Relationships between aerobic capacity, work ability, sick leave and age

The role of work ability in the relationship between aerobic capacity and sick leave: a mediation analysis.

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Objectives
To examine: (1) the relationships between aerobic capacity, work ability and sick leave; (2) the potential mediating effect of work ability in the relationship between aerobic capacity and sick leave; and (3) the influence of age on these relationships.
Methods
Information on aerobic capacity (predicted VO$_{2\text{max}}$), age, gender, type of work, cardiovascular risk and body mass index was collected from 580 workers at baseline. Work ability was assessed with the Work Ability Index at first follow-up (mean 3.4±1.3 years after baseline). The second follow-up period was defined as the time between completing the Work Ability Index and the first registered sick leave episode. Mediation analyses were performed using linear and Cox regression models.

Results
A lower aerobic capacity was found to be significantly related to sick leave (HR=0.98; $\tau$=-0.018; 95% CI 0.970 to 0.994). There was a significant positive relationship between aerobic capacity and work ability ($\alpha$=0.165; 95% CI 0.122 to 0.208). Also, lower work ability was significantly related to sick leave after controlling for aerobic capacity (HR=0.97; $\beta$=-0.033; 95% CI 0.949 to 0.987). The mediating effect of work ability in the relationship between aerobic capacity and sick leave was -0.005 (SE=0.002), and mediated 27.8% (95% CI 10.4 to 45.2) of the total effect of aerobic capacity on sick leave. Age did not influence the relationship between aerobic capacity and sick leave.

Conclusions
Fit workers had better work ability, and both fit workers and workers with higher work ability were at lower risk of starting an episode of sick leave.
Background

Aerobic capacity, work ability and sick leave are related to the future health status and functioning of workers [1,2]. Therefore, it is important for preventive occupational health programs to explore and understand the relationships between these parameters and the influence of age on these relationships, particularly as the promotion of health and work ability is increasingly important in a rapidly ageing workforce [3].

Several previous studies have explored the relationship between aerobic capacity and sick leave and showed mixed results [4,5]. Based on a review in 2001, it was concluded that the association between low aerobic capacity and elevated rates of absenteeism was “unknown” [6]. The relationship between aerobic capacity and perceived work ability is also unclear, with inconsistent results between two longitudinal studies [7,8]. Since work ability is closely related to health status, which has been found to be an important predictor of sick leave, it is hypothesised that work ability can also serve as a predictor of sick leave. Reiso et al indicated that work ability was one of the predictors of the duration of prolonged sick leave [9]. In addition, decreased work ability among young workers had a predictive value for long-term sickness absence [10]. A recent Danish cohort study confirmed these findings; reduced work ability was associated with increased risk of onset of long-term sickness absence [11].

Studying aerobic capacity, work ability and sick leave is relevant for preventive occupational health programs, especially with the ageing workforce. Ageing is characterised by increased prevalences of various chronic diseases (eg, cardiovascular diseases, musculoskeletal disorders). Consequently, a decline in work ability with age can be expected [12]. This was confirmed by Tuomi et al [13]. In addition, the physical capacity of workers decreases as a consequence of the age-related decline in aerobic capacity starting at approximately 30 years of age, and changes in musculoskeletal capacity after 45-50 years of age [14-16].

To gain insight into whether fit workers have better work ability and are therefore at lower risk of starting an episode of sick leave, it is necessary to understand these relationships better. Therefore, the aims of the present study were to examine: (1) the relationships between aerobic capacity, work ability and sick leave; (2) the potential mediating effect of work ability in the relationship...
between aerobic capacity and sick leave in workers; and (3) the effect of age on these relationships.

**Participants & Methods**

**Study design and population**

In this prospective dynamic cohort study, information on aerobic capacity, work ability and sick leave was collected during periodic health surveys (PHS) from 2000 until 2008. All workers employed at Siemens Netherlands (n=2500) were offered a voluntary PHS every 4 years. Approximately 54% of the invited workers attended a PHS. Information on aerobic capacity (predicted VO$_{2\text{max}}$), age, gender, type of work, cardiovascular risk and body mass index (BMI) were collected at baseline. Work ability was assessed with the Work Ability Index (WAI) at first follow-up (mean 3.4±1.4 years (min: 1, max: 6) after baseline). The time between work ability determination and sick leave was defined as the number of days between work ability measured at first follow-up and the first registered sick leave episode. Data on aerobic capacity at baseline and work ability at first follow-up had to be available for a worker to be included in the study.

