prospectively (change in mmHg from baseline to follow-up), adjusted for sex, age, BMI, smoking, LTPA, mental stress, and school education, and BP at baseline in the prospective analysis. To investigate whether age, level of LTPA and use of anti-hypertensives moderated the association between occupational lifting and SBP an interaction term was included for each of these variables (exposure*moderating factor). By significant interactions the linear regressions were applied to groups stratified by age (</ \geq 50 years), level of LTPA and use of anti-hypertensives.

Secondary analyses

As a previous paper suggested an effect from occupational lifting on DBP, but not SBP [7], the linear regressions were repeated for the outcomes of DBP, MAP, and PP.

Additionally, to investigate the sensitivity of the comparison group, the adjusted primary analyses were repeated in models with a comparison group split by the self-reported categories of OPA, resulting in four instead of two categories.

Moreover, to investigate the sensitivity of definition of hypertension, used in the primary analyses, two alternative definitions of hypertension were applied (SBP \geq 160 mmHg or DBP \geq 100 mmHg [24]; SBP \geq 130 mmHg or DBP \geq 80 mmHg [25]).

To investigate whether the BP differs between sub-groups defined by levels of OPA, exposure to occupational lifting, LTPA and use of anti-hypertensives, mean levels of BP across these sub-groups were compared in a generalized linear model adjusted for sex, age, BMI, smoking, mental stress and school education. Additionally, the odds for being classified as hypertensive, or becoming a SBP case, were investigated in sub-groups defined by level of LTPA, by use of maximum likelihood and logistic regression, adjusted for sex, age, BMI, smoking, mental stress, school education, and with no exposure for occupational lifting as reference.

Results

From the ongoing follow-up data collection we had access to responses from 17,216 participants. Based on the inclusion criteria, the final population for the cross-sectional analysis included 67,363 participants and 75,890 observations, and the prospective analysis included 7,020 observations and participants (Fig. 1).

Descriptive information of the included population

Descriptive information on the included observations is presented in Table 1. The included observations in the cross-sectional analysis differed from the excluded observations by being 17.7 years younger (included 51.9, excluded 69.6), having a 11.8 mmHg lower SBP (included 133.2, excluded 145.0), 19 percentage points (pp) fewer participants using anti-hypertensives (included 12%, excluded 33%), 9 pp more are exposed to occupational heavy lifting (included 33%, excluded 24%), 9 pp more are feeling stressed (included 27%, excluded 18%), and having 1.5 years more school education (included 11.3, excluded 9.8).

Table 1
Baseline characteristics of the included 75,890 observations in the cross-sectional analysis and the 7,020 participants in the prospective analysis.

	Cross-sectional analysis				Prospective analysis			
	Mean	SD	n (%)	Range	Mean	SD	n (%)	Range
Age (years)	51.9	9.5		20.1–69.9	49.2	8.4		20.6–69.8
Sex (%female)			41,843 (55.1)				4,550 (64.8)	
BMI (kg/m ²)	25.9	4.3		14.3–91.8	24.5	3.4		15.4–46.9
Smoking (%current smokers)			12,666 (16.7)				1,366 (19.5)	
Systolic blood pressure (mmHg)	133.2	19.5		70.0–240.0	122.2	10.0		71.0–139.0
Diastolic blood pressure (mmHg)	79.4	11.5		22.0–190.0	75.9	7.4		30.0–89.0
Blood pressure $\geq 90/\geq 140$ mmHg			29,261 (38.6)				-	
Using anti-hypertensives			8,961 (11.8)				-	
Hypertensive (% $\geq 90/\geq 140$ mmHg or using anti-hypertensives)			32,503 (42.8)				-	
Hypertensive (% $\geq 80/\geq 130$ mmHg or using anti-hypertensives)			50,967 (67.2)				3,801 (54.1)	
Hypertensive (% $\geq 100/\geq 160$ mmHg or using anti-hypertensives)			16,137 (21.3)				-	
School education (years)	11.3	1.7		0.0–14.0	11.2	1.6		1.0–14.0
Occupational physical activity								
Predominantly sedentary			33,397 (44.0)				2,884 (41.1)	
Sitting or standing, some walking			24,877 (32.8)				2,284 (32.5)	
Walking, some handling of material			14,961 (19.7)				1,635 (23.3)	
Heavy manual work			2,655 (3.5)				217 (3.1)	
Occupational heavy lifting (%yes)			9,652 (33.0)				990 (14.1)	
Leisure time physical activity								
Inactive/light physical active < 2 hours/week			4,836 (6.4)				401 (5.7)	
Light physical active 2–4 hours/week			30,531 (40.2)				2,936 (41.8)	
Light physical active > 4 hours/week OR MVPA 2–4 hours/week			34,537 (45.5)				3,244 (46.2)	
MVPA > 4 hours/week			5,701 (7.5)				416 (5.9)	
Mental stress (%often feeling nervous or stressed)			20,473(27.1)				2,112 (30.2)	

