Original Article

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Effects of Lifestyle on Muscle Strength in a Healthy Danish Population

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Background: Lifestyle is expected to influence muscle strength. This study aimed at assessing a possible relationship between smoking, alcohol intake and physical activity, and muscle strength in a healthy Danish population aged 20-79 years. Population study based on data collected from The Copenhagen City Heart Study (CCHS) and measurements of Isokinetic muscle strength from a sub-study of randomly selected healthy participants from CCHS.
Methods: 126 women and 63 men were studied. All participants completed a questionnaire regarding their lifestyle, including physical activity, alcohol intake and smoking habits. Isokinetic muscle strength was measured over the upper extremities (UE), trunk, and lower extremities (LE). Multivariate analyses including all of the variables were carried out.
Results: The level of daily physical activity during leisure was positively correlated to muscle strength in the lower extremities ($p = 0.03$) for women, and lower extremities ($p = 0.03$) and trunk ($p = 0.007$) for men. Alcohol Intake was in general not correlated to muscle strength. No clear effect of smoking was seen on muscle strength.
Conclusion: Our results show that physical activity during leisure is associated with a positive effect on muscle strength in both sexes. When keeping alcohol intake within the recommended limits, alcohol does not seem to affect muscle strength negatively. No effect of smoking on muscle strength was found in our group of healthy subjects. The findings are of importance when considering recommendation on life style when wishing to keeping fit with age to be able to carry out daily activities.

Key Words: Muscle strength, Aging, Activity of daily living, Lifestyle

INTRODUCTION

Muscle strength declines with age [1-11]. An earlier study showed that this decline starts from the second and fourth decade of life in men and from the fourth decade in women [2]. This will over time affect the ability to perform activities of daily living and have an implication on mortality [12-17]. In accordance with this, the risk of becoming disabled increases with lower muscle strength in an aging population [18-21]. Muscle strength can therefore be considered a marker of physical ability in old age. With a growing

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population of subjects above the age of 60, this group is expected to increase to 22% of the total population by 2050, compared to 10% in 2000, to more than 2 billion by the year of 2050 [22]. This asks for a strategy for maintaining the aging population as independent and mobile as possible by understanding which factors may be modifiable in maintaining a sufficient muscle strength through old age.

Sarcopenia, the age-related loss of skeletal muscle mass and strength [23], has shown to be influenced by several lifestyle habits including reduced physical activity [24-26], alcohol consumption [27,28], and smoking of tobacco [29,30]. The negative effect of alcohol consumption is though contradicted by Steffl et al. [31].

Based on the hypotheses that alcohol intake, smoking of tobacco, and physical activity will affect muscle strength, we aimed at testing these hypotheses by relating alcohol intake per week, smoking of tobacco as grams per day, and physical activity during work and leisure to muscle strength in a healthy Danish population aged 20-79 years.

MATERIALS AND METHODS

1. Participants

The present study was part of the Copenhagen City Heart Study (CCHS) [32], which aims at increasing our knowledge on prevention of firstly ischaemic heart disease and stroke, and secondly other defined diseases. Our sub-study focused on a randomly selected healthy sub-group [3]. 296 women and 128 men fulfilling being healthy from clinical and self-assessment, and command Danish language, were stratified into decades between 20 and 79 years of age in the recruitment process. Out of these, 126 women and 63 men responded and were included in the study [3]. Due to missing information, 5 women and 10 men were not included in the statistical analyses. The non-responder group did not diverge significantly from the included responders regarding age, height and weight [3]. The study was approved by Denmark's Capital Region's Ethics Committee (No .H-KF 01-144/01 31104) and Danish Data Protection Agency (J.nr. 2007-58-0015), and was carried out according to the Helsinki Declaration.

Table 1. Smoking categories

Category	Description
Never smoker	Has never smoked
Former smoker	Not smoker, but has previously smoked
Smoker 1	Smoking 0-4 grams of tobacco per day
Smoker 2	Smoking 5-14 grams of tobacco per day
Smoker 3	Smoking at least 15 grams of tobacco per day

2. Experimental design

Information concerning the participants' smoking and alcohol habits, as well as their level of physical activity, was extracted from the CCHS questionnaire [32].

