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Citation

Mänttari, S. K., Oksa, J. A. H., Virkkala, J., & Pietilä, J. A. K. (2019). Activity Level and Body Mass Index as Predictors of Physical Workload During Working Career. *Safety and Health at Work*.
<https://doi.org/10.1016/j.shaw.2019.09.002>

Year

2019

Version

Publisher's PDF (version of record)

Link to publication

[TUTCRIS Portal \(http://www.tut.fi/tutcris\)](http://www.tut.fi/tutcris)

Published in

Safety and Health at Work

DOI

[10.1016/j.shaw.2019.09.002](https://doi.org/10.1016/j.shaw.2019.09.002)

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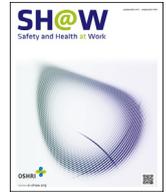
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Safety and Health at Work

journal homepage: www.e-shaw.org

Short Communication

Activity Level and Body Mass Index as Predictors of Physical Workload During Working Career

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ARTICLE INFO

Article history:

Received 15 June 2018

Received in revised form

27 June 2019

Accepted 4 September 2019

Available online xxx

Keywords:

Aging worker

Big data

Functional capacity

Physical activity

Work ability

ABSTRACT

The increasing prevalence of inactivity and obesity, along with aging, has implications on work capacity of labor force. This study reports the relationships between activity level and BMI by age with objectively measured physical workload. Data were examined from a sample of 19 481 Finnish employees using an estimate of minute-to-minute oxygen consumption based on R-R interval recordings. The mean estimated %VO₂max during the working day was 12.1 (±3.6) and 15.1 (±4.5)% for men and women, respectively. Based on a linear model, the mean %VO₂max increased by 1.5%-unit per 10-year increase in age, by 2.1%-unit per 5 kg/m² increase in BMI, and decreased by 1.6%-unit if improving physical activity class by two ($p < 0.001$ for all). Overweight and obesity, together with inactivity, notably increases workload throughout the career, even though at young adulthood, the daily workload is almost the same for each person regardless of the BMI, activity level, or gender. This study highlights the importance of regular physical activity and normal weight in protecting the worker from excessive physical (cardiovascular) workload during the whole working career.

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1. Introduction

The trend of aging as well as decline of the working-age population due to demographic, economic, and social changes is visible in many developed countries. Occupational demands, however, have not decreased even though aging is associated with a progressive decrement in various components of physical work capacity.

The energy required varies between different occupations being around twice the basal metabolic rate in light physical work and even nine times the basal metabolic rate in physically demanding work. The International Labor Organization has suggested 33% of maximal oxygen uptake (VO₂max) as the highest acceptable average load during an 8-h working day [1]. The World Health Organization recommends that the peak load should not exceed the level of 80% of the maximal capacity [2].

Aging has an impact on the physical work capacity diminishing it by 0.1-1% per year. On the average, a 65-year-old person has about

50% of the physical capacity left compared with a 25-year-old person. Changes in physical functional capacity are, thus, not rectilinear, unlike age. Changes start at different times and proceed in different manner between genders. On the average, the age-related decline in physical performance starts at the age of 30 years and decreases about 5-15% per ten years [3-6]. The World Health Organization has set the start of physical capacity decline at 45 years of age [2].

The changes in physical work capacity are not entirely related to aging because different factors, such as lifestyle, can accelerate or slow down such changes. According to Pronk et al [7], lifestyle-related health risk factors, such as physical inactivity and obesity, significantly impact employee work performance. In combination with aging, the increasing prevalence of inactivity and obesity, thus, contributes to decreasing work capacity of labor force. The purpose of this cross-sectional study is to investigate the relationships between activity level and BMI by age with objectively measured physical workload to emphasize and promote the importance of these modifiable factors in maintaining physical work capacity.

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2. Materials and methods

This study used data from Finnish employees who participated in the preventive occupational health care activities provided by their employers and who, as a part of a health care program, performed continuous beat-to-beat RR interval recordings (Bodyguard, Firstbeat Technologies Ltd., Finland) during their normal everyday life. The R-R interval data were analyzed using Firstbeat Analysis Server software (Firstbeat Technologies Ltd, Finland) as previously described in more detail in the study by Mutikainen et al [8]. The study protocol was approved by the ethics committee of Tampere University Hospital (Reference No R13160).

The inclusion criteria for this study data were that the participant was 18–65 years old with a BMI of 18.5–40 kg/m². The workdays had to be between 4 and 12 hours, and during the work, not more than 15% of R-R intervals in the recording could be erroneous.