In the prospective analysis, the included observations differed from the excluded observations by being 9.2 years younger (included 49.2, excluded 58.4), having a 26.0 mmHg lower SBP (included 122.2, excluded 148.2), 23 percentage points (pp) fewer participants using anti-hypertensives (included 0%, excluded 23%), 4 pp more are exposed to occupational heavy lifting (included 14%, excluded 10%), 6 pp more are feeling stressed (included 30%, excluded 24%), and having 1.0 years more school education (included 11.2, excluded 10.2).

Some of these differences between included and excluded observations in the cross-sectional analysis might be explained by the inclusion criteria of answering the question regarding exposure to OPA and heavy occupational lifting and being aged < 70 years old at time of data collection combined with the fact that 80% of the excluded participants were unemployed or retired. Additionally, some of the differences may be explained by the inclusion criteria of being normotensive at baseline combined with the fact that 52% of the participants at follow-up were hypertensive and 32% of the excluded participants were unemployed or retired at baseline.

Primary analyses

The adjusted cross-sectional analysis showed that those exposed to heavy occupational lifting had 3% lower odds of hypertension than the non-exposed (Table 2). The adjusted prospective analysis showed an 8% higher risk for being a SBP case by exposure to heavy occupational lifting. Exposure to heavy occupational lifting did not affect the risk of becoming a DBP case (Table 2). Linear regressions were performed to investigate the differences in SBP, DBP, PP, and MAP between participants exposed and non-exposed to heavy occupational lifting. No associations were seen in either adjusted models or crude models, neither cross-sectional nor prospectively (table S1).

Table 2

Crude and adjusted odd ratios of being hypertensive (in the cross-sectional model) and for becoming a SBP or DBP case, defined as an above median delta value of BP at follow-up – BP at baseline (in the prospective model) by self-rated exposure to heavy occupational lifting, stratified on age at baseline (\geq vs. < 50 years). No exposure to heavy occupational lifting was reference. [OR = Odds ratio; CI = Confidence interval].

Heavy occupational lifting	Crude model			Adjusted model								
				All			Age \geq 50 years			Age < 50 years		
	n	OR	99% CI	n	OR	99% CI	n	OR	99% CI	n	OR	99% CI
Cross-sectional Hypertensive	75,887	1.08	1.05–1.11	72,873	0.97	0.93–1.00	43,517	0.97	0.93–1.01	29,356	0.96	0.91–1.02
Prospective Systolic case	7,020	1.11	1.02–1.21	6,713	1.08	0.98–1.19	3,069	1.11	0.95–1.29	3,644	1.05	0.93–1.19
Prospective Diastolic case	7,020	1.08	0.99–1.18	6,713	1.02	0.93–1.12	3,069	1.04	0.90–1.21	3,644	1.01	0.89–1.14
Adjusted cross-sectional model includes adjustment for sex, age, BMI, smoking, LTPA, mental stress and school education. In addition, were the prospective models adjusted for BP at baseline.												

Significant cross-sectional interactions ($p < 0.0001$) were found between heavy occupational lifting and LTPA, use of anti-hypertensives and age, thus stratified analyses were performed. The cross-sectional analysis stratified by level of LTPA showed lowered odds for hypertension by exposure to heavy occupational lifting among participants reporting to be light physical active 2–4 hours/week. None of the prospective odd ratios reached statistical significance (Table 3). Yet, the odds for becoming a SBP or DBP case from heavy occupational lifting, within strata of LTPA, indicated lower odds among participants reporting to be inactive or moderately to vigorously physical active > 4 hours/week.

