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Resting heart rate, self-reported physical activity in middle age, and long-term risk of hip fracture. A NOREPOS cohort study of 367,386 men and women

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A R T I C L E I N F O

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A B S T R A C T

Enhanced knowledge regarding modifiable risk factors for hip fractures are warranted. We aimed to study the associations between two indicators of physical fitness (resting heart rate and level of physical activity) in middle-aged individuals, and the risk of hip fractures during the subsequent three decades. Data on objectively measured resting heart rate and self-reported leisure time physical activity from a national health survey (1985–1999) was linked to a database including all hip fractures treated in Norwegian hospitals from 1994 through 2018. We calculated hazard ratios (HR) with 95 % confidence intervals (95 % CI) for hip fractures according to categories of resting heart rate (mean of two repeated measures), and leisure time physical activity level in adjusted Cox proportional hazard models. In total, 367,386 persons (52 % women) aged 40 to 45 years were included, of whom 5482 persons sustained a hip fracture during a mean follow-up of 24.8 years. Higher resting heart rate was associated with higher hip fracture risk. Men with a resting heart rate above 80 bpm, who also reported low levels of physical activity, had a HR of 1.82 (95 % CI 1.49–2.22) for hip fracture compared to men with a resting heart rate below 70 bpm who reported high levels of physical activity. The same measure of association for women was 1.62 (95 % CI 1.28–2.06). Physical fitness measured by low resting heart rate in middle age, and a high physical activity level were associated with a lower long-term risk of hip fractures in both men and women.

1. Introduction

The incidence of hip fracture worldwide varies by >10 fold [1–4], with the Scandinavian countries at the very top. In Norway, the life-time risk of a hip fracture at the age of 50 is estimated to be 25 % in women and 9 % in men [5]. Hip fracture represents a significant clinical problem, may cause increased morbidity and mortality, and constitutes a substantial economic cost for the society [6–8]. The majority of hip fractures are low-trauma fractures and affect older adults (>65 years). Hip fracture etiology is multifactorial, with physical activity identified as a modifiable risk factor and associated with a reduced fracture risk [9,10]. There is a decreasing trend in level of physical activity, which may lead to an increase in hip fracture incidence [11,12]. Possible adverse outcomes of physical inactivity is important to communicate to decision makers, both in health care and the society in general, Risk factors that could be modified by lifestyle changes earlier in life are of interest both on an individual and population level. The association between physical activity level and cardiorespiratory fitness at younger ages and long-term hip fracture risk has not been extensively studied.

Physical activity is a major determinant of cardiorespiratory fitness, which is inversely associated with the risk of several chronic diseases and all-cause mortality [13–15]. Even a minor increase in physical fitness is related to a lower risk of death [16–19]. Objective measurements of physical fitness require extensive resources and are time

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consuming, thus challenging to collect from larger study populations. However, physical activity questionnaires remain a practical mapping tool in large health studies, and have shown acceptable validity, despite some limitations [20]. Resting heart rate is dependent on cardiac capacity and autonomic function. Furthermore, it correlates with more comprehensive measures of physical fitness, such as maximal oxygen uptake and objectively measured level of physical activity (accelerometry measurements), in an inverse dose-response relationship [16,20,21]. Resting heart rate may therefore be a suitable indicator of physical fitness in large studies. The relationship between resting heart rate and hip fractures has not been well studied, and previous studies have been limited by relatively low numbers of fractures [22–26]. Reporting the associations between resting heart rate and self-reported physical activity may add knowledge about their relationship with hip fracture risk. Several studies have looked at sex differences between physical activity and hip fractures, however there have been few studies on sex differences in the associations between physical activity, fitness, and risk of hip fracture. Relevant sex differences include higher levels of physical activity among men, a slightly higher resting heart rate among women and a higher hip fracture incidence among women [20,27,28].

The primary objective of this study was to investigate the association between cardiorespiratory fitness, measured by resting heart rate, in men and women aged 40–45 years, and long-term hip fracture risk, in a large cohort of almost 375,000 participants followed over a period of up to 34 years. The secondary objectives were to study the association between self-reported physical activity level in middle age and long-term risk of hip fracture, and to address sex differences. We hypothesized that high resting heart rate and low levels of physical activity in middle age are associated with a higher risk of hip fractures later in life.

