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Limitations to functioning and independent living after the onset of coronary heart disease: what is the role of lifestyle factors and obesity?

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Background: People with coronary disease have a higher risk of functional limitations than their same-age counterparts without disease. This study examined prospectively the extent to which functioning and independent living among individuals with coronary disease in early old age are associated with lifestyle factors before and after disease onset. **Methods:** Participants were 986 British civil servants (657 men and 329 women aged 35–55 years), who were free of coronary disease at study entry in 1985–88 but developed disease during 21 years follow-up (the Whitehall II study). Lifestyle factors (obesity, smoking, alcohol, diet and physical activity) were measured at baseline and follow-up in 2007–09. Post-disease limitations to functioning were measured in 2006–09 at mean age is 68 years using activities of daily living scales. **Results:** Low physical activity and being overweight [body mass index (BMI) ≥25] before and after disease onset were associated with having one or more limitations in activities of daily living among coronary patients [age-, sex- and socio-economic position adjusted odds ratios for pre-disease inactivity and obesity 1.53 [95% confidence interval (95% CI) 0.99–2.35] and 2.53 (95% CI 1.53–4.18), respectively]. A decrease in physical activity [odds ratio (OR): 2.42, 95% CI 1.59–3.68] and an increase of >5 U in BMI (OR: 2.05, 95% CI 1.34–3.13) were also related to limitations in activities of daily living after disease onset. These relationships were not accounted for by measured co-morbidities. No robust associations were observed for smoking, alcohol use and diet. **Conclusion:** Physical activity and weight control across the adult life course are associated with fewer limitations to functioning and independent living after the onset of coronary disease.

Introduction

The fatality rate from coronary heart disease (CHD) has been falling since the late 1970s in all high-income countries.[1] While these favourable trends are clearly to be celebrated, the increasing number of people that survive with the disease emphasizes the need to reduce the adverse impact of CHD on functional abilities. In the UK, for example, the fatality rate has dropped by 45% in the last 10 years for people under the age of 65 years[2] and currently there are ~2.6 million people living with CHD.[3]

Studies show significant impairment in physical and mental functioning after CHD events.[4,5] A recent analysis in the USA found, on average, CHD patients had 2.4% lower mental health scores; 4.6% lower health utility scores (mobility, self-care, activity, pain and anxiety) and 9.2% lower physical health scores.[6] In another US population-based study, restrictions on activities of daily life, such as walking across a room and transferring from bed to chair were experienced by 26.4% of people surviving a myocardial infarction (MI) compared with 11.9% without MI.[4] Such limitations have a profound impact upon the individual, their families and society.

To date, many studies on factors associated with functioning after CHD are based on clinical cases recruited after diagnosis[7,8] and therefore provide limited information on targets for preventive interventions before onset of disease. Lifestyle factors such as smoking, poor diet and lack of physical exercise are well-established modifiable risk factors for CHD.[9] However, it is unclear to what extent these factors contribute to functioning abilities after disease onset since there are few prospective studies from a general population setting with data recorded before and after disease onset.

To overcome some of these limitations in previous research, this 21-year prospective cohort study sought to (i) determine the prevalence of functioning limitations among those with CHD by age, socio-economic position and gender; (ii) assess whether lifestyle-related risk factors, such as smoking, heavy alcohol consumption, physical inactivity or obesity measured before and after onset of disease are associated with post-disease functioning; and (iii) examine whether changes in risk factors are associated with post-disease functioning.

Methods

Study population and design

The Whitehall II study was established in 1985 as a prospective cohort study to examine the socio-economic gradient in health and disease among 10 308 civil servants (6895 men and 3413 women).[10] All civil servants aged 35–55 years in 20 London-based departments were invited to participate and 73% agreed to take part. Baseline examination (Phase 1: 1985–88) involved a clinical examination and a self-administered questionnaire. Subsequent phases of data collection have alternated between postal questionnaire alone and postal questionnaire accompanied by a clinical examination. Home visits were offered at Phase 9 in 2008–09 to reduce selective attrition bias. The University College London ethics committee approved the study.