Table 3

Adjusted odd ratios for being hypertensive by self-rated exposure to heavy occupational lifting, in the cross-sectional model, and for becoming a SBP or DBP case, defined as an above median delta value of BP at follow-up – BP at baseline, in the prospective model, stratified on leisure time physical activity at baseline (cross-sectional n-values Inactive = 4,836, light physical active = 30,531, MVPA 2–4 hours/week = 34,537, MVPA > 4 hours/week = 5,701; prospective n-values Inactive = 233, light physical active = 2,230, MVPA 2–4 hours/week = 3,798, MVPA > 4 hours/week = 698). No exposure to heavy occupational lifting was reference. [OR = Odds ratio; CI = Confidence interval]

Leisure time physical activity	Inactive/light physical active < 2 hours/week		Light physical active 2–4 hours/week		MVPA 2–4 hours/week		MVPA > 4 hours/week	
	OR	99% CI	OR	99% CI	OR	99% CI	OR	99% CI
Cross-sectional Hypertensive	0.95	0.84–1.07	0.94	0.89–0.99	0.99	0.94–1.04	1.02	0.91–1.14
Prospective Systolic case	0.89	0.59–1.32	1.05	0.90–1.22	1.13	0.98–1.31	1.03	0.72–1.47
Prospective Diastolic case	0.87	0.58–1.30	1.07	0.92–1.24	1.03	0.90–1.19	0.84	0.59–1.19
Adjusted cross-sectional model includes adjustment for sex, age, BMI, smoking, LTPA, mental stress and school education. The prospective model are additionally adjusted for BP at baseline.								

The linear regressions stratified by use of anti-hypertensives, did not show any associations neither in the cross-sectional nor the prospective analysis, except for a minimally higher pulse pressure (0.54 mmHg, 99% CI 0.13–0.94) and mean arterial pressure (0.49 mmHg, 99% CI 0.12–0.86) among participants not using anti-hypertensives (table S2).

The age stratified analysis showed insignificant odds for becoming a SBP or DBP case by exposure to heavy occupational lifting, being somewhat higher for the older than the younger participants (Table 2).

Secondary analysis

The participants were stratified by their self-reported level of OPA to test the sensitivity to the choice of comparison group. The cross-sectional model showed exposure to OPA primarily including sitting or standing and some walking to associate to minimally higher SBP compared to predominantly sedentary work. The prospective model showed positive associations between level of OPA and SBP, pointing towards exposure for heavy occupational lifting to give the greatest rise in SBP compared to the reference group performing predominantly sedentary work (Table S3).

Additionally, the sensitivity to cut-point for definition of hypertension was tested by the OR for being hypertensive at both lower (SBP \geq 130 mmHg/DBP \geq 80 mmHg) and higher (SBP \geq 160 mmHg/DBP \geq 100 mmHg) cut-points, than those applied in the primary analysis (SBP \geq 140 mmHg/DBP \geq 90 mmHg). Significant decreased prevalence of hypertension (4% and 3%) by exposure to heavy occupational lifting was seen in the adjusted models for the two highest cut-points (table S4).

The linear regressions stratified by use of anti-hypertensives and LTPA showed no associations between level of OPA and SBP, among participants using anti-hypertensives. Conversely, among participants not using anti-hypertensives tendencies of positive associations were seen, among those exposed to moderate and vigorous OPA and reporting a light to moderate level of LTPA (0.93 mmHg, 99% CI 0.23–1.62) (table S5).

Supplementary analysis

The differences in mean baseline BP across groups stratified by level of OPA and LTPA, showed that the higher the level of LTPA the lower the SBP (p value < 0.05) across all levels of OPA (Table 5).

