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Relationship between physical fitness and lifestyle behaviour in healthy young men

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Background **There is substantial knowledge about the inverse association of physical fitness and CVD risk factors and CVD mortality. However, physical fitness per se might be influenced by lifestyle conditions such as physical training, smoking and drinking habits.**

Hypothesis **We evaluated the relationship between physical fitness, physical activity, endurance training, smoking and drinking habits and blood pressure, lipids and leukocytes as surrogate cardiovascular risk markers in a large-scale cross-sectional study of healthy young men.**

Study design and methods **A total of 6748 healthy young men were selected during their primary flight medical examination for military flying duties. Physical fitness was assessed by achieved physical working capacity at a heart rate of 170 beats per min (PWC_{170}) during cycle ergometry. Parameters such as physical activity, endurance sports, smoking of cigarettes and drinking of alcoholic beverages were assessed by means of standardized questionnaires. Systolic and diastolic blood pressures were measured manually. Fasting cholesterol and triglycerides as well as white blood counts were obtained.**

Results **Physical activity itself was not related to significant differences in the tested variables, whereas good physical fitness showed a significant association with improved blood pressure and blood lipids ($P<0.001$) with no detectable threshold. This effect was independent of endurance training, smoking and drinking. Whereas drinking was associated with elevated systolic blood pressure, smoking was associated with markedly increased triglycerides as well as with elevated leukocytes.**

Conclusion **Physical fitness is associated with improved blood pressure and blood lipids. This effect is independent of participating mainly in endurance or nonendurance sports, of physical activity per se, and it does not depend on smoking and drinking habits. Smoking itself revealed relevant higher inflammation independent of fitness. *Eur J Cardiovasc Prevention Rehab* 11:192–200 © 2004 The European Society of Cardiology.**

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Keywords: physical fitness, physical working capacity, PWC_{170}, sports activity, endurance training, alcohol, cigarettes, cardiovascular risk factors, adolescence, epidemiology

Introduction

Cardiovascular disease (CVD) is the most frequent cause of death in the western hemisphere. Generally accepted cardiovascular risk factors for both genders are age, hypertension, hyperlipidaemia, smoking and leukocyte count [13,14,27]. Cardiovascular risk factors are associated with atherosclerosis early in life [2]. Therefore, preventive strategies should start early in life. There is substantial knowledge about the inverse association of physical fitness and CVD risk factor status [5,8,19,20,24] and CVD mortality [7,16,18,20]. However, physical fitness per se might be influenced by lifestyle conditions such as physical training, smoking and drinking habits. Investigating a large young and healthy population might have the advantage of findings that could possibly be applied as primary prevention early in life. The purpose

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of the present study was to examine further the relationship between CVD risk factors and physical fitness, physical activity, endurance training, smoking and drinking habits in a large, homogeneous, young population.

Materials and methods

Subjects

Between 1977 and 2002 a total of 7483 young males, predominantly high school students in their final year, were screened for their fitness for military flying duties. Inclusion criteria for this study were absence of any military disabling disease or abnormality, an age between 18 and 21, an achieved heart rate (HR) under workload conditions of at least 170 beats per min [bpm], and absence of alcohol addiction. Of these, 6748 subjects (90%) met the inclusion criteria. Written informed consent was obtained.

Physical fitness

Physical fitness (determined by physical working capacity at a HR of 170 bpm = PWC_{170} [23]) was assessed by standard cycle ergometry in a 45° sitting position and expressed as the achieved performance (watts [W]) per kilogram of body weight [kg] at an actual (not extrapolated) HR of 170 bpm). This measurement shows acceptable correlation to maximal oxygen uptake (VO_2) [1,9,12]. Ergometric power was increased every 3 min by steps of 50 W, starting from 100 W up to the point of physical exhaustion or common termination criteria. Pedalling speed was kept between 50 to 60 revolutions per min [rpm]. Ergometric performance was monitored by continuous ECG, HR and BP recordings and supervised by an experienced physician.

Physical activity and endurance training

All men were interviewed by means of a standardized questionnaire (institutional design by the German Air Force Institute of Aviation Medicine) for quantity of regular sports activity and performed type of sports. Sports activity was expressed as average total training hours per week and average training hours per week per type of sports accomplished during the preceding year. Type of sport was stated by the probands and categorized by the investigators as mainly endurance training (that is, more than 50% of time for training spent in swimming, running, bicycling, inline skating or rowing) and mainly nonendurance training (ball games, body building, athletics except endurance, and other types not categorized as endurance).