Smoking habits were classified according to Table 1. Alcohol was measured in units/week, where one unit is 12 g alcohol. Level of physical activity during work and leisure was measured on a 4 point scale from 1 (inactive) – 4 (high physical activity) [3].

Height in cm and weight in kg were both measured at the health-check visit at the CCHS [22].

Isokinetic muscle strength was measured for upper extremities (UE) (wrist, elbow and shoulder), trunk, and lower extremities (LE) (ankle, knee and hip), as described in detail by Danneskiold-Samsøe et al. [12].

We defined 'modified age' as 'age since threshold where muscle strength starts to decline' and estimated the parameter for each combination of sex and muscle group (UE, trunk and LE). The estimated threshold values from this study were 26 years of age for all combinations of sex and muscle group except Trunk for males, which was 51 years of age [2].

3. Statistics

The muscle strengths were modelled separately for each combination of sex and muscle group, with muscle group being upper extremities, trunk, and lower extremities. For a fixed sex and muscle group, muscle strengths were assumed to depend on the following explanatory variables: Weight, height, modified age, physical activity, weekly amount of alcohol consumed, and smoking. Weight, height and modified age were considered confounding variables, while physical activity, weekly amount of alcohol consumed, and smoking were considered the *variables of interest*. All interactions between confounding variables as well as squared effects were included in the statistical modelling.

As the strength of different muscles are assumed to have strong within-person dependence, the muscle strengths for every fixed combination of sex and muscle group were modelled with a multivariate normal model, where muscle strength was regressed multivariately on the explanatory variables, i.e.

$$\begin{pmatrix} X_{i,1} \\ \vdots \\ X_{i,k} \end{pmatrix} = \alpha + \sum_{j=1}^{q} \beta_j x_{j,i} + \epsilon_i, i = 1, \ldots, n \qquad (A)$$

where n is the number of participating subjects ($n = 121$ for women and $n = 53$ for men, respectively), and k is the number of observations per subject in the relevant muscle group ($k = 24$ for the UE, $k = 6$ for trunk and $k = 30$ for the LE). In (A), the variables $X_{i,1}, \cdots, X_{i,k}$ contain the observations in the relevant muscle group for subject i, while $x_{1,i}, \cdots, x_{q,i}$ contains the values of the explanatory variables. With physical activity and smoking being modelled as factors with 4 and 5 levels, respectively, $q = 22$ for the saturated version of the model. α represents a $n \times 1$ parameter vector of constant terms, while the pairwise independent ε_i denotes the residual term for subject i. ε_i is assumed to follow a multivariate normal distribution, $\varepsilon_i \text{-} N(0, \Lambda)$, where the matrix of covariances Λ of dimension $k \times k$ is allowed to vary freely, thus allowing for arbitrary within-person dependence between muscle strengths. Model reductions in model (A) were performed through likelihood ratio tests, evaluated with the Wilks test statistic. After model reduction from saturated model to final model, a forward selection procedure was performed, including all variables of interest.

Furthermore, for the combinations of sex and muscle group where statistical significances of explanatory variables of interest in the models of form (A) were uncovered, marginal analyses of the individual muscle strength measurements were performed through the n univariate models

$$X_{i,j} = \gamma + \sum_{r=1}^{k} \eta_r x_{r,i} + \epsilon_{ij,} i = 1, \ldots, n \qquad (B)$$

restricted to the final models obtained from model (A). In model (B), $X_{i,j}$ describes the j'th muscle strength measurement for subject i, $i = 1, \cdots n$, $j = 1, \cdots, k$, while γ and the η's are univariate parameters, and the pairwise independent noise terms are assumed normally distributed. Model reductions in model (B) were performed as likelihood ratio tests, evaluated with the F distribution.

RESULTS

1. Explanatory variables

Table 2 gives the p-values for the explanatory variables after reduction to final models. In no instances did the forward selection procedure alter the final models.