Table 5
Cross-sectional mean of SBP and DBP in groups stratified by OPA with or without occupational lifting combined by LTPA and with or without use of an

		ALL				NOT using anti-hypertensives				USING anti-hyperter	
OPA	LTPA	n	SBP (mmHg)	DBP (mmHg)	Adjusted model SBP/DBP	n	SBP (mmHg)	DBP (mmHg)	Adjusted model SBP/DBP	n	SBP (mmHg)
Sedentary	Sedentary	2,399	135.7	81.6	< 0.0001/<0.0001	1,983	133.9	80.9	< 0.001/<0.0001	416	144.2
	Light	12,377	133.5	79.9		10,794	131.9	79.2		1,583	144.1
	Moderate	15,550	131.3	78.4		14,110	130.1	77.8		1,440	142.8
	Strenuous	2,808	131.0	77.7		2,624	130.2	77.2		184	142.2
Light	Sedentary	1,304	136.2	81.2	< 0.0001/<0.0001	1,073	134.5	80.8	< 0.0001/<0.0001	231	143.8
	Light	10,636	135.3	80.4		8,974	133.5	79.7		1,662	144.9
	Moderate	10,788	132.2	78.7		9,601	130.8	78.0		1,187	143.9
	Strenuous	1,433	130.3	77.3		1,327	129.4	76.8		106	142.3
Moderate - no occupational lifting	Sedentary	449	133.9	80.4	0.04/0.03	387	133.0	79.8	0.02/0.03	62	139.6
	Light	3,587	133.9	79.9		3,132	132.7	79.3		455	142.4
	Moderate	4,057	132.0	78.7		3,651	130.5	78.0		406	145.6
	Strenuous	616	131.1	78.0		583	130.3	77.6		33	145.4
Moderate and strenuous - with occupational lifting	Sedentary	684	137.0	81.7	0.01/<0.01	595	135.9	81.2	0.07/<0.01	89	143.9
	Light	3,931	135.5	80.9		3,419	134.0	80.2		512	145.4
	Moderate	4,141	134.0	80.0		3,670	132.9	79.4		471	142.3
	Strenuous	844	133.5	79.1		771	132.7	78.5		73	142.3
Adjusted cross-sectional model includes adjustment for sex, age, BMI, smoking, LTPA, mental stress and school education.											
Supplementary tables											

Differences in mean baseline BP across sub-populations stratified by level of OPA, LTPA and use of anti-hypertensives showed an overall trend (p value \leq 0.03, except for those stating their OPA to be "Moderate and strenuous - with occupational lifting" and not using anti-hypertensives) of the higher the level of LTPA the lower mean BP across all levels of OPA, among those not using anti-hypertensives. However, level of LTPA did not seem to affect BP among users of anti-hypertensives (Table 5).

The differences in follow-up mean SBP and DBP, stratified by level of OPA and LTPA, showed that the higher the level of LTPA the lower the mean SBP and DBP were among participants reporting exposure to light OPA (predominantly sitting or standing, including some walking) (p value \leq 0.03) (Table S6). No differences in SBP and DBP were seen across the remaining OPA and LTPA groups.

Differences in mean BP at follow-up, across sub-populations stratified by level of OPA, LTPA and use of anti-hypertensives, showed no differences in BP, except among participants reporting to be exposed to light OPA (predominantly sitting or standing, including some walking) and not using anti-hypertensives,

where a higher level of LTPA related to a lower mean SBP and DBP across all levels of OPA (p value ≤ 0.03) (table S6).

Discussion

This study contributes to the knowledge about the risk for hypertension from heavy occupational lifting by its aim to verify previous findings [7] and to perform further analysis accounting for the moderating effects from LTPA. Thus, this study explored cross-sectional and prospective associations between heavy occupational lifting and hypertension in the Copenhagen General Population Study.

Study findings

The adjusted cross-sectional analysis indicated a 3% lower risk of hypertension by exposure to heavy occupational lifting (Table 2), which was supported by the adjusted linear associations between heavy occupational lifting and SBP (mmHg) indicating a negative association (-0.29 mmHg, 95% CI -0.82–0.25 mmHg, table S1). These associations could be explained by the cross-sectional design of this analysis, meaning that this result may be owed to either i) exposure to heavy occupational lifting to lower the risk for hypertension or ii) those exposed to heavy occupational lifting being less frequently hypertensive than those not. Within occupational medicine studies, results are assumed to be prone to healthy worker selection bias, implicating less healthy workers migration into occupational groups less exposed to heavy occupational lifting or other strenuous activities [26]. Thus, one could speculate that the acute peaks in BP, while performing lifting tasks [5], may give rise to angina [27], among the workers with poor cardiovascular health. Hence, workers experiencing angina or such, would be more likely to migrate into less strenuous occupational groups.