Smoking and drinking habits

All men were interviewed for their regular drinking and smoking habits in a standardized questionnaire. Alcohol consumption was expressed as average litres or equivalents of beer consumed per week and categorized as 'nondrinkers' ($0\,l\,wk^{-1}$), 'light drinkers' ($0.01–1.0\,l\,wk^{-1}$), and 'moderate drinkers' ($>1\,l\,wk^{-1}$). Smoking was expressed as average numbers of cigarettes smoked recently and regularly per week and categorized as 'nonsmokers' ($0\,d^{-1}$), 'light smokers' ($1–10\,d^{-1}$), and 'heavy smokers' ($>10\,d^{-1}$). For further compound analysis the study population was divided in four subgroups: abstinent men ('abstainer'), men with regular alcohol consumption ('drinker'), men presently smoking cigarettes regularly ('smoker') and smokers with regular alcohol consumption ('smoking drinker').

Body mass index (BMI), heart rate (HR) and blood pressure (BP)

Body weight and height were measured between 7 a.m. and 8 a.m. before breakfast, after urination, and undressed to calculate BMI by division of weight by square of height [kg/m^2]. Resting BP [mmHg] and HR [bpm] were measured manually by trained personnel after 5 min of rest in supine position, between 7 a.m. and 9 a.m.

Laboratory analyses

Between 7 a.m. and 8 a.m. a blood sample was taken to determine serum cholesterol and triglycerides within 60 min. On the day of blood testing, the individuals had been fasting overnight for at least 8 h. Additionally, a standard blood count was obtained from every participant

Table 1 Characteristics of study population

n	6748
Age [year]	19.4 ± 0.9
Height [cm]	180 ± 6
Weight [kg]	73 ± 8
BMI [$kg{\cdot}m^{-2}$]	22.3 ± 2.1
Physical fitness [PWC_{170} $W{\cdot}kg^{-1}$]	2.69 ± 0.43
Physical activity [Sports $h{\cdot}wk^{-1}$]	6.5 ± 4.2
Mainly endurance sports [*n*]	2451 (36%)
Systolic blood pressure [mmHg]	130 ± 12
Diastolic blood pressure [mmHg]	79 ± 6
Heart rate [bpm]	71 ± 15
Cholesterol [$mg{\cdot}dl^{-1}$]	168 ± 30
Triglycerides [$mg{\cdot}dl^{-1}$]	76 ± 35
Leukocytes [$10^{9}{\cdot}l^{-1}$]	6.1 ± 1.4
Erythrocytes [$10^{12}{\cdot}l^{-1}$]	5.2 ± 0.3
Mean corpuscular volume [fl]	88.5 ± 3.7
Haematocrit [%]	46 ± 3
Regular alcohol consumption [*n*]	2357 (35%)
– Light drinkers [*n*]	1126 (17%)
– Moderate drinkers [*n*]	1231 (18%)
– Average consumption beer equivalents [$l{\cdot}wk^{-1}$]	1.8 ± 2.1
Regular cigarette smoking [*n*]	1574 (23%)
– Light smokers [*n*]	1080 (16%)
– Heavy smokers [*n*]	494 (7%)
– Average cigarette smoking [$n{\cdot}wk^{-1}$]	70 ± 38
Abstainer [*n*]	3588 (53%)
Regular alcohol consumption only [*n*]	1586 (24%)
Regular cigarette smoking only [*n*]	803 (12%)
Regular smoking and alcohol consumption [*n*]	771 (11%)

Table 2 Influence of fitness, activity, smoking and drinking on blood pressure and blood lipids in an univariate linear regression model in 6748 men

Dependent Variables	Systolic BP [mmHg]			Diastolic BP [mmHg]			Cholesterol [mg·dl^{-1}]			Triglycerides [mg·dl^{-1}]		
	r	F	*P*	r	F	*P*	r	F	*P*	r	F	*P*
Independent Variables												
Fitness [PWC_{170} W·kg^{-1}]	0.148	150.4	<0.001	0.198	79.5	<0.001	0.081	44.2	<0.001	0.084	47.8	<0.001
Activity [Sports h·wk^{-1}]	0.016	1.7	0.183	0.001	0.0	0.930	0.012	0.9	0.333	0.014	1.3	0.254
Smoking [n·d^{-1}]	0.085	48.8	<0.001	0.071	34.0	<0.001	0.019	2.3	0.128	0.153	161.7	<0.001
Drinking [l·wk^{-1}]	0.023	3.7	0.054	0.012	0.9	0.324	0.04	11.1	0.001	0.045	13.5	<0.001

Table 3 Influence of fitness, activity, and endurance in an univariate linear regression analysis, stratified for smoking and drinking habits