2. Materials and methods

2.1. Design and study population

This was a prospective cohort study. Data from a national health survey of Norwegian men and women aged 40–45 years (the Age 40 Program) were linked to the Norwegian Epidemiologic Osteoporosis Studies (NOREPOS) Hip Fracture Database (NORHip). Resting heart rate, measured during a physical examination in the Age 40 Program, was the main exposure in the study, and hip fractures registered in NORHip were the main outcome. Self-reported physical activity in leisure time was a secondary exposure variable.

2.1.1. The Age 40 Program

Between 1985 and 1999, the National Health Screening Service (subsequently the Norwegian Institute of Public Health) conducted a large, nationwide cardiovascular health survey. All Norwegian counties participated in the Age 40 Program, except Oslo, where a similar program was organized by a municipal hospital. The Age 40 Program was conducted continuously during the years 1985 to 1999, and was carried out three to five times in each county during the study period. The health survey consisted of a questionnaire and a standard physical examination. The questionnaire, completed in advance by the participant, included various life style and health related topics, previous and ongoing illnesses, as well as the use of certain medications. The physical examination included measurements of height, weight, blood pressure, resting heart rate and a non-fasting blood sample. Trained personnel from the National Health Screening service performed the examinations at screening sites, and checked the questionnaires for inconsistencies and missing data. Relevant questions for our study included information on self-reported physical activity levels in leisure time, smoking, alcohol use and level of formal education. All participants were identified with their personal national identification number, assigned to all Norwegian residents, to ensure no participant was entered into the study more than once.

Overall the participation rate was 73.5 %. More details about the participation rate in the Age 40 Program can be found in previously published literature [29].

In this study, we included men and women aged 40–45 years with a minimum of two resting heart rate measurements. We excluded participants with a resting heart rate below 30 and over 100 beats per minute (bpm) because these values may not represent a true resting heart rate. Participants reporting previous or current myocardial infarction, angina, stroke, diabetes mellitus, or current antihypertensive drug use were excluded. Out of the 417,339 individuals who participated in the Age 40 Program, 367,386 participants were eligible and included in the study (Fig. 1).

2.1.2. Hip fractures

The NORHip database provided hip fractures treated in Norwegian hospitals from 1 January 1994 until 31 December 2018 in the entire Norwegian population. Data on all inpatient contacts with a hip fracture diagnosis code (ICD-10: S72.0, S72.1, S72.2) from 1994 to 2007 were obtained from the patient administrative systems in the treating hospitals, and the corresponding data for 2008 to 2018 were obtained from the Norwegian Patient Registry. Using information from each hospital admission about co-occurrence of other diagnosis codes, surgical procedure codes, and whether the hip fracture occurred as a primary or secondary diagnosis, a comprehensive algorithm was applied when preparing the raw data, to identify the hospital admissions that represented a newly arisen (incident) hip fracture. The method of data preparation has been validated (www.norepos.no/documentation). We included only the first hip fracture sustained in each individual, and only fractures sustained after the age of 50 years. Almost all patients who suffer a hip fracture undergo surgery. Participants who had suffered a hip fracture before inclusion were excluded from the study.

2.2. Measurements

2.2.1. Resting heart rate

Resting heart rate was measured together with blood pressure using an automated device, DINAMAP (Criticon, Tampa, USA), through an oscillatory method [30]. After 2 min of rest, blood pressure and heart rate was measured three times in a sitting position, with one minute interval between each recording. Mean values of the two last recordings were used in the present study.

2.2.2. Self-reported physical activity

Level of leisure-time physical activity was self-reported in a questionnaire using the validated Saltin-Grimby Physical Activity Level Scale [31,32]. The question reads: “State your bodily movement and physical exertion in leisure time. If your activity varies widely, for example between summer and winter, then give an average. The question refers only to the last twelve months”. The four mutually exclusive response categories were: 1: *Reading, watching TV, or other sedentary activity*; 2: *Walking, cycling, or other forms of exercise at least 4 h per week*; 3: *Participation in recreational sports, heavy gardening etc. at least 4 h per week (including walking or cycling to work, Sunday walking, etc.)*; 4: *Participation in hard training or sports competitions regularly, several times a week*. This scale has been widely used and has been validated in a middle-aged Norwegian population. In our analysis we have combined categories three and four since there were few participants in the latter category. Since this question was not used in all waves of the Age 40 Program, data on self-reported leisure time physical activity was available for 82 % of the participants with heart rate measurement.