On the contrary, the adjusted prospective analysis indicated an 8% higher risk for being a SBP case by exposure to heavy occupational lifting (Table 2), while the linear regressions showed the greatest increase in SBP among those exposed to heavy occupational lifting (Table 4). Opposite to the BP effects from resistance training during LTPA [28, 29], these results indicate heavy occupational lifting to have hazardous effects on BP, as previously indicated [7]. The background for increased risk for hypertension by exposure to heavy occupational lifting, may lie within the repeated acute peaks in BP during lifting tasks [5], occurring due to the occlusion of the vessels induced by static muscle activity leading to increases in total peripheral resistance [14]. During heavy occupational lifting these BP peaks are repeated, both during the 7–9 hour workday, as well as during the 5-day work-week. Thereby the recovery between BP peaks may be insufficient [13, 30], and could give rise to the increased BP both during working hours as well as across the 24 h BP [6]. However, this higher risk of being a SBP case by exposure to heavy occupational lifting is not reflected in the linear regressions, showing no associations between heavy occupational lifting and SBP, DBP, PP and MAP (table S1). Thus, these findings ought to be interpreted with care.

Table 4
Cross-sectional mean of SBP and DBP in groups stratified by OPA with or without occupational lifting combined by LTPA and with or without use of an

OPA	LTPA	ALL				NOT using anti-hypertensives				USING anti-hyperter	
		n	SBP (mmHg)	DBP (mmHg)	Adjusted model SBP/DBP	n	SBP (mmHg)	DBP (mmHg)	Adjusted model SBP/DBP	n	SBP (mmHg)
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	Strenuous	844	133.5	79.1		771	132.7	78.5		73	142.3

Adjusted cross-sectional model includes adjustment for sex, age, BMI, smoking, LTPA, mental stress and years of school education.

The age-stratified prospective analysis showed exposed to heavy occupational lifting to increase risk for being a SBP case; 11% higher risk among workers aged ≥ 50 years and 5% higher risk among workers aged < 50 years (Table 2), similar to a previous study [7]. Older workers are likely to have been occupationally active throughout a longer time span than younger workers, and therefore the effect of the occupational exposures might be more pronounced. Furthermore, a higher strain from occupational lifting will be expected among older than younger workers, due to the combination of age-related declines in aerobic capacity [12] and arterial compliance [14, 15], giving rise to greater increase in BP and thus a potentially higher risk of hypertension [6].

The adjusted OR for being hypertensive by exposure to heavy occupational lifting stratified by level of LTPA showed a minimal numerical tendency of increasing risk for hypertension and for being a SBP case, by increased level of LTPA (Table 3). These OR indicate more positive associations between heavy occupational lifting and BP and higher levels of LTPA than seen among those with lower levels of LTPA. However, these rather weak associations does not support the common assumption of a beneficial effect of decrease in risk of hypertension by increased levels of LTPA, as presented in general physical activity recommendations and previous literature [21, 24, 25, 31]. Thus, it could be assumed that the volume of physical activity by combination of leisure time MVPA with heavy occupational lifting, results in overstrain, and cardiovascular damage, rather than optimized cardiovascular health. This notion is supported by previous findings among both veteran athletes [32], and workers having both high OPA and high LTPA [33, 34]. However, the lack beneficial effect from LTPA on BP was not reflected in the cross-sectional mean BP, showing higher levels of LTPA to relate to a lower BP, regardless of OPA level (Table 5). Nevertheless, the mean BP, at follow-up, did not show any effect by level of LTPA, independently of level of OPA, except for those reporting a light level of OPA and not using anti-hypertensives (table S6). Thus, these tendencies of effect from level of LTPA and OPA on BP, only seen in the cross-sectional analysis, could be explained by the fact that in the prospective analysis, the stratification on level of LTPA and OPA are made at baseline values and thus the effect from the level of LTPA and OPA at baseline seems to have vanished in the 10-year follow-up BP. Conclusively, as causal effects cannot be drawn from cross-sectional analysis, these presented results do not indicate level of LTPA to affect BP across OPA strata.