Applying the inclusion criteria, a cross-sectional data sample of 19481 Finnish employees (8690 men and 10791 women; mean \pm SD age of 44.5 \pm 9.8 years, BMI of 25.9 \pm 4.0 and activity class [AC, a value describing a person's self-reported physical activity/fitness level of which 0–3, 4–6 and 7–10 represent inactive, moderately active and active participants, respectively] of 4.9 \pm 1.8) was examined. In total, 43444 working days were examined with respect to the participants' background information data. The cardiovascular strain during work was quantified by estimating 1-minute oxygen consumption based on the beat-to-beat R-R interval recordings [9] and related to the maximum oxygen consumption (VO₂max), thus obtaining relative oxygen consumption (% VO₂max) during the workdays.

2.1. Statistical analysis

The relationship between %VO₂max and the participants' background characteristics were studied using a linear model. In the simple model, the average %VO₂max was used as a continuous dependent variable and the independent variables included age, BMI, physical activity level, the gender, the estimated average of oxygen consumption during work, the duration, and start time of the workday. To study the effect of BMI and physical activity by age, a linear model with the interaction terms between the age and the rest of the independent variables was included. In the models, the

gender was used as a categorical variable, whereas the rest of the variables were used as continuous variables.

Additional analyses were conducted for participants whose % VO₂max during work exceeded the recommended limit for the average or the peak strain. VO₂max and average oxygen consumption during the workday were compared with the rest of the sample by gender using Mann-Whitney U-test. Statistical analyses were conducted with MATLAB (R2015b). The significance level of 0.05 was used in all statistical analyses.

3. Results

There were 16264 participants with two and 3217 participants with three or more workdays measured. The average \pm SD VO₂max for men was 39.7 \pm 6.5 mL/kg/min and for women, 29.4 \pm 7.0 mL/kg/min. The average oxygen consumption estimate of two working days was 4.7 \pm 1.3 and 4.2 \pm 1.0 mL/kg/min for men and women, respectively. The intensity of aerobic activity was, thus, 12.1 \pm 3.6 and 15.1 \pm 4.5 %VO₂max for men and women, respectively, corresponding to 1.3 \pm 0.4 and 1.2 \pm 0.3 MET (metabolic equivalent).

Across the ages of 18 to 65, the mean %VO₂max increased by 1.5%-unit per 10-year increase in age, by 2.1%-unit per 5 kg/m² increase in BMI, decreased by 1.6%-unit if improving physical activity class by two, and was 4.6%-unit lower for men than for women ($p < 0.001$ for all). Neither the duration nor the start time of the workday affected the cardiovascular strain.

Based on the linear model, at age 18 years, the %VO₂max used at work was approximately the same among the same gender regardless of BMI or activity level (Fig. 1, Table 1). Between genders, there was a 1.6%-unit difference in %VO₂max at age 18 years. The %VO₂max used increased with advancing age, increasing BMI, and decreasing physical activity level, the incline being steeper for women. At age 65 years, the difference between weight categories and activity levels was the most substantial (7.0%-unit between normal weight and obese and 7.8%-unit between inactive and very active participants). Similar cardiovascular workload required up to 17.5%-unit higher %VO₂max used among older, compared with younger employees.

The recommended exposure limit of 33% of VO₂max was exceeded by 70 participants, i.e., 0.4% of the sample (1 male, 69 female). The male participant was 60-year old with a BMI of 23.4 kg/m², activity level of 4 (i.e. moderately active), and VO₂max of