Dependent Variables	Systolic BP [mmHg]			Diastolic BP [mmHg]			Cholesterol [mg·dl^{-1}]			Triglycerides [mg·dl^{-1}]		
	r	F	*P*	r	F	*P*	r	F	*P*	r	F	*P*
Independent Variables Abstainer (n=3588)												
Fitness [PWC_{170} W·kg^{-1}]	0.13	60.5	<0.001	0.12	57.0	<0.001	0.08	25.3	<0.001	0.09	29.1	<0.001
Activity [Sports h·wk^{-1}]	0	1.1	0.299	0	0	0.924	0	0.1	0.744	0	0	0.858
Endurance sports [y/n]	0.04	5.8	0.015	0	0.3	0.556	0	0.1	0.701	0.05	10.6	0.001
Drinker (n=1586)												
Fitness [PWC_{170} W·kg^{-1}]	0.17	42.0	<0.001	0.05	4.9	0.027	0.06	6.1	0.014	0.04	3.4	0.066
Activity [Sports h·wk^{-1}]	0	0.4	0.531	0	0.1	0.711	0.03	2.1	0.149	0	1.0	0.317
Endurance sports [y/n]	0	1.3	0.254	0	0	0.965	0	1.1	0.287	0	1.6	0.201
Smoker (n=803)												
Fitness [PWC_{170} W·kg^{-1}]	0.17	22.7	<0.001	0.13	14.7	<0.0001	0.10	8.5	0.004	0.14	15.7	<0.001
Activity [Sports h·wk^{-1}]	0	0.1	0.746	0	0.5	0.477	0.05	2.5	0.118	0.05	2.7	0.099
Endurance sports [y/n]	0	0.1	0.726	0	0.5	0.489	0.07	4.0	0.046	0.11	10.4	0.001
Smoking drinker (n=771)												
Fitness [PWC_{170} W·kg^{-1}]	0.20	30.9	<0.001	0.12	11.9	0.001	0.08	4.8	0.030	0.07	3.8	0.050
Activity [Sports h·wk^{-1}]	0	0.8	0.359	0	0.4	0.535	0	0	0.857	0	0.1	0.743
Endurance sports [y/n]	0.04	1.4	0.233	0	0	0.906	0.06	3.1	0.080	0	0.4	0.517

Table 4 Influence of fitness, activity, endurance, smoking and drinking in a multivariate linear regression analysis on blood pressure and blood lipids in 6748 men

Dependent Variables	Systolic BP [mmHg]			Diastolic BP [mmHg]			Cholesterol [mg·dl^{-1}]			Triglycerides [mg·dl^{-1}]		
	Beta	T	*P*	Beta	T	*P*	Beta	T	*P*	Beta	T	*P*
Independent Variables												
Fitness [PWC_{170} W·kg^{-1}]	−0.15	−12.7	<0.001	−0.11	−9.1	<0.001	−0.08	−6.6	<0.001	−0.08	−6.9	<0.001
Activity [Sports h·wk^{-1}]	0.04	2.8	0.004	0.01	0.7	0.481	0.01	0.6	0.576	0.02	1.9	0.062
Endurance sports [y/n]	−0.03	−2.1	0.034	−0.01	−0.7	0.467	−0.03	−1.9	0.047	−0.05	−4.3	<0.001
Drinking [l·wk^{-1}]	0.04	3.0	0.002	0.00	−0.2	0.872	0.04	3.0	0.002	0.02	1.6	0.110
Smoking [n·d^{-1}]	−0.09	−7.4	<0.001	−0.07	−5.8	<0.001	0.01	0.89	0.371	0.15	12.2	<0.001
	r	F	*P*	r	F	*P*	r	F	*P*	r	F	*P*
Total regression model	0.18	44.9	<0.001	0.13	23.4	<0.001	0.09	11.9	<0.001	0.18	46.3	<0.001

for analysis by an electronic blood cell counter (Technicon H) to determine leukocyte levels.