**Measurements**

**Aerobic capacity**

Aerobic capacity in the majority of workers was determined by a maximal exercise test on a cycle ergometer (Corival V2, type 906900; Lode, Groningen, The Netherlands). In workers accustomed to aerobic endurance sports (ie, distance runners), predicted VO$_{2\text{max}}$ was determined by running on a treadmill. Before starting, participants were attached to a heart rate monitor (Cardio-Vac, type 041701 EX; Golmed, Gremlingen, Germany) to measure maximum heart rate during the test. Workers were asked to maintain a pedal frequency of between 60 and 70 revolutions per minute (revs/min) [17,18]. During the test, the workload was increased stepwise each minute until exhaustion, which was reached when the worker was unable to maintain the pedal frequency of at least 60 revs/min for a full minute [19]. Initial workload and rate of increase during the test were specified for each weight category (<60 kg, 60-70 kg, 70-80 kg, 80-95 kg and >95 kg). For example, if a worker weighted 75 kg, then the initial workload was 30 W and was increased by 30 W per minute.
During the test, workers were verbally encouraged by the medical assistant to continue exercising until exhaustion. Maximal oxygen uptake (ml/min/kg), corrected for age (Åstrand’s age correction factor, range 0.65-1.22) and body weight in kilograms (BW), was then predicted from the maximum heart rate (HRmax) and the workload in Watts (WL), obtained in the last full minute of the test using the following equations [22]:

For men: \( VO_{2\text{max}} = ACF*((174.2*WL + 4020)*(103.2 * HRmax – 6299)-1)*(1000 * BW)-1 \)

For women: \( VO_{2\text{max}} = ACF*((163.8*WL + 3780)*(104.4*HRmax – 7514)-1)*(1000*BW)-1 \)

In approximately 10% of workers (ie, workers participating in aerobic endurance sports), \( VO_{2\text{max}} \) was predicted using a maximal treadmill test (Trackmaster, Newton, Kansas, USA) following the Bruce protocol [23]. This protocol consists of 3 min stages (maximum of 10 stages) with workload increments of approximately 2 metabolic equivalents (METs) per stage. This was achieved by increasing both slope (by 2% for each stage) and speed at 3 min intervals. The test starts with a speed of 2.74 km/h and a slope of 10%. Since the slope always increased by 2%, the speed increase varied for each stage. For example, after the first stage (2.74 km/h), the speed increased to 4.0 km/h in the second stage, and so on. Workers were verbally encouraged during the test by the medical assistant to continue running until exhaustion. The test score was the time taken on the test (T) in minutes (expressed in minutes and fractions of a minute, e.g., 6 min 45 sec = 6.75 min). This was converted to a \( VO_{2\text{max}} \) using the following equation for men: \( VO_{2\text{max}} \) (ml*min-1*kg-1) = (2.94*T) + 7.65; and for women: \( VO_{2\text{max}} \) (ml*min-1*kg-1) = (2.94*T) + 3.74 [24].

**Work ability**

Work ability was measured using the WAI questionnaire, which includes a series of questions dealing with seven items [25]: (1) present work ability compared with lifetime best; (2) physical and mental work demands; (3) diagnosed diseases; (4) experienced limitations in work due to disease; (5) occurrence of sick leave in the previous 12 months; (6) work ability prognosis; and (7) mental resources. Work ability was calculated by summing the points for each item. The possible index ranged from 7 to 49 points; a higher score indicated higher work ability.
**Sick leave**

Sick leave registrations were obtained for 2000-2008. In cases of sickness absence and subsequent recovery, workers informed their supervisors personally. Supervisors communicated this to the Siemens occupational health and safety section, where data consisting of the first and last day of a sick leave period were recorded for each worker.