The analytic sample of this article was restricted to participants who were free of CHD at baseline ($n = 9885$), had an incident CHD event (non-fatal MI or angina) between Phases 1 and 7 ($n = 1311$) and a measurement of functioning at Phase 8 and/or 9, giving a total of 986 individuals (657 men and 329 women). Of these, 866 individuals (88%) had measurement of functioning at both Phases 8 and 9, 83 (8%) had functioning measured only at Phase 8 and 37 (4%) had functioning measured only at Phase 9. Lifestyle factors were assessed at Phase 1 (on average of 8.2 years before onset of the disease) and at Phase 9 (on average of 13.3 years after disease onset).

Ascertainment of incident CHD

CHD incidence was based on self-reported, screening data and clinically verified events from health registers. Participants were flagged by the British National Health Service (NHS) Central Registry. Non-fatal MI was defined following MONICA criteria[11] based on questionnaires, study electrocardiograms, hospital acute ECGs, cardiac enzymes and physician records. Angina was assessed on the basis of participants' reports of symptoms (Rose angina symptoms of chest pain questionnaire)[12] and diagnoses with corroboration in medical records or abnormalities on a resting ECG, exercise ECG or coronary angiogram.

Assessment of limitations to physical functioning and independent living

Physical functioning was measured at Phases 8 and/or 9 using the Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) scales. The ADL scale[13] consists of six self-completed questions on participants' ability to carry out everyday tasks such as dressing, walking, washing and using the toilet (Supplementary Appendix A1). The IADL questions attempt to capture the ability to live independently in a community and involve cognitive and physical competences[14] including preparing a hot meal, taking medication, doing work around the house and shopping for groceries (Supplementary Appendix A1). For both ADL and IADL, reporting one or more difficulty at either phase from the list of six items was taken as a limitation.

Assessment of lifestyle-related risk factors before and after CHD event

Lifestyle-related risk factors were measured using standardized protocols with cigarette smoking, alcohol consumption, diet and physical activity ascertained by questionnaire and body mass index (BMI) measurements obtained from clinical examinations. Cigarette smoking categories were non-smokers, ex-smoker and current smoker. Alcohol consumption in the previous week was measured as units per week, then categorized as none, within recommended limit for gender ($\leq$21 U for men, $\leq$14 U for women), high consumption (22–50 men, 15–35 women) and harmful consumption ($\geq$51 U men, $\geq$36 U for women) as described by the UK Department of Health.[15] A summary index of diet quality was based on milk, bread and fruit and vegetable consumption. Physical activity was based the frequency and duration of participation in moderately energetic (e.g. dancing, cycling) and vigorous physical activity (e.g. running, playing squash). Participants were classified as active (>2.5 h/week of moderate physical activity or >1 h/week of vigorous physical activity), inactive (<1 h/week of moderate physical activity and <1 h/week of vigorous physical activity) or moderately active (if not active or inactive).

Assessment of covariates

Covariates were age, sex, socio-economic position and prevalent long-standing illness. Socio-economic position was measured at baseline using the civil service employment grade, which is based on salary and work role and ranges from senior executive officers to clerical and support staff.[10] To determine prevalent long-standing illnesses at baseline and at Phase 9, participants were requested whether they had 'any longstanding illness, diseases or medical conditions for which [they] sought treatment in the last 12 months'. Participants' age was calculated at their last measurement of functioning (Phase 9 for 99% of participants).

Statistical analysis

The proportion of participants with limitations in physical functioning was tabulated for all risk factors and odds ratios (OR) [adjusted for age, sex and socio-economic position, together with 95% confidence intervals (95% CIs)] were calculated using logistic regression. All models included two dummy variables to adjust for whether physical functioning was assessed at two phases or only once at either Phase 8 or 9. For lifestyle factors after disease, Phase 9 measures were used since most of these measures were not available at Phase 8. Therefore, Phase 9 non-responders could not be included in the analyses of post-disease lifestyle factors or in the analyses of change in lifestyle factors. In order to test whether any relationships, at baseline or follow-up, between lifestyle factors and functioning levels were accounted for by other long-standing illnesses, we repeated the analysis after adjustment for prevalent self-reported long-standing illness.