2.2.3. Other measurements

Body mass index (BMI) was defined as weight in kilograms per height in meters squared and is calculated from measured height and weight according to a standard protocol. From the questionnaire, data on the following questions were used: Self-reported current or previous myocardial infarction, angina pectoris, stroke and diabetes mellitus and

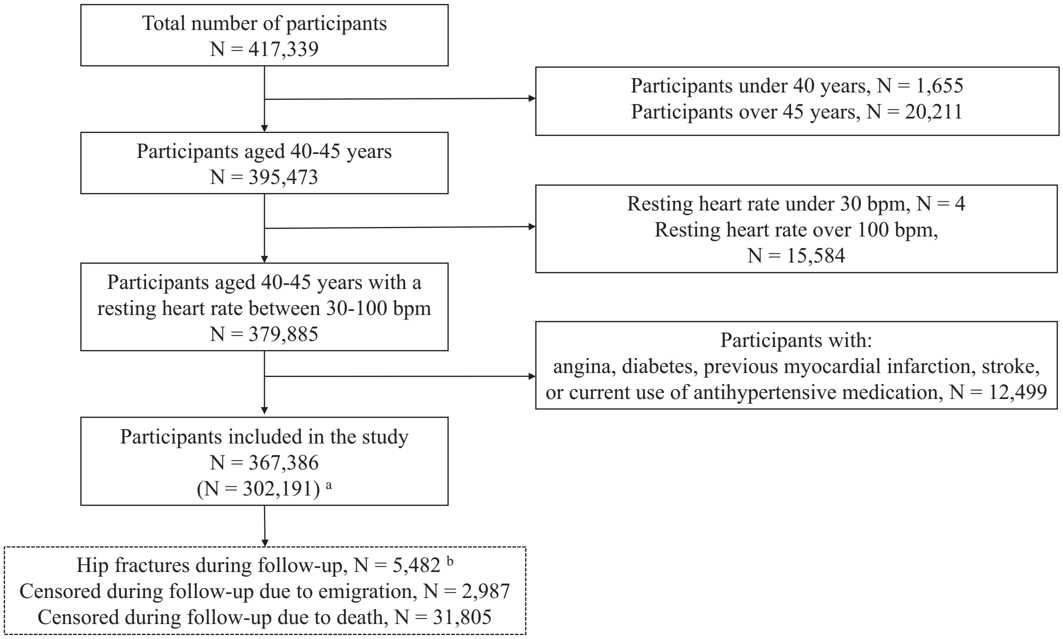


Fig. 1. Flowchart of the study population.
[a]Number of participants who received the question about self-reported leisure time physical activity with four response options (not all waves of the questionnaire included the self-reported physical activity question).
[b]Only hip fractures sustained after the age of 50 have been included in our study.

current antihypertensive drug use; all with a yes or no option. Data on smoking were categorized into three groups (no cigarette smoking, 1–14 cigarettes daily and ≥15 cigarettes daily). Alcohol consumption was assessed through the following question "*How many times per month do you drink alcohol?*". Highest attained education level at study entry was categorized into one of five levels corresponding to the current Norwegian standard: (1) basic (7–10 years of education); (2) intermediate 1 (11–12 years of education); (3) intermediate 2 (13 years of education); (4) higher education or undergraduate (14–16 years of education); and (5) higher education, graduate, or postgraduate (≥17 years of education).