2. Physical activity

Self-reported levels of physical activity during work and leisure are given in Table 3.

We found no statistically significant correlation between

Table 2. p-values for statistically significant explanatory variables of interest

Muscle group	Physical activity work	Physical activity leisure	Smoking	Alcohol
Men				
UE	NS	NS	0.002**†	NS
trunk	NS	0.007**	NS	NS
LE	NS	NS	NS	NS
Women				
UE	NS	NS	NS	0.03*
trunk	NS	NS	NS	NS
LE	NS	<0.05*	NS	NS

*p < 0.05; **p < 0.01.
†Smoking as a factor was statistically insignificant; the p-value is for the category 'smoker 1' vs. remaining categories (See Table 5).

Table 3. Self-reported levels of physical activity

Sex/activity level	Physical activity work	Physical activity leisure
Men		
Level 1	16	5
Level 2	8	23
Level 3	9	22
Level 4	5	3
Not reported	15	0
Women		
Level 1	26	8
Level 2	83	61
Level 3	27	50
Level 4	0	2
Not reported	5	0

physical activity at work and muscle strength for any combination of muscle group and sex.

The level of physical activity during leisure was found to correlate with muscle strength for women in the LE and for men in the trunk, Table 2.

Only five participants, three men and two women, reported activity level 4 during leisure. Estimates for this category could therefore not be assigned any validity.

Comparisons were then only carried out between activity level 1 and either level 2 or level 3. Looking at isokinetic muscle strength of LE in women at activity levels 2 and 3, an average increase in muscle strength relative to activity level 1 was found to be 9% (± 7%) at activity level 2 , and 15% (± 8%) at activity level 3. To disregard random fluctuations in muscle strength measurements, where physical activity during leisure did not impact, we estimated the effect for only those muscle strength measurements where physical activity during leisure was statistically significant, in model (B). 7 out of 30 muscle strength measurements had statistically significant impact of physical activity during leisure. For these 7 measurements, we estimated the average increase in muscle strength relative to activity level 1 to be 13% (± 8%) at activity level 2, and 25% (± 9%) at activity level 3. Looking at isokinetic trunk strength in men where strength measurements were recorded during 3 forward movements and 3 backwards movements and model (B) was applied, all 3 forward movement measurements indicated a statistically significant increase in muscle strength for both activity level 2 and 3 relative to activity level 1, while none of the backward movement measurements did. The average increases in muscle strength for the forward movements for activity level 2 and 3 relative to activity level 1 were 15% (± 7%) and 11% (± 7%), respectively.

Table 4. Self-reported weekly intake of alcohol in units (1 unit = 12 g alcohol). Age is given in years

Age	Women		Men	
	Mean	SD	Mean	SD
20-29	1,9	1,7	7,9	4,6
30-39	5,0	3,7	8,0	6,2
40-49	7,8	8,0	15,4	12,4
50-59	4,4	4,8	10,0	6,2
60-69	4,1	7,2	12,8	11,5
70-79	5,3	6,6	12,0	12,5

3. Alcohol

Self-reported weekly intake of alcohol is given in Table 4.

When alcohol consumption was reported by this population, recommended upper weekly limits for intake were 14 units for women and 21 units for men, with one unit being 12 g alcohol [33]. For both participating men and women, the mean values for intake were below these upper limits. For women, muscle strength of the UE showed a positive significant correlation to amount of weekly intake of alcohol ($p = 0.03$), Table 2. The corresponding correlations for the UE for men, and for Trunk and the LE for both men and women, were all non-significant. Attempting to estimate an overall effect of a moderate alcohol intake on LE muscle strength in women, the increase in muscle strength was found to be 0.28%, and showing great uncertainty.

4. Smoking

The self-reported smoking habits for female and male participants are given in Table 5.

When analysing the effect of smoking habits on muscle strength in the multivariate model (A) for men, we found a significant effect of the category ‘smoker 1’ (See Table 1) on muscle strength measurements in the UE. Smoking habits as a 5-level factor was not statistically significant, nor was the category ‘smoker 1’ in any of the other combinations of sex and muscle group. As with alcohol, the marginal analysis with model (B) only revealed two muscle strength measurements with significant effect of the ‘smoker 1’ category, indicating that the effect could not be allocated to specific

Table 5. Self-reported smoking habits according to the set categories, Table 1.