Results

The mean age at measurement of functional ability was 67.6 years (SD 6.0) (table 1). Of 657 men with CHD, 19.8% reported that they had at least one limitation on the ADL scale and 14.0% on the IADL scale. The proportions for women were higher with 26.8% on the ADL scale and 21.6% on the IADL scale. Men and women aged >65 years were more likely to report limitations, particularly for ADL scale (25.2% for >65 year olds compared with 16.8% for those aged 55–64 years). There was a strong social gradient with those in the lowest employment grades being more likely to report limitations (32.5% for ADL and 26.2% for IADL) compared with high employment grades (18.9% for ADL and 11.3% for IADL). Participants who had measurement of functional ability assessed only at Phase 8 were more likely to report limitations than those who attended Phase 9.

There were strong relationships between baseline (pre-disease) BMI and risk of having functional limitations at follow-up (table 2). Compared to those with a normal BMI at baseline, those who were overweight were 60% more likely (OR 1.62, 95% CI 1.16–2.26) to report limitations on the ADL scale. Those who were obese at baseline were two and a half times as likely (OR 2.53, 95% CI 1.53–4.18). There was a similar strong association of baseline obesity with the IADL scale. When BMI was measured at follow-up, post-diagnosis of CHD, there were similar increased risks from being overweight or obese on risk of reporting limitations on the ADL scale but not the IADL scale. Those whose BMI increased $\geq 5\,\mathrm{kg\,m^{-2}}$ during the follow-up period had a 2-fold increased risk of functional limitations compared to those with less change in BMI.

There was a strong association between physical activity levels and risk of having functional limitations; the corresponding OR for ADL for being inactive vs. active before and after disease onset were 1.53 (95% CI 0.99–2.35) and 3.69 (95% CI 2.47–5.52), respectively (table 3). There were strong negative effects of staying inactive (OR 2.84 and 3.49 for ADL and IADL, respectively) compared with those who were active at both phases. Decrease in physical activity was associated with excess risk of functional limitations.

Table 1 One or more limitations on ADL and IADL score by sex, age and socio-economic position

	N	ADL % (*n*)	IADL % (*n*)
Total	986	22.1 (218)	16.5 (163)
Sex			
Male	657	19.8 (130)	14.0 (92)
Female	329	26.8 (88)	21.6 (71)
Age (when ADL/IADL measured) (years)			
55–64	363	16.8 (61)	14.1 (51)
65–79	623	25.2 (157)	18.0 (112)
Socio-economic position at baseline			
High employment grade	293	18.9 (53)	11.3 (33)
Intermediate employment grade	487	20.1 (98)	15.6 (76)
Low employment grade	206	32.5 (67)	26.2 (54)
Phase at which functional ability was measured			
Both Phases 8 and 9	866	21.7 (188)	14.7 (127)
Only Phase 8	83	28.9 (24)	34.9 (29)
Only Phase 9	37	16.2 (6)	18.9 (7)

Table 2 Association between BMI and change in BMI with one or more limitations on ADL and IADL score