Statistical analyses

Continuous data are presented as mean ± standard deviation, SD (all figures show error bars with 95% confidence intervals) and categorical data are presented as frequencies. Physical fitness and activity were categorized as quintiles for comparison of cardiovascular risk factors (first quintile representing the lowest fitness resp. activity group, fifth quintile the highest). Differences in cardiovascular risk factors were analysed by ANOVA. Significant differences were defined as a $P < 0.05$. Uni- and multivariate linear regression analyses for systolic, diastolic BP, cholesterol and triglycerides (as dependent variables) were performed for PWC_{170}, sports activity, endurance training, smoking and drinking (as independent variables) (Tables 2 and 4). Univariate linear regression was performed for the whole study population as well as for subgroups, which were stratified for smoking and drinking habits, analysing fitness, activity and endurance training (dependent variables) (Table 3). Finally, uni- and multivariate linear regression analyses were performed for leukocytes (dependent variable) and

Table 5 Influence of fitness, activity, and smoking in linear regression analyses on leukocytes in 6748 men

Dependent Variables	Univariate				Multivariate		
	Leukocytes [G·l^{-1}]				Leukocytes [G·l^{-1}]		
	r	T	F	*P*	Beta	T	*P*
Independent Variables							
Fitness [PWC_{170} W·kg^{-1}]	0.03	−2.5	6.3	0.012	−0.03	−2.5	0.013
Activity [Sports h·wk^{-1}]	0.00	−1.1	0.0	0.91	0.02	1.7	0.08
Smoking [n·d^{-1}]	0.18	14.9	221.5	<0.001	0.18	14.9	<0.001
					r	F	*P*
Total Regression Model					0.18	76.7	<0.001

fitness, activity and smoking (independent variables) (Table 5). All calculations were performed using SPSS® for Windows® version 11.0.

Results

Study population

The included subjects represent a very healthy population of adolescent men with high physical activity and good physical fitness. Detailed characteristics of the study population are given in Table 1.

Relationship between endurance training, physical fitness and activity, and blood pressure and lipids

As plotted in Figure 1, left column, physical fitness showed a highly significant association with low systolic and diastolic BP and low cholesterol and triglycerides. There was no detectable threshold. Better physical fitness (fifth quintile) provided more favourable parameters. The lowest quintile of physical fitness prompted the highest systolic and diastolic BP and the highest values for cholesterol and triglycerides. This effect could be observed equally well in participants in both endurance training and nonendurance sports. In contrast, self-reported physical activity as represented by quintiles of hours of training per week did not produce any statistically significant effect on analysed factors in either young men participating mainly in endurance training or those practising mainly nonendurance sports (Figure 1, right column).

In a univariate linear regression model physical activity was not associated with altered blood lipids or blood pressure (Table 2). This association was also investigated by a linear regression analysis stratified for smoking and drinking habits as given in Table 3. Independently from smoking or drinking, physical activity was not associated with altered lipid levels or blood pressure, while physical fitness showed a consistent association. Participating mainly in endurance sports yielded significant results only for levels of triglycerides in all men, abstainers and smokers (not in drinkers and smoking drinkers).

However, the overall effect of fitness was rather small ($r \leq 0.20$). This was also true in a multivariate linear regression analysis shown in Table 4. Physical fitness (PWC_{170}) showed the highest significant influence on all dependent variables (SBP, DBP, cholesterol, triglycerides; all being inversely effected), followed by smoking for SBP (inverse), DBP (inverse), and triglycerides. Physical activity (sports hours per week) did not have significant advantageous effects. For all dependent variables this multivariate linear regression model (inclusion method) was stable enough not to exclude any of the independent variables. Overall the total model revealed significant ($P < 0.001$) but only weak ($r < 0.2$) effects in this large population of young healthy men.

Relationship between smoking and drinking habits with blood pressure, lipids and leukocytes