2.3. Statistical analyses

Continuous variables are reported as means ± standard deviation, and categorical variables as proportions (%). We used Student's *t*-test for means of continuous variables and Pearson's Chi square test of independence for categorical variables to compare characteristics of men and women, in three categories of resting heart rate (30–69 bpm, 70–79 bpm and 80–100 bpm). We performed Cox proportional hazards regression to estimate hazard ratios with 95 % confidence intervals (CIs) for hip fracture with resting heart rate as the exposure variable. Similar analyses were done with self-reported physical activity as the exposure variable. Test for interaction on the multiplicative level was done by including the interaction term between resting heart rate as a continuous variable and categories of physical activity. The number of observation years for each participant was calculated from date of participation in the Age 40 Program to the date of hospital admission for their first incident hip fracture occurring after the age of 50, date of emigration for those who emigrated, date of death, or December 31st 2018, whichever came first. Information about dates of emigration and death came from Statistics Norway.

Covariates were selected using the directed acyclic graph method using DAGitty (www.dagitty.net). Variables related to both resting heart rate and hip fracture were included in the regression models as confounding factors. Models were adjusted for age, BMI and smoking. The confounding variables of alcohol intake and education level did not change the effect estimates, and were therefore not included in the final model. The proportional hazards assumption for resting heart rate was evaluated visually from ln-ln survival curves. Firstly, using resting heart rate as a continuous variable, we estimated hazard ratio of hip fracture per 10 beats per minute increase. This also provides a test for linear trend. Secondly, to enable detection of a potential non-linear pattern, resting heart rate was entered as an ordinal variable with three categories (30–69 bpm (reference level), 70–79 bpm and 80–100 bpm). The cutoffs were chosen with the intent to obtain three groups of approximately the same size. Finally, we investigated the risk of hip fracture among those with very low resting heart rates (30–55 bpm) compared to those with a resting heart rate of 56–69 beats per minute to look for a j-shaped relationship. We used cubic splines of resting heart rates (with 4 knots) to assess the shape of the association between resting heart rate and risk of hip fracture. Sensitivity analyses were performed where participants with heart disease and diabetes were included in the dataset, as well as exclusion of participants with a heart rate below 40 beats per minute. Statistical significance was set at $p < 0.05$.

Less than one percent of the observations had missing data; for resting heart rate (0 %), age (0 %), sex (0 %), BMI (0.2 %) and smoking (0.5 %). Data were analyzed using Stata software version 16.1 (StataCorp, College Station, TX, USA).

3. Results

Baseline characteristics by sex and categories of resting heart rate are presented in Table 1. Of the 367,386 individuals included in the study, 191,069 (52 %) were women. The mean age at inclusion, both among men and women was 41.4 years, and did not differ across resting heart rate categories. For both sexes, participants with a lower resting heart rate were slightly taller and had a lower BMI. In addition, men and women in the lowest resting heart rate category spent more of their leisure time in intermediate or high physical activity, were less likely to be smokers, drank alcohol less frequently and had a higher level of education than the participants with the highest resting heart rate. All differences were statistically significant.

During a total of 4,354,784 person years follow-up for men, 2132

Table 1
Baseline characteristics of participating men and women divided into the three categories of resting heart rate.

	Men			Women		
Resting heart rate (bpm)	30–69	70–79	80–100	30–69	70–79	80–100
Participants (%)	45	31	24	30	36	34
Age (years) at inclusion - mean (SD)	41.4 (1.06)	41.4 (1.06)	41.4 (1.06)	41.4 (1.06)	41.4 (1.06)	41.4 (1.06)
Height (cm) - mean (SD)	179.3 (6.4)	179.0 (6.5)	178.6 (6.5)	166.2 (5.9)	165.9 (5.8)	165.6 (5.9)
BMI (kg/m2) - mean (SD)	25.4 (2.9)	25.8 (3.3)	26.1 (3.6)	24.2 (3.5)	24.3 (3.8)	24.5 (4.2)
Physical activity (%)[a]						
Low	15	22	26	15	19	22
Intermediate	48	54	56	69	70	70
High	37	23	19	15	11	8
Smoking cigarettes (%)						
Yes	28	44	53	30	39	49
Alcohol habits (%)[b]						
None	16	18	19	27	31	35
Moderate: Up to 3 times per week	81	79	78	72	68	63
Frequently: 4 or more times per week	3	3	3	1	1	1
Education (%)						
Primary/lower secondary school	14	18	22	15	19	23
Upper secondary school	67	66	65	70	68	66
College/ University/ PhD	17	13	11	13	10	8