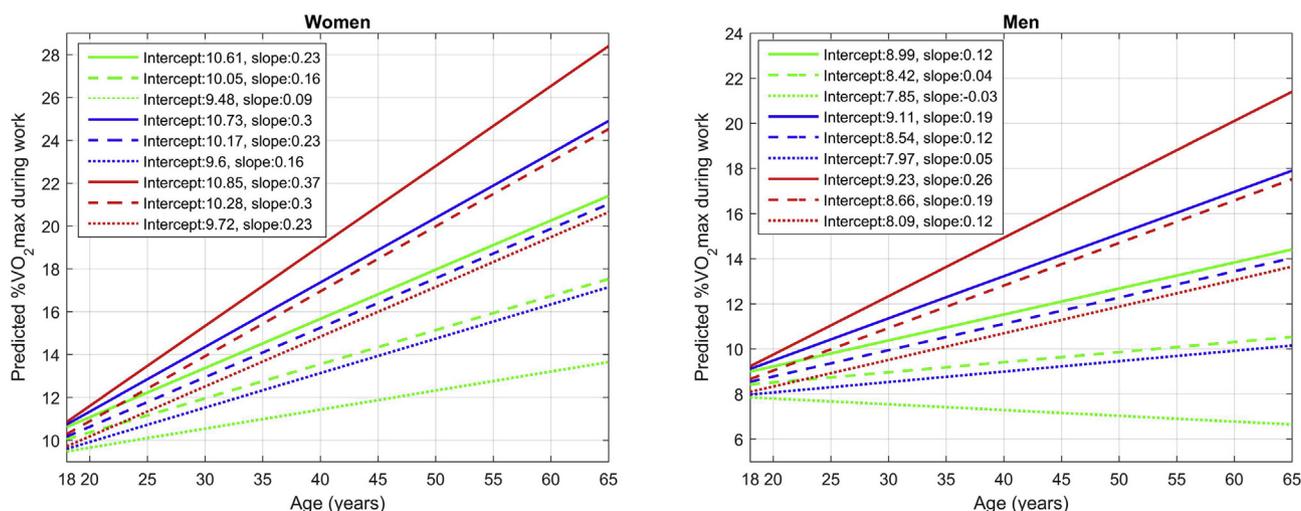


Fig. 1. The predicted average physical strain during work for women and men. The green, blue, and red lines represent normal weight, overweight, and obese participants, respectively, and the solid, dashed, and dotted lines represent inactive, moderately active, and active participants, respectively.

Table 1

Results of the linear models estimating the average cardiovascular strain during work based on participant's background characteristics, workday duration, and start time of the workday

Parameter	Simple linear model			Linear model with interaction terms of age		
	Estimate	Standard error	P-value	Estimate	Standard error	P-value
Intercept	8.0361	0.0727	<0.001	7.8418	0.1499	<0.001
Age (0 = 18 years)	0.1520	0.0013	<0.001	0.1550	0.0053	<0.001
BMI (kg/m ²), (0 = 18.5 kg/m ²)	0.42191	0.0031	<0.001	0.0239	0.0078	<0.001
Activity class (0-10)	-0.8022	0.0067	<0.001	-0.1894	0.01574	<0.001
Gender (1 = Male, 0 = Female)	-4.6327	0.0242	<0.001	-1.6253	0.0584	<0.001
VO ₂ (0 = 3.5 mL/kg/min)	2.7184	0.0105	<0.001	1.9917	0.0206	<0.001
Workday duration	0.0054	0.0101	0.60	-0.0613	0.0241	0.011
Workday start time	0.0045	0.0033	0.17	0.0010	0.0081	0.91
Age: BMI	NA	NA	NA	0.0144	0.0003	<0.001
Age: Activity class	NA	NA	NA	-0.0235	0.0006	<0.001
Age: Gender	NA	NA	NA	-0.1143	0.0021	<0.001
Age: VO ₂	NA	NA	NA	0.0318	0.0008	<0.001
Age: Workday duration	NA	NA	NA	0.0027	0.0008	0.001
Age: Workday start time	NA	NA	NA	0.0002	0.0003	0.52
Adjusted R-squared	86.6%			90.5%		

34.5 mL/kg/min. For female participants, the average \pm SD age was 56.4 ± 4.4 years, BMI 35.0 ± 3.2 kg/m², AC 1.7 ± 1.2 , and VO₂max 11.7 ± 3.2 mL/kg/min. The exposure limit of 33%, if only participants with an average of 8-hour workday were included, was exceeded by 31 participants (31 women; average age 56.4 ± 4.4 years, BMI 35.0 ± 3.2 kg/m², AC 1.7 ± 1.2 , VO₂max 11.9 ± 2.1). In both cases, the average VO₂max of women was significantly lower ($p < 0.001$) and the average VO₂ during workday was significantly higher ($p > 0.01$) than for the other females in the sample. For the male participant, the average %VO₂max did not differ but the average VO₂ was significantly higher ($p = 0.04$) compared with the other male participants.

Of the sample, 652 participants (3.3%) were exposed to a peak load of over 80% of VO₂max for at least one minute at a time. Two groups were identified from this sample (Fig. 2); mainly women having quite low fitness level (VO₂max \pm SD 14.2 ± 2.9 and

29.2 ± 1.8 mL/kg/min for women and men, respectively), and participants doing momentarily heavy work bouts demanding high energy metabolism besides having a good fitness level (VO₂max \pm SD 32.5 ± 6.2 and 42.5 ± 5.8 mL/kg/min, respectively).