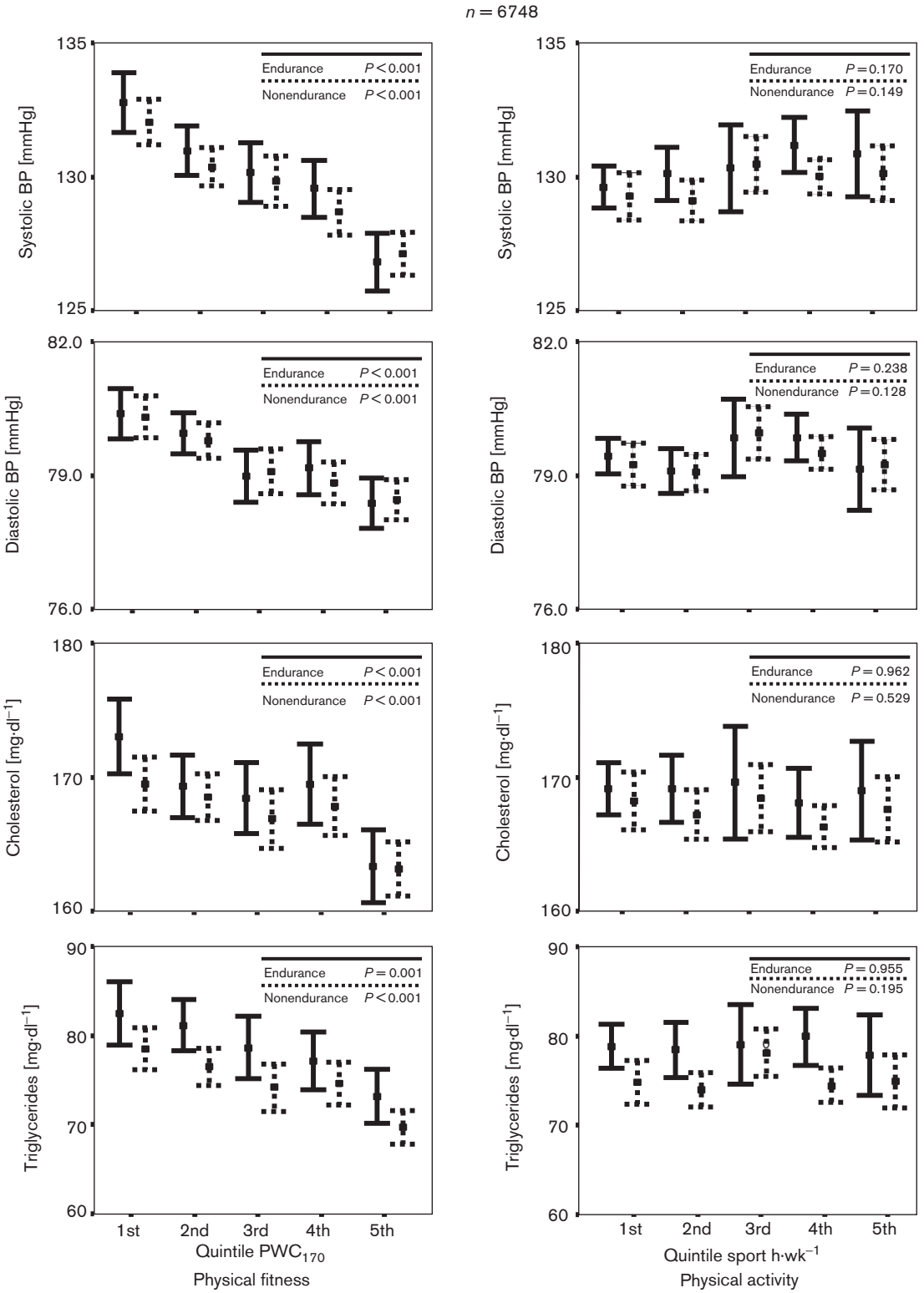
The relationship between smoking and drinking vs. blood pressure, and blood lipids is illustrated in Figure 2. In general, while drinking was associated with elevated systolic BP, regular cigarette smoking was associated with lower systolic and diastolic BP. Total cholesterol was neither correlated with smoking nor drinking habits, while drinking was associated with slightly elevated levels of triglycerides, smoking was associated with markedly elevated triglycerides.

Whereas physical fitness and activity did not show an relevant influence on leukocytes, smoking was associated with elevated leukocytes (Fig. 3). Drinking did not reveal any relevant effect on leukocytes (data not shown). As presented in Table 5, in a uni- and multivariate linear regression on leukocytes (dependent variable) for fitness, activity and smoking (independent variables), activity yielded no statistical influence, while fitness showed a very weak effect on leukocyte counts. Smoking was of high significance and greater effect. This relation is also illustrated in Figure 3.