Abbreviations: bpm = beats per minutes, SD = standard deviation, BMI = body mass index.
[a] Levels of physical activity: Self-reported bodily movement and physical exertion in leisure time previous year. Low: Reading, watching TV, or other sedentary activity; Intermediate: Walking, cycling, or other forms of exercise at least 4 h per week; High: Participation in recreational sports, heavy gardening *etc.* or participation in hard training or sports competitions regularly, several times a week.
[b] Alcohol has 68 % missing (this question was only included in the two last versions of the questionnaire.)

participants sustained a hip fracture. Among women, 3350 hip fractures occurred during 4,741,232 person years of follow-up. We found an inverse association between resting heart rate and risk of hip fracture across all three categories of resting heart rate, with the highest hazard ratios in participants with resting heart rate 80–100 beats per minute compared with the lowest resting heart rate (30–69 bpm) (Table 2). Examination of hazard ratio with heart rate as a continuous variable revealed that each increase of 10 beats per minute was associated with a 15 % higher risk of hip fracture among men and a 6 % higher risk among women (Table 2). The absolute risk difference between those with high contra low resting heart rate was 2.45 per 10,000 in men and 3.50 per 10,000 in women (Table 2).

Figs. 2 and 3 show the association between resting heart rate as a continuous variable and hazard ratio for hip fracture. Among both men and women there was an almost linear association except for a steeper increase at resting heart rate above 70 beats in men.

In a model using categories of physical fitness (combination of resting heart rate and self-reported level of leisure time physical activity), men with a resting heart rate above 80 beats per minute and low levels of self-reported physical activity had a hazard ratio of 1.82 (95 % CI 1.49–2.22) for hip fractures, compared to men with a resting heart rate below 70 beats per minute and high levels of self-reported physical activity. The same measure of association for women was 1.62 (95 % CI 1.28–2.06).

There was no interaction between resting heart rate and self-reported physical activity on the risk of hip fracture among either men ($p = 0.12$) or women ($p = 0.82$). Figs. 4 and 5 show the estimated hazard ratios for hip fracture at combined levels of heart rate and self-reported physical activity. Among both men and women, low levels of self-reported physical activity were associated with a higher fracture risk at any level of resting heart rate. The hip fracture risk was higher with increasing resting heart rate, regardless of the level of self-reported physical activity.

The Spearman rank-order correlation coefficient (Rho), between categories of self-reported physical activity and categories of resting heart rate, was −0.21 for men ($p < 0.001$) and −0.11 for women ($p < 0.001$).

Analyses where participants with cardiovascular disease and diabetes were included did not change the estimates or significance of the results (data not shown). Neither did exclusion of participants with a resting heart rate below 40 beats per minute.

4. Discussion

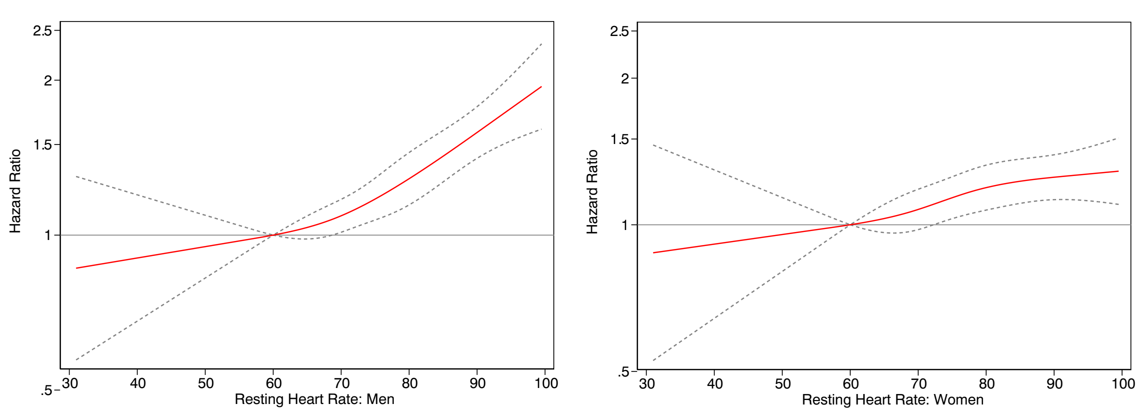
In this large prospective cohort study followed for over three decades, we found that for both men and women aged 40 to 45 years, a lower resting heart rate was associated with lower long-term risk of hip fracture. In addition, higher levels of self-reported physical activity in leisure time during middle-age were associated with a lower long-term risk of hip fractures. To the best of our knowledge, this is the largest study conducted on the associations between resting heart rate, self-reported physical activity level, and long-term hip fracture risk in both sexes. The associations were not attributable to possible confounders, such as age, BMI or smoking. The highest risk of hip fracture was found in men and women with a high resting heart rate, who also reported low levels physical activity in of their leisure time.