The analysis stratified by use of anti-hypertensives did not show results indicating users of anti-hypertensives to be especially vulnerable to rises in BP when exposed to heavy occupational lifting, as previously shown [7]. Yet, users of anti-hypertensives did not seem to have the beneficial lowering effects on BP by increasing level of LTPA, in the cross-sectional analysis (Table 5). Previously, greater or similar beneficial effects on BP from LTPA have been seen among hypertensives compared to normotensives [21, 35], however these previous studies did not take OPA or heavy occupational lifting into consideration. Thus, future investigations on effects from LTPA on BP among working-age adults, should account for level of OPA.

Hence, to develop recommendations for prevention of hypertension more knowledge is needed, especially targeted to vulnerable groups of older workers. In addition, further investigations are needed to uncover the potential for prevention of progression of hypertension among users of anti-hypertensives, as level of LTPA does not seem to have the assumed BP-lowering effect [21, 35].

Methodological considerations

The population included in the cross-sectional analysis were younger, less hypertensive, better educated and more frequently exposed to heavy occupational lifting than those excluded from analysis. For the prospective analysis, the differences between those in- and excluded from analysis were similar to the cross-sectional analysis. Besides the inclusion criteria of answering the question regarding exposure to OPA and heavy occupational lifting and being aged < 70 years at baseline, these differences may be explained by the frequency of excluded participants being retired or unemployed (80% in the cross-sectional data and 32% in the prospective data). Moreover, the inclusion criteria for the prospective analysis of being normotensive excluded 52% of the participants at follow-up. Taken together, these differences between in- and excluded participants indicate that the population analyzed was overall healthier, but also more frequently exposed to heavy occupational lifting, and thus the results may reflect associations being more conservative than if based on the entire sample of participants. Also, as the complete follow-up sample is currently being collected, these associations should be repeated for verification in the complete sample.

The main strengths of this study include the limited risk of false negative classification of hypertension due to the determination of hypertension based on both use of anti-hypertensives and the casual BP in mmHg, and the high number of randomly selected participants in the study population. Limitations are the single measurement of a casual BP, shown to have a lower prognostic value than ambulatory BP or BP monitored during sleep [36, 37], and the self-rated exposure to occupational lifting that could be biased by recall [38, 39] and duration of working hours, as exposure to occupational lifting seems to affect the odds for prolonged working hours [40].

Perspectives of the proposed findings

The Eurofound survey states that 33% of the European workforce is exposed to occupational lifting (6th survey in Eurofound). Knowledge of the impact on cardiovascular health from occupational lifting is sparse, and to be able to develop preventive initiatives and clinical guidelines, investigations of heavy occupational lifting in relation to precursors of cardiovascular disease should be encouraged. In this paper, the associations indicated workers aged ≥ 50 years to have an increased risk for hypertension, when exposed to heavy occupational lifting. Thus this group holds a potential for prevention of hypertension by minimizing exposure to heavy occupational lifting, e.g. by automatization of manual work tasks or use of assistive devices.

Furthermore, future preventive initiatives and clinical guidelines should strive to modify the exposure to heavy occupational lifting, as well as stay informed on the growing knowledge of the effects on BP from the combined LTPA and OPA levels to avoid the risk of cardiovascular overstrain. However, for this development, it is essential to keep in mind the lower effect from LTPA on BP among users of anti-hypertensives. Thus, to develop preventive initiatives and clinical guidelines for heavy occupational lifting in relation to risk for hypertension more knowledge are needed.

Conclusion

No cross-sectional associations between heavy occupational lifting and BP nor hypertension were found. Prospectively heavy occupational lifting indicated to increase the risk of hypertension, especially among workers aged ≥ 50 years, or reporting light to moderate LTPA.

List Of Abbreviations

OPA – occupational physical activity

LTPA – Leisure time physical activity

BMI – Body mass index

BP – Blood pressure

SBP – Systolic blood pressure

DBP – Diastolic blood pressure

pp – percentage points

GEE – generalized estimation equation

OR – Odds ratio

CI – Confidence interval

MVPA – Moderate to vigorous physical activity

Declarations

Ethics approval and consent to participate

The data are collected after signed informed consent by the participants according to the Helsinki declaration.

Consent for publication

All of the authors have read and approved the submission of the manuscript.

Availability of data and materials

Requests of data and other materials should be by correspondence to Mette Korshøj, PhD, Senior Researcher, Department of Occupational- and Social Medicine, Holbæk Hospital, Gl. Ringstedvej 4B, 4300 Holbæk, Denmark, email melars@regionsjaelland.dk.