Sex	Never Smoker (%)	Former Smoker (%)	Smoker 1 (%)	Smoker 2 (%)	Smoker 3 (%)
Men	26	13	4	9	47
Women	46	27	5	14	8

muscles within the UE, as these may be ruled out as mass significances. Of the 24 regression coefficients in model (A), 22 were positive.

DISCUSSION

The aim of the study was to test if alcohol intake, tobacco smoking, and physical activity would affect muscle strength in a healthy adult Danish population. To take an age effect into account, a uniform representation of age ensured that a changing effect with age would be seen.

1. Physical activity

Physical activity during work was not seen to have an effect on muscle strength, but physical activity during leisure correlated positively to muscle strength in the LE muscle group in women and the UE and trunk muscle groups in men. According to our results, being physically active during leisure time has some beneficial effect on muscle strength in movements important for coping with daily living.

The level of physical activity was based on a self-assessment questionnaire. We therefore had to consider the possibility, that part of the participants could have under- or overestimated their degree of daily physical activity. With an underestimation, the significance of the effect seen is still valid, as would be the case with an overestimation. In the latter case, the effect might be even higher, if a higher degree of physical activity was taken. The message that physical activity during leisure time does improve isokinetic muscle strength for certain important muscle groups implies the great importance of staying active with age to counteract the age-related changes in muscle strength [2]. The effect is further put into perspective by the fact that the study population contains healthy individuals only. Individuals with a low level of physical activity which has resulted in, or contributed to lifestyle diseases, would have been excluded in this study.

2. Alcohol

Alcohol consumption to excess is known to affect muscle strength and function [24-26]. Alcohol intake following heavy exercise with assumed minor damage to muscle fibres does also slow down muscle recovery [27-40]. In the present study, the participants all had an alcohol intake below the recommended level. Although self-reported, we did not find alcohol to be negatively correlated to the muscle strength in any of the muscle groups, and there is no indication that the given intake should not be close to the truth. The causality in the fact that alcohol was found to have a minor positive effect on muscle strength in the UE group in women is not interpretable as a direct effect and may be ascribed to confounding. One possible confounding effect could be that a (moderate) higher intake of alcohol is correlated to a specific active lifestyle among the otherwise healthy population, giving the subjects slightly higher muscle strength in the UE.

The recommended upper limit of alcohol consumption in Denmark has following our study changed to 7 units per week for women and 14 for men. When comparing the mean values of the respondents' alcohol consumption with today's recommendations, only the age group 40-49 is exceeding the upper limits, further confirming that the studied group were below the alcohol intake level which would affect health significantly. Since we were not looking at top athletes, nor individuals so severely affected from the use of alcohol that they do not qualify for the inclusion criteria for the study population, muscle maintenance in a healthy population must be said to be unaffected of alcohol consumption in the recommended range.

3. Smoking

Smoking has been found to be a risk factor for developing sarcopenia [26], and in middle-aged to older men a lower muscle mass has been found in smokers compared to non-smokers [41]. Decreased hand-grip strength has also been found in smokers compared to non-smokers [42,43], as have higher structural damage to muscle fibres [44,45]. We did not see any clear effect of smoking in this group of healthy individuals despite of the age span. It may be that it is due to the selection of a healthy group assessed on own judgement and clinical examination, thereby taking out any subjects who might have comorbidities in connection with their smoking.

CONCLUSION

Overall, this study on healthy subjects comparing self-reported alcohol intake and smoking habits, as well as physical activity, with isokinetic muscle strength measured over the main joints for movements of the body, does show a positive effect of being physically active during leisure time. Alcohol intake according to recommended levels does not seem to affect muscle strength negatively. No effect of smoking on muscle strength was found in our group of healthy subjects. The findings are of importance when considering recommendation on life style when wishing to keeping fit with age to be able to carry out daily activities.

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