**Age**

Information on age was collected at baseline by asking for date of birth. Age was included as a potential confounder when examining whether age was associated with the relationships between aerobic capacity, work ability and sick leave.

**Potential covariates**

Potential covariates were gender, body weight and height (to calculate BMI), type of work and risk score for cardiovascular disease. Body weight was measured to the nearest 0.1 kg on a digital scale (Siemens body analyser; Siemens, Zoetermeer, the Netherlands) with light clothes and without shoes. Body height was determined to the nearest 0.1 cm without shoes. Body mass index (weight (kg)/square of height (m²)) was calculated using the measured body weight and height. The risk score for cardiovascular disease was calculated using the total Framingham Risk Score (FRS), which is a widely used sensitive screening instrument for predicting the 10-year risk of coronary heart disease, and is applicable to European as well as US populations [26]. Age, total blood cholesterol, high-density lipoprotein (HDL) cholesterol, smoking habits (yes/no, number of cigarettes/cigars/pipe, year of quitting) and the systolic blood pressure of each worker were used to calculate the FRS [27]. Information about total blood cholesterol and HDL-cholesterol were obtained from laboratory tests of venous blood samples taken by the medical assistant during the PHS. Systolic blood pressure was measured by the medical assistant when the worker was in a sitting position, using an automated digital blood pressure monitor (SunTech Tango+; SunTech Medical, Morrisville, North Carolina, USA).

**Statistical analysis**

The single-mediation model is shown in figure 1, where \( \alpha \) represents the...
relationship between aerobic capacity and work ability, β the relationship between work ability and sick leave, and τ the relationship between aerobic capacity and sick leave adjusted for work ability. To test whether work ability mediates the relationship between aerobic capacity and sick leave, the product-of-coefficients test of MacKinnon was applied [28]. This test is based on three regression equations and consists of four steps.

**Figure 1. The single-mediation model**

Panel A: Illustrations of the direct relation where aerobic capacity (predicted VO$_{2\text{max}}$) affects sick leave

Panel B: Illustrations of the single-mediation model where aerobic capacity affects sick leave indirectly through work ability and the influence of age in these relations.

**Equations to estimate mediation effect:**
Panel A: Sick leave = τ * aerobic capacity
Panel B: Sick leave = β * work ability + τ1 * aerobic capacity
Work ability = α * aerobic capacity
First, the relationship between aerobic capacity and sick leave was examined (sick leave=$\tau$\text{*aerobic capacity}) as illustrated in area A of figure 1. This relationship was tested using Cox proportional hazards analysis (time from measured work ability to first sick leave episode) with the $\tau$ coefficient as outcome for both crude and adjusted models. Second, aerobic capacity is most probably significantly related to the potential mediator work ability (work ability=$\alpha$\text{*aerobic capacity}) as illustrated in area B of figure 1. This relationship was tested using linear regression analysis with the $\alpha$ coefficient as outcome for both crude and adjusted models. Third, the potential mediator work ability is most probably significantly related to sick leave when controlling for aerobic capacity (sick leave=$\beta$\text{*work ability + $\tau_1$\text{*aerobic capacity}}), also illustrated in area B of figure 1. This relationship was tested using Cox proportional hazards with the $\beta$ coefficient as outcome for both crude and adjusted models. The time variable used in the Cox proportional regression models was defined as the time (days) between the measured work ability and the first registered sick leave episode. And fourth, the magnitude of the mediated effect, its statistical significance and the proportion mediated was estimated by calculating the product-of-coefficients by multiplying the $\alpha$ and $\beta$ values ($\alpha\beta$ coefficient) and dividing the result by its SE ($SE_{\alpha\beta} = \sqrt{(\alpha^2*SE_{\beta}^2 + \beta^2*SE_{\alpha}^2)}$). The proportion mediated was estimated by dividing the estimated mediated effect ($\alpha\beta$ coefficient) by the total relationship between aerobic capacity and sick leave ($\tau_1+\alpha\beta$), where $\tau_1$ is the direct relationship when the indirect/mediated relationship of work ability is accounted for. All the above relationships were first tested in crude analyses (model 1). To study the effect of age on these relationships, all regression analyses were also performed adjusted for age (model 2). Furthermore, BMI, type of work and risk for cardiovascular disease were included as potential confounders. Confounders remained in the model if a greater than 10% change in the regression coefficient occurred when the potential confounder was included in the regression model. These potential confounding variables, including age (aged $\geq$45 years or aged <45 years) were also checked for effect modification. Potential interaction was tested for by interaction terms using a significance level of $p<0.10$. Potential confounders were included in the regression model that already included age (model 3). Assumptions regarding linear regression analysis and Cox proportional hazard models were tested in prior analysis. A $p$ value $<0.05$ was considered statistically significant. All analyses were performed using SPSS v 15.0.
Results