Competing interests

The authors state to have no conflicts to declare.

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Author contributions

MK, AH and HH concepted the initial idea for the study. MK, AH, HH and EC drafted the protocol for analysis and raised funding for performance of the study. MK analyzed the data and drafted the paper. RFS, JLM and PS participated in the building of the cohort, RFS was managing the data and JLM supervised the statistical analysis. All authors discussed the protocol for analysis and the interpretation of the results, as well as commented on the manuscript.

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Figures

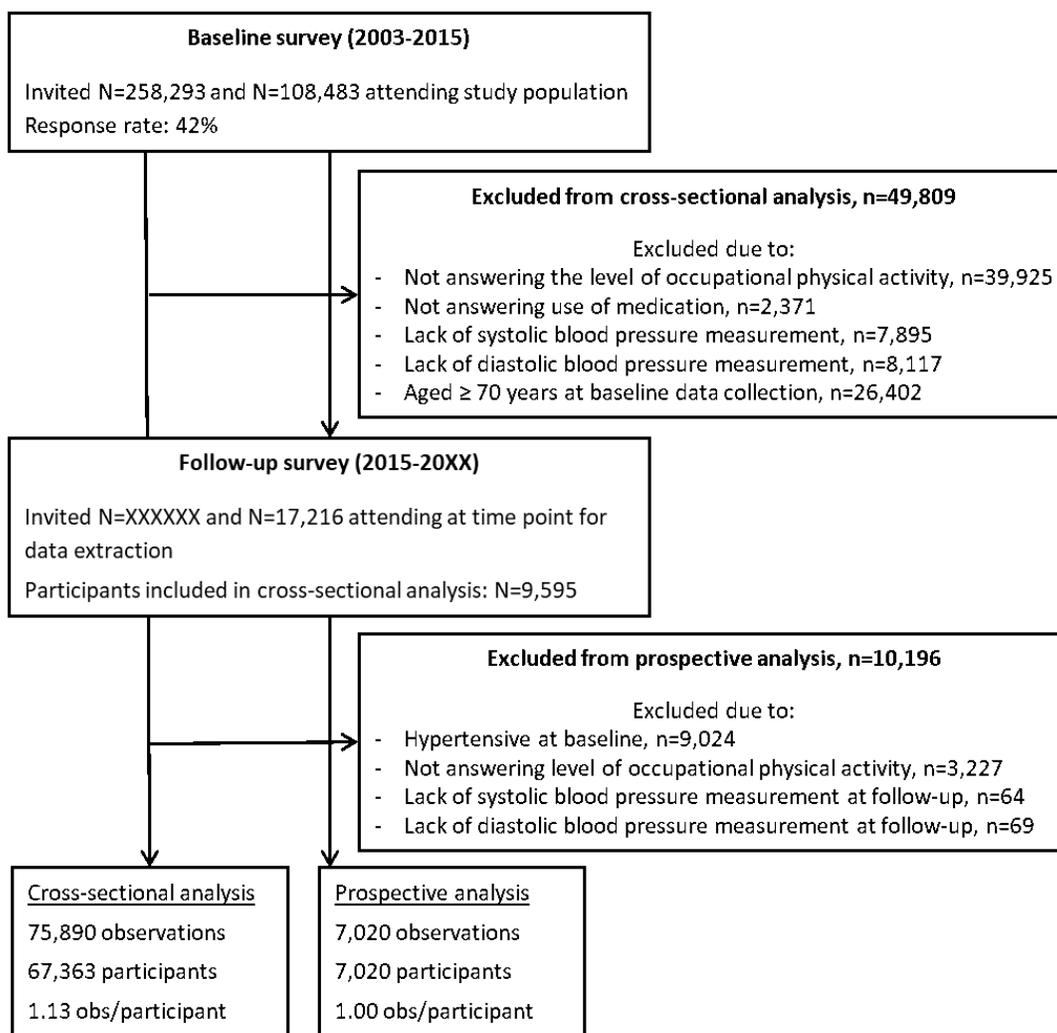


Figure 1

Flow of the observations and participants in the examination of the Copenhagen General Population Study.

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