Resting heart rate is an indicator of physical fitness. Physical fitness is a protective factor against declining bone mineral density and plays a preventative role in hip fracture risk management [33,34]. However, the link between resting heart rate and hip fracture is likely to be more complex, with several mechanisms involved. Undiagnosed comorbidities or comorbidities not defined as exclusion criteria, as well as poor health could explain why some people exercise less than others. The prevalence of comorbidities among studied populations, as well as different models used in the statistical analyses, may influence the results and at least partly explain diverging results between our study and other previous similar studies [22–24,26]. Another possible explanation for the observed association between an elevated resting heart rate and higher hip fracture risk is that an elevated resting heart rate could represent an ageing process [35]. In that respect, it should be emphasized that our study population consisted of presumably heathy 40–45 years old individuals at the baseline examination. An elevated resting heart rate may also be a sign of declining baroreflex function, and a shift from parasympathetic to sympathetic regulation of the cardiovascular system [36–39]. In addition, elevated resting heart rate might signal autonomic dysfunction, which again could play a role in the pathogenesis of osteoporosis [37,40,41]. Autonomic dysfunction is also associated with an increased risk of falling, which could counteract the benefit of physical activity [42,43]. Contrary to this theory, a low resting heart rate could be a marker of an inherently healthier parasympathetic nervous system. The parasympathetic nervous system plays an indirect role in bone mass growth through upregulation of osteoclasts apoptosis [44,45]. The parasympathetic nervous system is associated with a greater heart rate variability which appears to play an independent role in hip fracture risk for older women [46]. Alternative mechanisms that might link an elevated resting heart rate to a higher fracture risk is

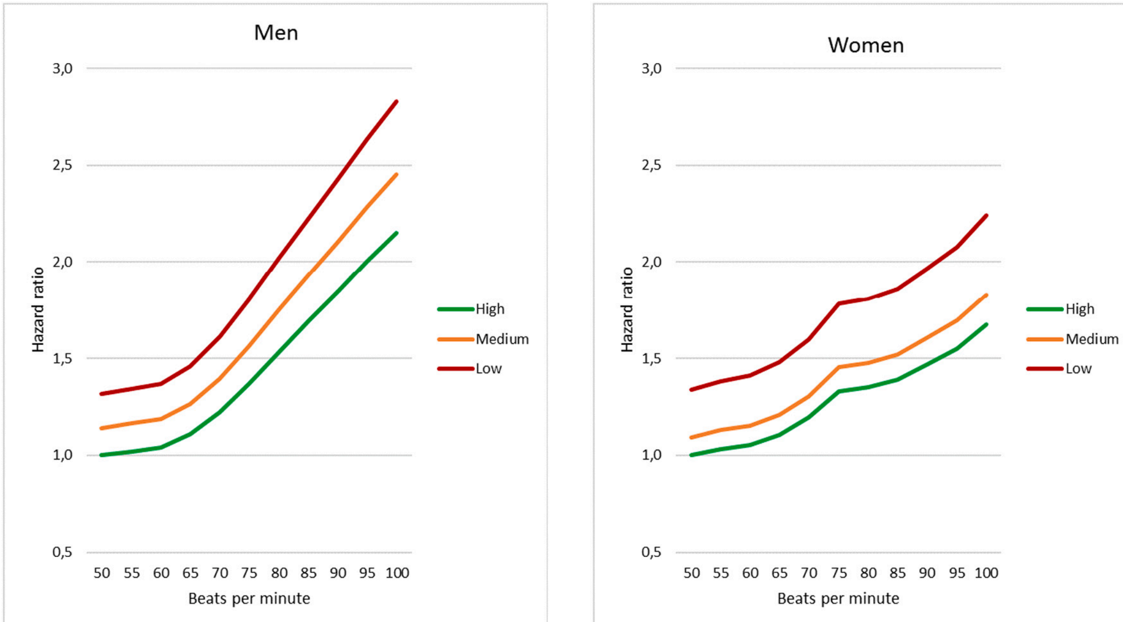
Table 2
Hip Fracture incidence (IR) and hazard ratios (HR) with 95 % confidence intervals (95 % CI) for hip fracture according to resting heart rate.