	N	ADL		IADL	
		%(*n*)	OR[a] (95% CI)	%(*n*)	OR[a] (95% CI)
BMI at Phase 1					
Underweight[b]	12	16.7 (2)	–[c]	25.0 (3)	–[c]
Normal weight	500	16.8 (84)	1.0	13.4 (67)	1.0
Overweight	382	25.4 (97)	1.62 (1.16–2.24)	16.5 (63)	1.18 (0.81–1.73)
Obese	90	37.8 (34)	2.53 (1.53–4.18)	33.3 (30)	2.55 (1.50–4.33)
BMI effect per kg m^{-2}			1.10 (1.06–1.15)		1.07 (1.02–1.12)
BMI at Phase 9					
Underweight	5	20.0 (1)	–[c]	20.0 (1)	–[c]
Normal weight	225	11.1 (25)	1.0	12.9 (29)	1.0
Overweight	373	19.0 (71)	1.87 (1.14–3.06)	11.2 (42)	0.82 (0.49–1.39)
Obese	243	31.3 (76)	3.61 (2.18–5.99)	20.2 (49)	1.60 (0.95–2.69)
BMI effect per kg m^{-2}			1.10 (1.06–1.14)		1.03 (0.99–1.07)
BMI change at Phases 1 and 9					
Decrease in BMI	135	18.3 (25)	0.89 (0.54 -1.48)	19.0 (26)	1.47 (0.88 -2.48)
Increase: 0–4 kg m^{-2}	558	18.1 (99)	1.0	12.3 (67)	1.0
Increase: $\geq$5 kg m^{-2}	163	29.8 (48)	2.05 (1.34 -3.13)	17.4 (28)	1.40 (0.84–2.34)

a: OR adjusted for age, sex, socio-economic position and the number of times and phase at which functioning was measured
b: Underweight groups excluded from the analyses of BMI per 1 kg m^{-2} and underweight group at Phase 1 excluded from analysis of BMI change
c: OR for underweight groups not presented because of the small numbers in these groups

Table 3 Association of level of and change in physical activity with having one or more limitations on ADL and IADL score

	N	ADL		IADL	
		% (*n*)	OR[a] (95% CI)	% (*n*)	OR[a] (95% CI)
Exercise at Phase 1					
Active	568	18.7 (106)	1.0	13.2 (75)	1.0
Moderately active	236	25.0 (59)	1.43 (0.99–2.07)	18.6 (44)	1.36 (0.90–2.08)
Inactive	149	29.5 (44)	1.53 (0.99–2.35)	24.2 (36)	1.72 (1.07–2.75)
Exercise at Phase 9					
Active	533	14.6 (78)	1.0	9.4 (50)	1.0
Moderately active	189	22.2 (42)	1.73 (1.13–2.64)	16.4 (31)	1.91 (1.17–3.11)
Inactive	178	39.9 (71)	3.69 (2.47–5.52)	28.1 (50)	3.29 (2.09–5.19)
Exercise at Phases 1 and 9					
Unchanged exercise					
Active	361	15.0 (54)	1.0	9.4 (34)	1.0
Moderately active	48	20.8 (10)	1.62 (0.75–3.49)	14.6 (7)	1.63 (0.67–3.95)
Inactive	49	38.8 (19)	2.84 (1.44–5.59)	32.7 (16)	3.49 (1.69–7.23)
Changed exercise					
Increased activity[b]	198	18.2 (36)	1.18 (0.73–1.88)	12.6 (25)	1.26 (0.72–2.20)
Decreased activity[c]	216	30.1 (65)	2.42 (1.59–3.68)	19.9 (43)	2.27 (1.38–3.71)

a: OR adjusted for age, sex, socio-economic position and number of times and phase at which functioning was measured
b: Increased activity: inactive to moderate; inactive to vigorous; moderate to vigorous
c: Decreased activity: vigorous to inactive + vigorous to moderate + moderate to inactive

Mutual adjustment for BMI and physical activity indicated that the effects of these two factors on functional limitations were independent of each other (data not shown).

There were no significant associations between pre- or post-disease smoking status and risk of having one or more limitation on the functioning scales (Supplementary Table S1), although the prevalence of smoking in this cohort was low, especially by the time of follow-up at Phase 9 (9% current smokers). In the alcohol analyses (Supplementary Table S2), there was suggestive evidence that, at Phase 9, non-drinkers had a higher risk of having functional limitations than those drinking moderately (OR for Phase 9, 1.85 for ADL and OR 1.57 for IADL). There was some evidence that exceeding recommended alcohol consumption was a risk factor for poor ADL functioning. In addition, both decreased and increased changes from moderate consumption were associated with increased ADL limitations compared with those who did not change their moderate alcohol consumption. In general, diet improved during the follow-up (Supplementary Table S3), but there were no strong associations between pre- or post-disease diet and risk of having poor functioning.