Participants' characteristics

The 580 workers had a mean age of 39.3 (SD 8.5) years and a healthy BMI of 24.8 (SD 3.1) and were mostly male (88.1%). White collar workers represented 81.6% of the population. According to their FRS (14.2±5.8), the workers had a low 10-year cardiovascular risk of approximately 3%. Overall, 392 workers (67.5%) had a sick leave episode with a mean duration of 11.3 days (SD 36.8; min: 1, max: 416). Regarding aerobic capacity, the mean predicted VO\(_{2\text{max}}\) was 38.6 ml/min/kg (SD 7.5) for men and 29.3 ml/min/kg (SD 6.8) for women, which is fair to good for both gender groups [29]. Workers had an average score of 42.7 (SD 4.4) on the WAI, which corresponds with the category ‘good’ according to the WAI classification [25]. The average WAI score for the 292 fit workers (i.e., VO\(_{2\text{max}}\): men ≥38.1 ml/min/kg, women ≥30.9 ml/min/kg) was 44.1 (SD 4.8), which corresponds with the category ‘excellent’ work ability. The average WAI score for the 288 unfit workers was 41.6 (SD 4.8), which equals ‘good’ work ability. Work ability also varies with age: older workers (i.e. ≥45 years, n=409) scored 43.2±3.9 (category ‘good’) and younger workers (n=171) 41.7±5.3 (category ‘good’).

Relationship between aerobic capacity and sick leave (τ coefficient)

As a first step in the mediation analyses, the relationship between aerobic capacity and sick leave (sick leave = τ*aerobic capacity) was examined (table 1). There was a significant negative relationship between aerobic capacity and sick leave (model 1) (HR=0.98; τ=-0.018; SE=0.006; p=0.004), indicating that a higher aerobic capacity was associated with a lower risk of absence from work due to sick leave. After adding age to the model, this relationship became slightly stronger (model 2) (HR=0.98; τ=-0.023; SE=0.007; p=0.001). There were no confounding or effect modifying variables for this relationship.

Relationship between aerobic capacity and work ability (α coefficient)

As second step in the mediation analyses, the relationship between aerobic capacity and the potential mediator work ability (work ability = α*aerobic capacity) was examined (table 1). There was a significant positive relationship between aerobic capacity and work ability (model 1) (α=0.165; SE=0.022;
This indicated that workers with higher aerobic capacity had a higher work ability score. After adding age to the model, this relationship became somewhat weaker but was still significant (model 2) ($\alpha=0.150$; SE=0.022; $p=0.000$). There were no confounding or effect modifying variables for this relationship.

### Relationship between work ability and sick leave ($\beta$ coefficient)

As the third step in the mediation analyses, the relationship between the potential mediator work ability and sick leave when controlling for aerobic capacity (sick leave=$\beta$*work ability + $\tau_1$*aerobic capacity) was examined (table 2). There was a significant negative relationship between work ability and sick leave after controlling for aerobic capacity (model 1) (HR=0.97; $\beta=-0.033$, SE=0.010, $p=0.001$). These results indicated that those workers with higher aerobic capacity still had a lower risk of sick leave after controlling for work ability. After adding age to the model, this relationship became slightly stronger (model 2) (HR=0.97; $\beta=-0.036$; SE=0.010; $p=0.000$). There were no confounding or effect modifying variables for this relationship.