	N	Hip fractures events	Person years	IR per 10,000	HR (95 % CI)[a]	HR (95 % CI)[b]	HR (95 % CI)[c]
Men							
Resting heart rate (bpm)							
30–69	79,767	794	1,969,329	4,03	1.00 (reference)	1.00 (reference)	1.00 (reference)
70–79	54,841	671	1,356,036	4,95	1.21 (1.09–1.34)	1.23 (1.11–1.37)	1.13 (1.02–1.26)
80–100	41,709	667	1,029,419	6,48	1.57 (1.42–1.74)	1.63 (1.47–1.80)	1.43 (1.29–1.59)
Resting heart rate as a continuous variable per 10 beats	176,317	2132	4,354,784	4,90	1.20 (1.15–1.24)	1.22 (1.17–1.26)	1.16 (1.12–1.21)
Level of physical activity							
High	41,302	458	1,062,731	4,31	1.00 (reference)	1.00 (reference)	1.00 (reference)
Intermediate	74,816	992	1,897,286	5,23	1.23 (1.11–1.38)	1.27 (1.14–1.42)	1.20 (1.07–1.34)
Low	28,680	454	715,579	6,34	1.52 (1.34–1.73)	1.57 (1.38–1.79)	1.40 (1.23–1.60)
Women							
Resting heart rate (bpm)							
30–69	57,794	805	1,417,964	4,68	1.00 (reference)	1.00 (reference)	1.00 (reference)
70–79	68,524	1219	1,701,820	7,16	1.22 (1.12–1.33)	1.23 (1.12–1.34)	1.16 (1.06–1.27)
80–100	64,751	1326	1,621,448	8,18	1.36 (1.24–1.48)	1.37 (1.25–1.49)	1.22 (1.12–1.33)
Resting heart rate as a continuous variable per 10 beats	191,069	3350	4,741,232	7,07	1.12 (1.09–1.16)	1.13 (1.09–1.16)	1.08 (1.04-1-11)
Level of physical activity[d]							
High	17,652	284	450,346	6,31	1.00 (reference)	1.00 (reference)	1.00 (reference)
Intermediate	108,356	2001	2,782,911	7,19	1.13 (1.00–1.28)	1.16 (1.02–1.31)	1.12 (0.99–1.26)
Low	28,975	697	739,722	9,24	1.47 (1.28–1.69)	1.52 (1.32–1.74)	1.37 (1.20–1.58)

N = number of participants; IR = incidence rate; bpm = beats per minute.
[a] Adjusted for age.
[b] Adjusted for age and BMI.
[c] Adjusted for age, BMI and smoking.
[d] Levels of physical activity: Self-reported bodily movement and physical exertion in leisure time previous year. Low: Reading, watching TV, or other sedentary activity; Intermediate: Walking, cycling, or other forms of exercise at least 4 h per week; High: Participation in recreational sports, heavy gardening *etc.* or participation in hard training or sports competitions regularly, several times a week.



Figs. 2 and 3. Cubic splines with 4 knots, for men (Fig. 2) and women (Fig. 3), with a resting heart rate on the x-axis and hazard ratio for hip fracture on the y-axis. A resting heart rate of 60 beats per minute is used as a reference value. The dotted lines on either side of the solid graph represent the 95 % confidence interval. These graphs give a visual ability to assess the shape of the association between resting heart rate and risk of hip fracture.