In sensitivity analyses, adjustments were made for participants who reported musculoskeletal disorders, cancer and stroke/nervous system disorders as long-standing illnesses at baseline (13.2, 0.5 and 3.3%, respectively) and at follow-up (23.7, 1.4 and 4.1%, respectively). After adjustment, the effects of physical activity and BMI on functional ability differed little from those presented in the tables. We also repeated our analyses separating the participants into those who had MI and those who had angina only. We found suggestive evidence that the associations between lifestyle factors (BMI and physical activity) and functioning were stronger among those who had angina events rather than MI.

Discussion

In this group of middle-aged and elderly men and women, there was considerable functional limitation among those with CHD. Nearly, one-quarter experienced one or more limitation on the ADL scale. This compares to 11.7% among similarly aged participants without CHD in the Whitehall II study. The prevalence of functional limitations was strongly socially patterned with higher prevalence among those with lower socio-economic position.

We found some risk factors measured before detectable onset of disease and at follow-up that were associated with a reduced risk of being functionally impaired at follow-up. These were having a low BMI (but not underweight) and being physically active. Importantly, we also saw that individual changes in risk factors, for example declines in BMI and increases in activity between baseline and follow-up were associated with lower risk of functional limitation. This reinforces the message that it is never too late to get the benefits of losing weight and becoming physically active.

Our findings emphasize the importance of obesity as a determinant of independent living in those with CHD. One in three obese individuals experienced functional limitations around the age of 70 years, compared with fewer than one in six in the normal weight category. We observed an even stronger link between physical activity level and functional limitation, emphasizing that the nature of such effects is likely to be bi-directional. For example, someone with acute angina may experience limitations in their daily activities which limits the amount of exercise they can comfortably perform, and which in turn increases their BMI. By looking at the relationship between levels of activity before onset of disease and functional ability afterwards, we provide evidence of protection from disability from favourable BMI and activity levels. In sensitivity analyses, we showed that the relationships between physical activity and BMI on functional ability were not accounted for by measured comorbidities.

There were no clear effects of smoking or poor diet in this data set and only suggestive benefits from moderate drinking. This may be partly due to the low prevalence of poor health behaviours among the surviving members of the cohort. Others have shown that dietary quality after CHD is poor;[16] however, we found that few people reported unhealthy diets and so were not able to detect the possible negative effects of poor nutrition. Previous studies have found that moderate drinkers and even drinking more than recommended amounts is associated with having fewer functional limitations.[17,18] These levels of drinking may be a proxy marker of well-being, in that these participants may be relatively active and able to engage in a sociable habit. We need further follow-up to see if any benefit it is sustained.

Strengths and limitations

Unlike previous studies of functioning in individuals with CHD, we measured lifestyle factors before (on average 8.2 years) disease onset and again after disease detection. This has two major advantages. First, it allows for analysis of the possible protective effects of modifiable behaviours long before disease incidence and secondly, it is also possible to examine the consequences of individual changes in lifestyle factors over time.

There are limitations to the study design. The cohort is at risk of selection bias as the participants who attended Phase 9 might be relatively healthy compared with those who no longer participate. Of the 1311 participants with a CHD event between Phases 1 and 7, 294 did not attend Phase 8 or 9 and so have no measurement of post-disease functional ability. These non-attenders had marginally higher Phase 1 BMI (25.7 vs. 25.4, $P = 0.19$) and were less active at baseline (23.3 vs. 15.6% inactive, $P = 0.003$) compared with those who attended the last follow-up screening. However, we attempted to minimize selective attrition by offering home visits to all those who were unwilling to attend the London clinic.

The completeness of follow-up for CHD is very high. Among the 8574 participants deemed to have no CHD event before Phase 7, the completeness of follow-up (the total observed person-time of follow-up as a percentage of the potential time of follow-up[19]) is over 93% suggesting that the majority of CHD events should have been detected. The degree of missingness for both BMI and exercise is small and the conclusions from the large OR for the effects of obesity and inactivity on limitations in functional ability should be robust.