#### Table 1. Regression analyses to examine: 1) the relationship between aerobic capacity (predicted VO$_{2\text{max}}$) and sick leave, and 2) the relationship between aerobic capacity and work ability

<table>
<thead>
<tr>
<th>Aerobic capacity</th>
<th>Sick leave</th>
<th>Work ability</th>
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<tr>
<td></td>
<td>$\tau$</td>
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<tr>
<td>Model 1</td>
<td>-0.018**</td>
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<tr>
<td>Model 2</td>
<td>-0.023*</td>
<td>0.007</td>
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<tr>
<td>Model 3</td>
<td>-0.018*</td>
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* $p \leq 0.001$; ** $p \leq 0.01$; model 1 crude analysis; model 2 adjusted for age; model 3 adjusted for age and gender; NA=not applicable
Mediating effects (αβ coefficient)

As a last step in the mediation analysis, the mediating effect and its significance were calculated (Table 3). The single-mediator model revealed that the negative association between aerobic capacity and sick leave was partly mediated by an increase in work ability. The crude estimate of the mediated effect of
work ability in the relationship between aerobic capacity and sick leave was -0.005 (SE=0.002). There was no evidence that age had an effect on this relationship (αβ =-0.005; SE=0.002). The variables gender, BMI, type of work and risk for cardiovascular diseases appeared to be neither confounders nor effect modifiers. The effect of work ability on the relationship between aerobic capacity and sick leave mediated 27.8% (95% CI 10.4 to 45.2) of the total effect of aerobic capacity on sick leave.

Discussion
This study showed that workers with higher aerobic capacity had a higher WAI score and thereby a decreased risk of having a sick leave episode. Furthermore, the hypothesis that age would influence the relationship between aerobic capacity, work ability and sick leave was not supported in this study population consisting of mainly male (88.1%), relatively healthy (i.e. good VO$_{2\text{max}}$ and work ability, low cardiovascular disease risk score and healthy BMI) and young (mean age 39.3 years) workers.

The findings of this study indicate that those with a higher aerobic capacity were at lower risk for sick leave. This observed relationship seems physiologically plausible, since high levels of aerobic capacity are associated with a reduced incidence of many chronic diseases and therefore might be associated with reduced sick leave [30]. Furthermore, there is evidence that participation in sports and/or vigorous physical activity is associated with reduced sick leave [31-34]. Regarding the relationship between aerobic capacity and work ability, our findings are supported by a Finnish study among home care workers [7]. However, contrary to our findings, the study of Sorensen et al did not find such a relationship among middle aged male workers [33]. The small study sample (n=104) and the characteristics of their study population (i.e. construction and manufacturing workers) may partly account for the difference between their results and those of the present study. As for the relationship between work ability and sick leave, the present study found that those with higher work ability had a decreased risk of sick leave. This result was confirmed by several other studies [9-11], and might be explained by the fact that two items of the WAI include questions concerning experienced limitations in work due to disease and occurrence of sick leave in the previous 12 months. It seems plausible that previous self-reported sick leave predicts sick leave events during follow-up,
resulting in a significant relationship between work ability and sick leave in the present study [35].

In the present study, age did not influence the relationship between aerobic capacity (predicted VO$_{2\text{max}}$), work ability and sick leave. This might be explained by the relatively young study population; the majority (70.5%) of workers were less than 45 years of age. Since the period after the age of 51 was found to be critical for reduced work ability in a study by Ilmarinen et al [12], it can be argued that our study population was too young for any influence of age on the relationship between aerobic capacity, work ability and sick leave to be detected.