Figs. 4 and 5. Predicted hazard ratios for hip fracture in men and women at different levels of resting heart rate and self-reported leisure time physical activity. Reference category is a heart rate of 50 beats per minute and high physical activity. Estimated from Cox proportional regression models entering resting heart rate as restricted cubic splines and self-reported physical activity as a categorical variable.

through the various measures of cellular stress. An increased heart rate has been linked to both increased circulating catecholamines and cortisol, which in turn plays a role in the development of osteoporosis and fractures [47,48].

Our study included two complementary measures of physical fitness with results showing that a higher resting heart rate was related to a higher risk of hip fracture regardless of physical activity level. In addition, self-reported physical activity seemed to be independently associated with fracture risk where lower levels of physical activity was associated with a higher fracture risk at any level of resting heart rate. Our results could also suggest that the two measurements cover different aspects of the beneficial effects of physical fitness on bone health and fracture risk.

Although our results showed that with an increasing resting heart rate the hazard ratio for risk of hip fracture was higher in men than women, the absolute risk difference was higher in women. One can therefore not draw conclusions about sex differences based on hazard ratios alone.

Vigorous physical activity may increase the risk of injuries such as hip fractures. However, we found no evidence for a j-shaped association between activity level or resting heart rate and risk of fracture in our data. We therefore believe that any potential increased risk of activity-related injuries is attenuated by the benefits of physical activity on cardiorespiratory fitness, general health status and enhanced bone density [25,49,50].

4.1. Strengths and limitations

A major strength of our study is the large number of participants and hip fracture events. Furthermore, the main exposure, resting heart rate, was objectively measured using a standardized protocol and provides a reliable estimate of physical fitness. Although both resting heart rate and self-reported physical activity are approximations for physical fitness, the value of each may potentiate the other, providing more in-depth knowledge on fracture risk than they could individually. Additional strengths include the prospective study design, inclusion of both sexes, information on possible confounding factors available for adjustment, long follow-up time (up to 34 years) and an almost complete national registry of hip fractures. A limitation of the NORHip database is the lack of opportunity to distinguish between low and high energy fractures. However, in the elderly, low bone mineral density is similarly associated with both high-trauma and low-trauma fractures [51]. Resting heart rate was measured only at one point in time, at enrolment into the study. This measurement could have been affected by inadequate rest prior to measurement and the "white coat effect" [52,53]. Furthermore, self-reported physical activity is flawed because people tend to over-estimate their leisure-time physical activity when reporting moderate levels of physical activity, which also could explain why self-reported physical activity in leisure time was only weakly associated with resting heart rate, in line with previous studies [20]. Even though our analyses are adjusted for relevant confounding factors, there might still be unmeasured comorbidities or factors that represent residual confounding.

5. Conclusion

Low resting heart rate in middle age as a surrogate of physical fitness was associated with a lower long-term risk of hip fractures in both men and women. The combination of low resting heart rate and a high level of self-reported physical activity in leisure time seemed to have the best protective effect and gave the lowest long-term risk of hip fracture. Our study suggests that physical fitness among middle-aged individuals might be important for the risk of subsequent hip fractures at a more advanced age.

CRediT authorship contribution statement

Ida Kalstad Landgraff: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Visualization. **Haakon E. Meyer:** Conceptualization, Methodology, Formal analysis, Data curation, Resources, Visualization, Writing – review & editing, Supervision. **Anette Hylen Ranhoff:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Kristin Holvik:** Conceptualization, Methodology, Formal analysis, Resources, Writing – review & editing. **Ove Talsnes:** Conceptualization, Writing – review & editing. **Marius Myrstad:** Conceptualization, Methodology, Formal analysis, Visualization, Writing – review & editing, Supervision.

Declaration of competing interest

None.

Data availability

The authors do not have permission to share data.

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Ethics declaration

The study and data linkages have been approved by the Regional Committee for Medical and Health Research Ethics (REK Sør-Øst A, ref. 15538), Statistics Norway, the Norwegian Directorate of Health and the Norwegian Institute of Public Health. The data were handled in accordance with the General Data Protection Regulation, and a Data Protection Impact Assessment has been conducted.

Ethics approval

Use of the Norwegian data was approved by the Regional Committee for Medical and Health Research Ethics in Norway and by the government agencies responsible for the registries.

Consent to participate

No consent for publication required.

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