4. Discussion

The results of this cross-sectional study indicate that both, body mass index and activity level of a worker, are statistically significantly related to the physical workload. At the beginning of the working career, neither BMI nor activity level affects the individual workload. However, in addition to age-associated functional decline, BMI and activity level, together and separately, influence the workload during the work career, and the effect is more pronounced in women. One plausible explanation for this gender-dependent difference is the percentage body fat/muscle mass–BMI relationship, i.e., the relative proportions of muscle mass and fat mass are different for men and women. This leads to profound effects on physical capacities irrespective of fitness level and, thus, women have lower overall work capacity and get physically more exposed than men in similar tasks [10].

Although the participants nonselectively represented a wide range of nonmanual and manual labor employees, the average estimated proportion of maximal aerobic capacity used during the working day is a typical energy metabolism for an office worker [11]. The recommended exposure limit of 33% of VO₂max was, however, exceeded by 0.4% of the sample. The average VO₂max of these participants was, nevertheless, lower than the average of the whole sample indicating that the work per se was not demanding high energy metabolism but the aerobic strain was, rather, due to poor physical fitness. Because the type of work in the present study sample was reasonably low-intensive, the significance of the impact of BMI and activity level on work strain is even further emphasized.

Previously in a systematic review by van den Berg et al [12], it was shown that the factors associated with a decreased work ability (measured with Work Ability Index) were lack of leisure-time vigorous physical activity, poor musculoskeletal capacity, older age, obesity, and high physical and psychosocial demands. The results of the present paper are in accordance with the meta-analysis by indicating that increasing leisure-time physical activity and prevention of overweight are essential determinants in managing the physical workload of aging workers.

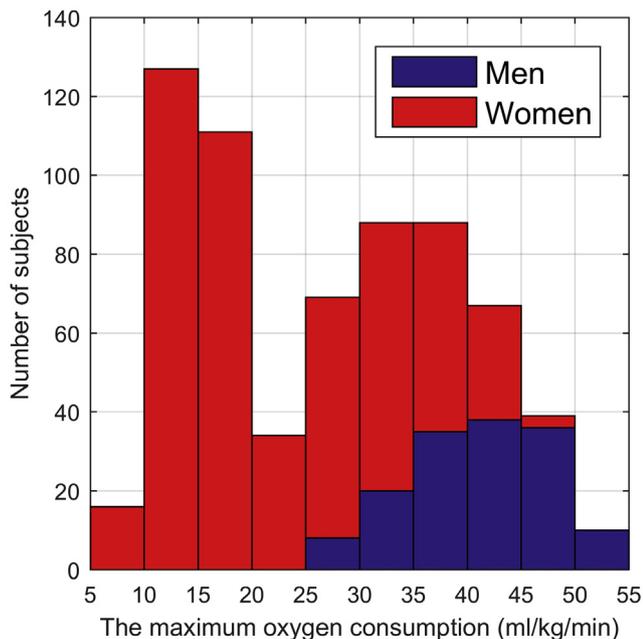


Fig. 2. The distribution of maximal oxygen consumption in participants whose peak oxygen consumption exceeds the limit of 80% of the maximal oxygen consumption during the workday.

The two alterable determinants studied, i.e., BMI and activity level, have quite similar effect sizes because, e.g., inactive normal weight workers have approximately the same workload as moderately active overweight have. Similarly, the work capacity of inactive overweight women is approximately the same as that of moderately active obese women. Previously it has been reported that regular physical activity has many beneficial health effects and may compensate the negative health effects of overweight and obesity [13]. Therefore, even more attention should be given to increasing leisure-time physical activity, especially in health promotion programs and preventive interventions at work.

This study has many strengths such as a very large sample size including a wide range of different labor employees, a reasonably accurate measure of job strain using ambulatory R-R interval-based method and strict inclusion criteria for the data. Nonetheless, some limitations do exist. The information on self-reported job titles would have been good addition for the analysis to more accurately define the nature of the work.

Typically, papers evaluating the effect of aging on physical work capacity refer to health issues, work-related illness, and injuries [14]. Not that often is the isolated influence of age-related decrease in functional work capacity, nor factors affecting it, addressed. The results of the present study stress the importance of preventive, adjustable means, such as regular physical activity and normal weight, in maintaining lifelong physical work capacity.

Conflicts of interest

All authors have no conflicts of interest to declare.

Acknowledgments

This project was funded by Finnish Funding Agency for Technology and Innovation (under Health Data Mining project), grant 40116/14 and the Strategic Research Council at the Academy of Finland, decision No. 303430.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.shaw.2019.09.002>.

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