Based on the key finding of our study that 27.8% of the relationship between aerobic capacity and sick leave was mediated by work ability, some recommendations for both practice and future research can be made. Concerning occupational health practice, this study indicates that aerobic capacity should be considered when focusing on the prevention of sick leave. Further, future occupational health tools for preventing sick leave should also aim to improve work ability. Since work ability is influenced by both work demands (mental and physical demands in relation to work) and health status (diagnosed disease, experienced limitations in work due to disease, and the occurrence of sick leave in the previous 12 months), the promotion of work ability should include activities aimed at decreasing work demands and improving health. Concerning work demands, work ability can be promoted by focusing on, for example, time pressure [36], supervisors’ attitudes [13,36], possibilities to control one’s own [13,36,37], and ergonomics [36]. As for health, this study shows that future interventions aimed at improving workers’ aerobic capacity (i.e. by vigorous physical activity) would help promote work ability and therefore reduce the risk of starting a sick leave episode. Regarding future research, although this study showed work ability mediated 27.8% of the relationship between aerobic capacity and sick leave, the influences on the other 72.2% remain unknown. Future research could focus on investigating other factors, for instance energy and overweight, which may lie in the causal pathway between aerobic capacity and sick leave. Lastly, one of the assumptions was that the estimated coefficients and standard errors reflected true causal relations. Since the independent and mediating factors in this study (i.e. VO$_{2\text{max}}$ and work
ability) were not randomly assigned, the causal inference among variables could be questioned due to confounding factors [38,39]. To eliminate possible confounders, more evidence is needed from well conducted randomised controlled trials.

Some points should be considered when interpreting the results of this study. First, most of the study population were fit men with ‘good’ work ability on average. Also, the 580 workers included in this study represent only a small percentage of the workforce who had a PHS (23.2% of 2500). This may be due to strict inclusion criteria (i.e. workers had to participate in at least two PHS, namely at baseline for aerobic testing and at first follow-up for work ability) or to possible selection bias (i.e. healthy workers are more likely to participate in PHS). Results may therefore not be generalised and may be different in other population with a more diverse prevalence of illnesses, work ability and aerobic capacity and different proportions of women. Moreover, in our study we could not adjust for the presence of chronic diseases, although this may be an important determinant of the onset of the first sick leave episode [40]. Another consideration is that the WAI is mostly applied as a simple instrument in PHS and workplace surveys [11,13,41], where the total WAI score is translated into four categories: poor, moderate, good and excellent [25]. For each category a certain follow-up policy is formulated. For example, if a worker scores ‘moderate’, then the health policy should be aimed at promoting work ability to prevent future work disability. However, the aim of this study was to investigate a relationship with work ability. Also, a mediation analysis with Cox regression analysis using a categorical outcome measure makes interpretation and calculation of the mediation effect too difficult. Therefore, we chose to use work ability as a continuous measure. When interpreting the results of this study, it should be taken into account that they are presented according to each one point improvement on the WAI scale instead of WAI category. A last consideration is that the outcome measure sick leave was defined as the time to first sick leave episode. Since a worker can have multiple episodes and duration of sick leave varies between workers, the time to first sick leave episode may not be the most valid measure. Choosing outcome measures in epidemiology has consequences for the applied statistical method and vice versa. In occupational epidemiology, statistical methods used to analyse sick
leave are mostly focused on the frequency of sickness absences using Poisson regression or time to first sick leave episode using Cox regression models [42]. Since using Poisson regression models is only reasonable if all subjects are followed for the same period of time (i.e. a fixed amount of time at risk), which was not possible in our study because there were no data available on the date workers left their jobs or went on extended leave, using Cox regression analysis appeared to be the most appropriate available method for analysing sick leave.

To our knowledge, findings on the mediating effect of work ability in the relationship between aerobic capacity and sick leave have not been previously published. In addition, this study used data from a dynamic prospective cohort to analyse the relationship between aerobic capacity, work ability and sick leave, making it possible to investigate whether aerobic capacity predicts work ability and whether work ability predicts sick leave, and the mediating effect of work ability in the relationship between aerobic capacity and sick leave. Furthermore, the use of survival analysis as part of the procedure to estimate the mediating effect is not a standard approach. Consequently, no studies have been previously published using survival analysis in mediation analyses. However, Tein and MacKinnon demonstrated that survival analysis can be applied appropriately to test mediation effects [43]. Taking all this into account, the results of this study are innovative and provide valuable information for occupational health epidemiology as well as for practical use in occupational health settings.

**Conclusion**

This study showed that fit workers had significant better work ability, and that workers with higher work ability were at lower risk of starting an episode of sick leave. Also, work ability mediated 27.8% of the relationship between aerobic capacity and sick leave.
Reference List


