

# Directed acyclic graphs helped to identify confounding in the association of disability and electrocardiographic findings: results from the KORA-Age study

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Accepted 12 August 2013; Published online 1 November 2013

## Abstract

**Objectives:** To examine the association between electrocardiographic (ECG) findings and disability status in older adults.

**Study Design and Setting:** KORA-Age, a population-based cross-sectional study of the MONICA/KORA project, a randomized sample from Southern Germany of people aged 65 years or older.

**Results:** A total of 534 (51.5%) of 1,037 participants were characterized as disabled. Disabled participants were on average 4.5 years older than those who were not disabled. Crude associations of left-axis deviation, ventricular conduction defects, atrial fibrillation, and QT prolongation with disability status were significant ( $P < 0.05$ ). In models controlled for age and sex, these effects remained constant except for QT prolongation. In the models adjusted for the minimal sufficient adjustment set (consisting of the variables sex, physical activity, age, obesity, diabetes, education, heart diseases, income, lung diseases, and stroke) identified by a directed acyclic graph (DAG), no significant association could be shown.

**Conclusion:** Associations between specific ECG findings and disability were found in unadjusted analysis and logistic models adjusted for age and sex. However, when adjusting for other possible confounders identified by the DAG, all these associations were no longer significant. It is important to adequately identify confounding in such settings. © 2014 Elsevier Inc. All rights reserved.

**Keywords:** Electrocardiography; ECG abnormalities; Disability evaluation; Aged; Directed acyclic graph (DAG); Cross-sectional study

**Funding:** The KORA research platform (Cooperative Research in the Region of Augsburg) was initiated and financed by the Helmholtz Zentrum München—German Research Center for Environmental Health, which is funded by the German Federal Ministry of Education and Research and by the State of Bavaria. The KORA-Age project was financed by the German Federal Ministry of Education and Research (BMBF FKZ 01ET0713) as part of the “Health in Old Age” program. The study on disability was funded by the German Research Foundation (DFG, FKZ GR 3608/1-1).

**Conflict of interest:** No conflict of interest has been declared by the authors.

**Author contributions:** N.R., R.S., E.G., S.P., S.K., E.M., and M.M. developed the study concept and design. N.R., R.S., E.G., S.P., and M.M. were involved in the analysis and interpretation of the data. N.R., and R.S. drafted the manuscript. Critical revision of the manuscript was done by E.G., S.P., M.M., A.P., and B.L.

**Sponsor's role:** None.

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## 1. Introduction

In industrialized countries, the number of individuals aged 60 years and over is growing faster than any other age group. The World Health Organization (WHO) predicts a total of about 1.2 billion people who exceed the age of 60 years in 2025 [1]. It is still unclear whether the increase of life expectancy will raise the amount of life years spent with disabilities and loss of autonomy [2]. A person's independence is determined by his or her disability and functional state. Disability in aged people increases their care needs and health-care utilization. Consequently, this affects families and informal caregivers as well as the entire health-care system [3].

Very often, disability in older people is a consequence of diseases, especially of chronic diseases. Understanding the association of chronic diseases with disability is essential

### What is new?

- Large parts of the predictive value of electrocardiographic (ECG) findings for the presence of disability can be attributed to confounding.
- In attempts to identify a parsimonious model while also adjusting for confounding, standard variable selection methods are prone to bias. A possible solution is the application of directed acyclic graphs that are able to identify a minimum set of confounding variables for the association of ECG findings on the presence of disability.
- Literature research and expert knowledge should be used to identify associations between possible covariates rather than methods based on statistical algorithms alone.

for potential strategies to prevent loss of functioning and mortality. Several studies have shown that cardiovascular diseases (CVDs) are among the leading chronic conditions that are associated with functional limitations and disability in the aged [3–7]. Kattainen et al. [8] showed that 33% of disability in men and 24% in women was attributable to CVD.

There is increasing evidence that even subclinical CVD such as internal carotid wall thickness, carotid stenosis, or a major electrocardiographic (ECG) abnormality operationalized by ultrasonogram and ECG may substantially compromise functioning [9]. However, the causal pathways among subclinical ECG signs, CVD, and disability are not completely clear. It has been suggested that the association between subclinical signs and disability is still present when controlling for clinical manifestations of the disease [9], but which specific signs are indicative for disability remains debatable.

To gain further insight into the causal pathways leading from CVD to disability, ECG can be used to show the current state of the heart [10]. Therefore, the ECG is not only a diagnostic tool for CVD in cardiology but might also be an indicator for subjects who appear healthy [11]. Identifying causal mechanisms might lead to particular interventions or new theories, and ECG findings might be helpful for the clinician to identify high-risk patients.

Furthermore, it is unclear which part of the effect of ECG signs on disability might be induced by confounding. In general, a covariate is considered a confounder if it is associated with, but not affected by, the exposure and is a direct cause of the outcome. Traditional methods to reduce confounding bias include simple adjustment of potential confounding variables in a multivariate regression. However, this simple approach may create additional bias, for example, collider bias [12], instead of reducing it. One

method to decide if inclusion of a covariate is more likely to induce than reduce bias is the graphical representation of the causal effects that are potentially important for the exposure–outcome relationship. One recently developed method for this is based on directed acyclic graphs (DAGs). By this, parsimonious sets of covariates—the minimally sufficient adjustment sets—can be identified. Adjusting regression models for these sets allows estimation of the association of ECG with disability in a less-biased way [13].

The objective of this study was to analyze how different types of ECG findings are associated with disability status. Specifically, we wanted to apply DAGs to identify a minimally sufficient adjustment set. We hypothesized an independent association between ECG findings and disability status after adjusting for this set of confounders.

## 2. Methods

### 2.1. Study design and participants

The KORA-Age project was carried out within the framework of KORA (Cooperative Health Research in the Region of Augsburg). KORA consists of four surveys, S1–S4, which were based on representative samples of the population of the city of Augsburg and two surrounding counties [14]. The KORA-Age cohort included all participants of the MONICA/KORA Survey S1–S4 aged 65 years or older at the end of 2008, that is, year of birth before 1943 [15].

### 2.2. Data collection procedures

After a mailed health survey, all participants were asked to attend a 30-minute telephone interview. Interviews were performed by trained and experienced interviewers of the study center in Augsburg. If the participant was unable to follow a telephone interview because of either his or her mental or physical condition, a proxy interview with a family member, friend, or a caregiver was carried out. A random sample of participants stratified by age and gender was invited to the KORA study center for medical examinations. Home visits were carried out for people who could not come to the study center because of major individual health problems. The interviews and examinations took place between September 2008 and November 2009. All participants gave informed consent; informed consent was obtained from the patient's caregiver in cases when the participant was unable to make an informed decision. Approval from the local ethics committee was obtained.

### 2.3. Measures

#### 2.3.1. Disability

Disability status was measured by the Health Assessment Questionnaire—Disability Index (HAQ-DI). The HAQ-DI includes 20 items in eight categories: activities, reach, grip, eating, dressing, hygiene, walking, and arising

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