Discussion

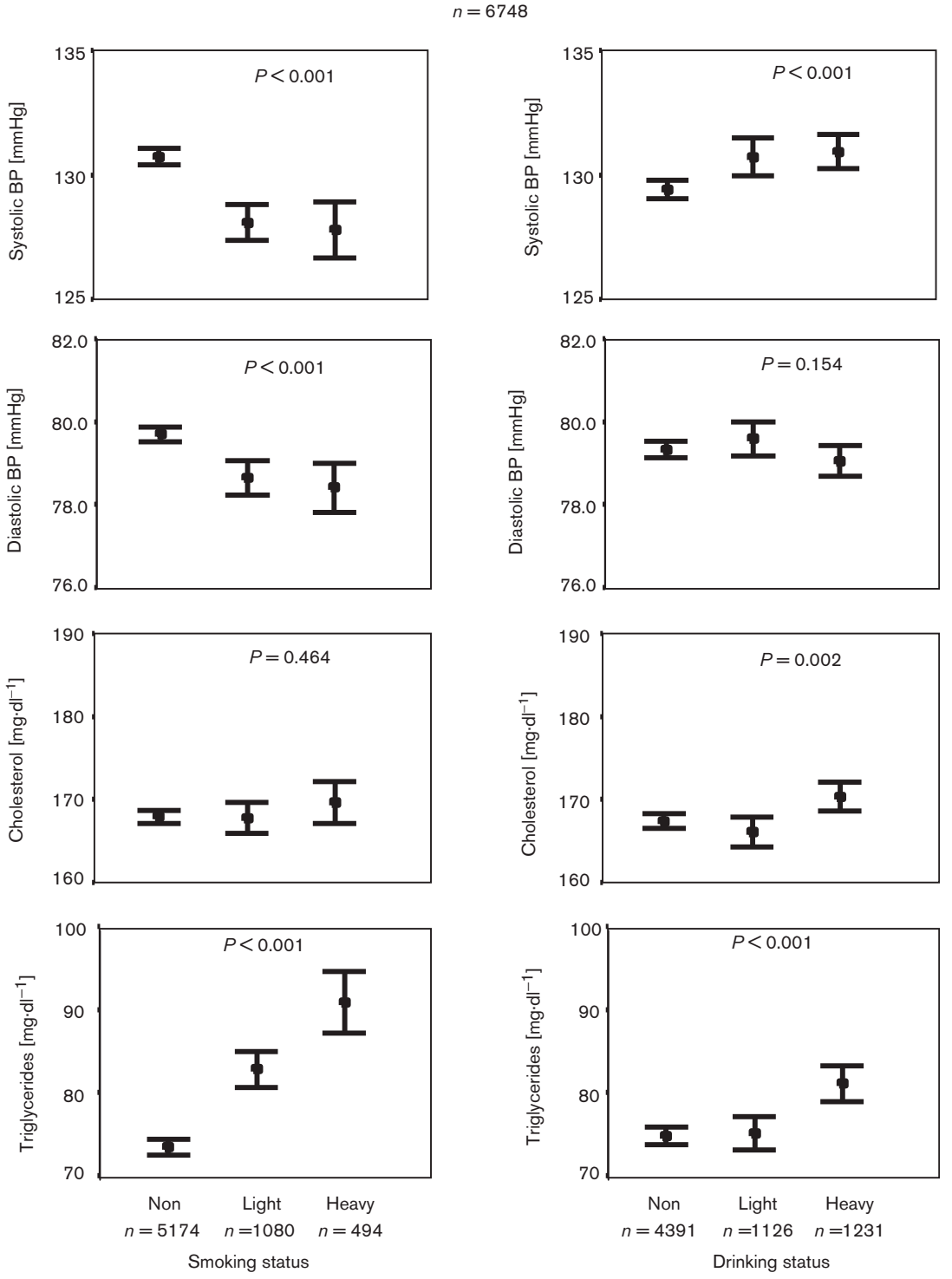
Physical fitness is inversely correlated to cardiovascular risk factors [4,10,25]. However, since physical fitness per se is associated with certain lifestyle conditions, which might strongly influence cardiovascular risk factors themselves, physical fitness might be just an epiphenomenon. Lifestyle conditions that might modulate