The Whitehall II study is based on white-collar workers and is not representative of the general population in terms of the socio-economic spectrum or the range of unhealthy behaviours.

A further limitation is use of self-reported measures. Future data collection will include assisted means to function such as mobility aids and carers. Attempts will be made to include all participants who reside in assisted living homes.

Previous studies have shown that there is a social gradient in functional limitations with people lowest in the spectrum faring worse. For example, in a representative study of US adults, it was shown that self-reported functional limitations were strongly socially patterned up to the age of 85 years.[20] We extend the step-wise social gradient in functional limitations shown in the general population to those living with disease.[21]

There are very few studies that set out to explore whether lifestyle-related factors before onset of disease are related to later ability to function independently. In one study, greater levels of physical exercise were associated with better functioning among people with heart disease over a 2-year period.[8] However, there was no assessment of activity levels before disease. In a longitudinal study (follow-up 6 years), physical activity in middle-aged adults was shown to reduce the risk of functional impairment, independent of its effect on body weight.[22] However, the study was not based on people with heart disease.

The demographic trend towards aged populations plus the decline in fatal CHD and switch to less severe disease[23] means that an increasing number of people in rich countries will be living with disease. Physical functioning is a key influence on the probability of institutionalization and disability[24] and here we show that there are potentially modifiable lifestyle-related factors in early-to-middle age that may reduce functional limitations in later life, after onset of coronary disease. Our findings need to be replicated in other populations and there may be other factors, such as depression, that play a mediating role.[25]

These data emphasize the importance of physical activity and weight control across the adult life course for functioning and independent living after the onset of coronary disease. This can be used to inform targets for preventive interventions before onset of disease, and also for secondary interventions for those with newly diagnosed CHD. Functional limitation is a precursor of disability, dependence at older ages and life expectancy,[24] and therefore a key public health policy issue, particularly as more and more people live with CHD.

Supplementary Data

Supplementary Data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Key points

What is already known on this subject?

- The fatality rate from CHD has fallen and the number of people living with heart disease has risen.
- People with heart disease have a higher risk of having functional limitations than their same-age counterparts without disease.
- There is a social gradient in functional limitations in the general population with people lowest in the spectrum faring worse.
- Identification of modifiable lifestyle factors that reduce the risk of limitations among those with heart disease is needed.

What this study adds?

- Among people with coronary disease, those with low physical activity levels and those who are overweight or obese before

and after disease onset are more likely to experience difficulties in daily living activities.
- There is a strong social gradient in functional limitations among those living with CHD.
- Maintaining adequate physical activity levels and controlling body weight across the life-course may preserve functioning and the chances of living independently after the onset of CHD.

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Low serum lycopene and β-carotene increase risk of acute myocardial infarction in men

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Objective: Previous studies have shown that high intake or concentrations of serum carotenoids may protect against acute myocardial infarction (AMI). The role of carotenoids on the risk of AMI remains inconsistent. The aim of the present study was to examine if serum concentrations of major carotenoids are related to AMI in men. **Methods:** The study population consisted of 1031 Finnish men aged 46–65 years in the Kuopio Ischaemic Heart Disease Risk Factor (KIHD) cohort. Serum concentrations of carotenoids, retinol and α-tocopherol were measured by high-performance liquid chromatography. The association between the serum concentrations of lycopene α-carotene and β-carotene and the risk of AMI was studied by using the Cox proportional hazard models. **Results:** A total of 194 incident AMI cases occurred during an average of 11.5 follow-up years. After adjusting for potential confounders, the risk of AMI for men in the lowest tertile of serum concentrations compared with men in the highest tertile was 1.55 (95% CI 1.05– 2.30; $P = 0.028$) for lycopene and 1.60 (95% CI 1.09–2.35; $P = 0.017$) for β-carotene. **Conclusions:** This cross-sectional study shows that low serum lycopene and β-carotene concentrations may increase the risk of AMI in men.