Fig. 1



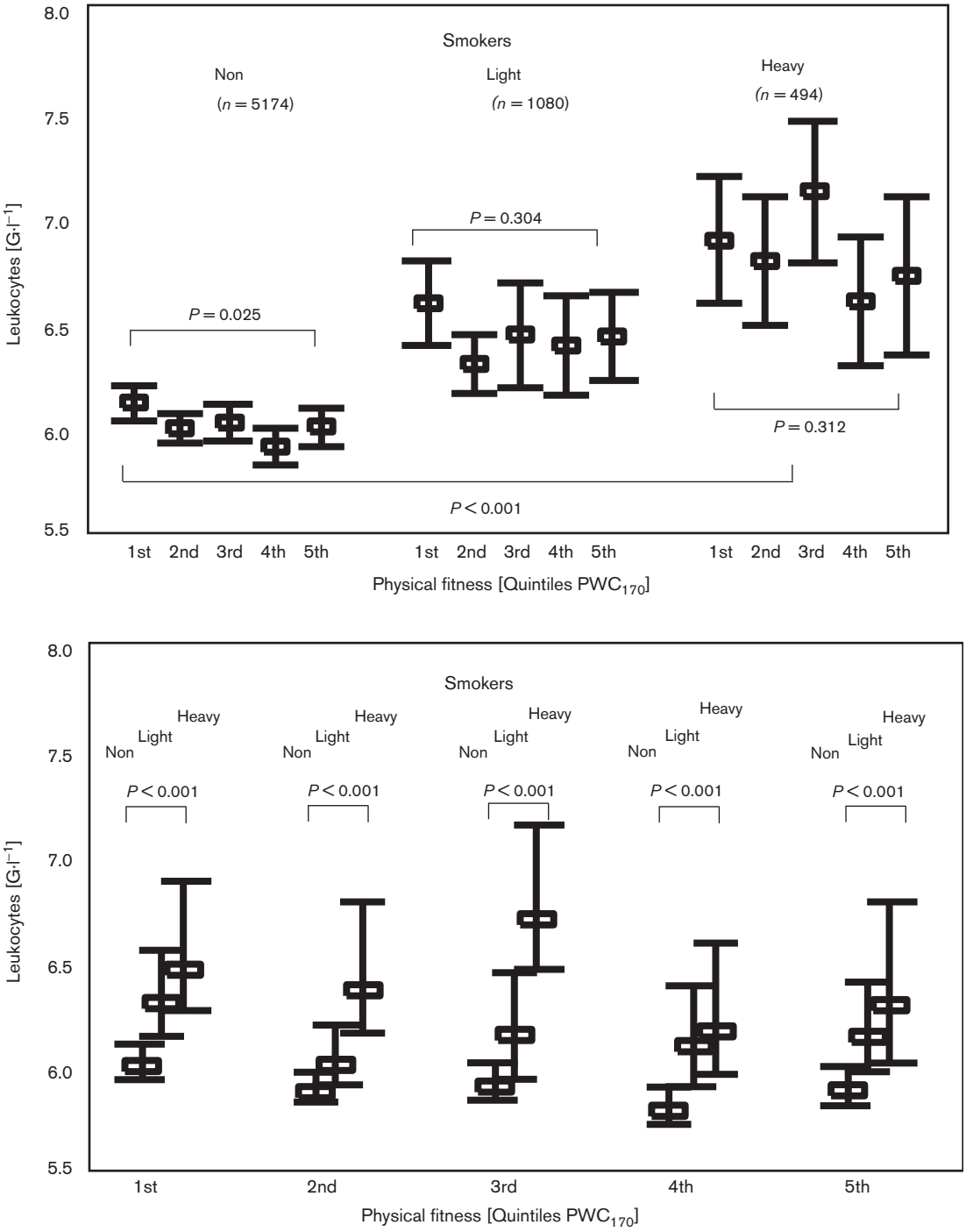
The left panel of the figure shows the relationship between physical fitness (PWC_{170} = physical working capacity at a heart rate of 170 beats per min [W kg^{-1}], categorized as quintiles) and systolic and diastolic blood pressure, cholesterol, and triglycerides separated for groups participating mainly in endurance sports (n = 2451, solid bars) and mainly nonendurance sports (n = 4297, dotted bars). All analysed cardiovascular risk factors were significantly influenced by physical fitness. The right panel shows the relationship between physical activity (sports hours per week, categorized as quintiles) and systolic and diastolic blood pressure, cholesterol and triglycerides. In contrast to fitness, physical activity itself did not influence the analysed cardiovascular risk factors significantly. Shown are error bars with 95% confidence intervals. All P-values were calculated by ANOVA.

Fig. 2



The figure illustrates the relation of smoking and drinking habits to systolic and diastolic blood pressure, cholesterol and triglycerides in a total of 6748 men. Whereas moderate consumption of alcohol ('drinker') elevates the systolic blood pressure significantly, regular cigarette smoking ('smoker') was associated with slightly reduced systolic and diastolic blood pressures. Smoking was also significantly associated with elevated triglycerides. Shown are error bars with 95% confidence intervals. All *P*-values were calculated by ANOVA.

Fig. 3



The figure illustrates the relationship between leukocytes and non-, light and heavy smokers, each grouped into quintiles of PWC_{170} (upper part) and quintiles of PWC_{170} each grouped into non-, light and heavy smokers (lower part). Shown are error bars for each quintile of PWC_{170} with 95% confidence interval of leukocyte counts. First quintile represents lowest fitness, fifth quintile highest fitness portion. All *P*-values were calculated by ANOVA.

There was no relevant difference between quintiles within each smokers' group. However, high significance was found between the three groups of non-, light and heavy smokers, emphasizing the strong effect of smoking on increased systemic inflammation and the lack of impact of fitness in respect to leukocyte counts (upper part).

The same association is given in the lower part, where a highly significant difference between the three smokers' groups of each fitness quintile was found, but no differences between the five fitness quintiles. This represents the strong effect of smoking on increased systemic inflammation which is independent of physical fitness status (lower part).

cardiovascular risk factors are physical activity, type of performed sports, and smoking and drinking habits. Physical activity is known to be a weaker predictor for cardiovascular risk factors in comparison with physical fitness [4,11,24]. However, it is uncertain how endurance training and smoking and drinking habits interact with physical fitness. The purpose of this study was to test whether physical fitness is inversely associated with blood pressure, lipids and leukocytes as surrogate cardiovascular risk markers, independently of physical activity, endurance training, drinking and smoking habits. Secondly, we wanted to evaluate if a fitness threshold exists, that is associated with a benefit for these surrogate markers.

We chose a submaximal test of bicycle ergometry (PWC_{170}) as a surrogate parameter for physical fitness which is widely used and easy to apply as a screening tool for large cohorts. Although we are aware of various other measures to describe 'fitness' differently and in some ways more accurately, this method has been validated and shown acceptable correlation to maximal oxygen uptake (VO_2) and is a practical method, especially for large numbers of subjects of similar age and stature [1,9,12,23]. Important parameters such as blood pressure values can reliably be obtained during cycle ergonometry. A submaximal test, as compared with a maximal one, has the advantage of being independent of the subject's motivation and also his age with respect to heart rate at a given submaximal intensity.

The major new finding of this large study of healthy young men is that physical fitness is highly significantly but only weakly correlated with an improved profile of blood pressure and lipid values, whatever kind of sports are performed, no matter how many hours per week of training and whether a man drinks and/or smokes moderately or not. It was proposed that certain kinds of sports are more favourable than others concerning the cardiovascular risk profile [3]. In this large-scale study, fitness was associated with an improved profile of blood pressure and lipid values in men performing dominantly endurance sports as well as in subjects practising mainly nonendurance sports. Thus, the beneficial effect of fitness seems to be independent of the preponderance of explicit endurance activities. The advantageous effect was also present in physically fit smokers and drinkers of this population. Regarding improvement of these variables, no threshold could be detected in this study. Thus, the risk profile of the tested variables of a man might be as good as his physical fitness. It may be that the effect on blood pressure can be explained by fitness modulating the autonomic system in favouring vagal activity.

It has been proposed that enhancing fitness has an antiinflammatory potential [15]. Smoking is known to increase leukocyte levels and leukocytes can be regarded as a surrogate parameter for systemic inflammation [27]. Inflammation is a known risk factor for cardiovascular disease [17]. In our population physical fitness status did not have an influence on the impact of smoking on increasing leukocyte counts. Independent of fitness a highly significant increase of leukocytes could be seen between groups of non-, light and heavy smokers. Therefore, good fitness might not counteract the deleterious effect of smoking.

A limitation of this study is its cross-sectional character and no definite conclusion can be drawn concerning cardiovascular mortality. However, the study's strength lies in the large number of subjects included and their homogeneity concerning male gender, Caucasian race, adolescent age, social status and personality traits. Greater homogeneity might help to clarify some differences in findings of other studies with less homogeneous populations concerning correlates of physical activity and fitness [6,19]. The young age and the fact that lipids and blood pressure of our probands are rather normal might be the reason for finding only small correlation coefficients between fitness and risk factors (blood pressure and blood lipids) which are commonly known to increase in the elderly (and also for finding no correlation between activity per se and risk factors). The relationship, however, was highly significant for physical fitness but neither significant nor relevant for physical activity in this large sample. How meaningful these differences of correlation coefficients between physical fitness and physical activity clinically are in the long run cannot be foreseen from the cross-sectional findings of these young healthy men.

In summary, this study demonstrates that physical fitness is weakly but significantly associated with improved values for blood pressure and blood lipids and this effect is without an upper or lower threshold and independent of endurance or nonendurance sports, physical activity, as well as drinking and smoking habits. Thus, in advising men for primary prevention of CVD high physical fitness might be a desirable goal independent of the kind of sports effectively practised and independent of moderate drinking and smoking habits. Smoking, however, showed a strong effect on increasing systemic inflammation, which could not be compensated for by fitness. Thus, another important goal even in men with good physical fitness might be to stop smoking.

Future longitudinal studies of large, homogeneous cohorts stratified for lifestyle factors might evaluate the effect on long-term mortality.

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J.R. Ortlepp designed the study, and conducted the statistical data analysis, J. Metrikat coordinated and realized the data collection and participated in statistical analysis, M. Albrecht and P. Maya-Pelzer helped with data collection. All authors helped to write the report. This work is part of the doctoral thesis of J.M.

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