English version of "Kardiorespiratorische Fitness bei Erwachsenen in Deutschland. Ergebnisse der Studie zur Gesundheit Erwachsener in Deutschland (DEGS1)"
Bundesgesundheitsbl 2013 · 56:772–778
DOI 10.1007/s00103-013-1672-y
© Springer-Verlag Berlin Heidelberg 2013

J.D. Finger[1] · S. Krug[1] · A. Gößwald[1] · S. Härtel[2] · K. Bös[2]
[1] Department of Epidemiology and Health Monitoring, Robert Koch Institute, Berlin
[2] Institut für Sport und Sportwissenschaft, Karlsruher Institut für Technologie (KIT), Karlsruhe

Cardiorespiratory fitness among adults in Germany

Results of the German Health Interview and Examination Survey for Adults (DEGS1)

Regular aerobic physical activity that demands at least one fifth of the skeletal muscles such as running, cycling or swimming, improves the "general dynamic aerobic endurance capacity" [1]. Thereby, a large number of physiological adaptations occur in the musculoskeletal and cardiorespiratory systems, moreover, the metabolism improves, which bring about positive effects on health [1, 2, 3]. In an epidemiological research context, the result of regular aerobic physical activity is also referred to as "cardiorespiratory fitness" [4, 5], which can be objectively measured [6]. People with good cardiorespiratory fitness, compared to those with low fitness, are less likely to suffer from chronic conditions and to die from preventable causes of death [3, 4, 7, 8, 9, 10].

In the first wave of the German Health Interview and Examination Survey for Adults (DEGS1), a submaximal cycle ergometer test was used to obtain cross-sectional information on cardiorespiratory fitness among adults aged 18–64.

The aim of this analysis is to examine the state of cardiorespiratory fitness among men and women aged 18–64 according to age groups and socioeconomic status. Furthermore, the aim is to analyse whether test-qualified and test-unqualified participants differ according to selected variables.

Methods

Study design

The German Health Interview and Examination Survey for Adults ("Studie zur Gesundheit Erwachsener in Deutschland", DEGS) is part of the health monitoring system at the Robert Koch Institute (RKI). The concept and design of DEGS are described in detail elsewhere [11, 12, 13, 14, 15]. The first wave (DEGS1) was conducted from 2008–2011 and comprised interviews, examinations and tests [16, 17]. The target population comprises the residents of Germany aged 18–79 years. DEGS1 has a mixed design which both permits cross-sectional and longitudinal analysis. For this purpose, a random sample from local population registries was drawn to complete participants of the German National Health Interview and Examination Survey 1998 (GNHIES98). A total of 8,152 persons participated, including 4,193 first-time participants (response rate 42%) and 3,959 revisiting participants of GNHIES98 (response rate 62%). In all 7,238

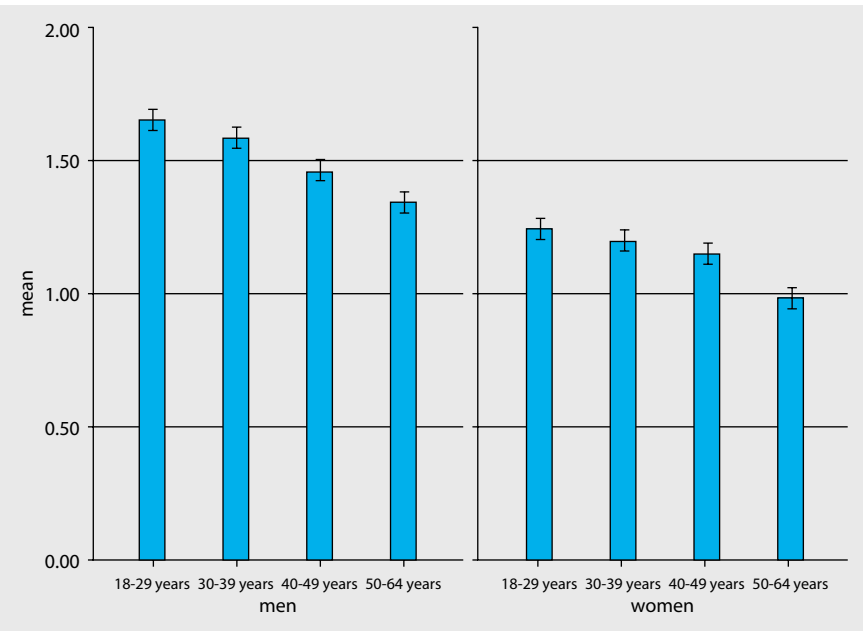

Fig. 1 ▲ Physical work capacity at 75% of maximum heart rate in watts per kg body weight for men and women by age (mean values with 95% confidence intervals, n=2,827)

Tab. 1 Percentages (%) and 95% confidence intervals (***95%CI***) of selected characteristics in 18- to 64-year-old DEGS1 participants (n=5,263) by test qualification status defined on the basis of the modified Physical Activity Readiness questionnaire (***PAR-Q***)

	Test-qualified		Test-unqualified		Total	
Age groups	%	(95%CI)	%	(95%CI)	%	(95%CI)
18–29	30.3	(28.8–31.7)	10.8	(9.1–12.4)	23.4	(22.4–24.4)
30–44	35.1	(33.2–36.9)	22.4	(19.9–24.9)	31.2	(29.8–32.5)
45–64	34.6	(32.7–36.6)	66.8	(64.1–69.5)	45.4	(43.8–47.1)
Sex						
Women	47.5	(45.2–49.7)	53.8	(50.4–57.3)	49.4	(47.6–51.2)
Men	52.5	(50.3–54.8)	46.2	(42.7–49.6)	50.6	(48.8–52.4)
Body Mass Index						
<25 kg/m²	51.8	(49.4–54.2)	32.7	(30.0–35.5)	44.8	(42.9–46.7)
25 to <30 kg/m²	34.7	(32.7–36.9)	33.0	(30.3–35.7)	34.6	(33.0–36.2)
≥30 kg/m²	13.4	(11.8–15.0)	34.3	(31.5–37.1)	20.6	(19.1–22.2)
General state of health						
(Very) Good	89.9	(88.6–91.3)	59.8	(56.9–62.7)	79.5	(78.1–80.9)
Previous medical diagnosis of						
High blood pressure	10.3	(9.1–11.6)	54.1	(50.5–57.6)	25.3	(23.9–26.7)
Coronary heart disease	<1.0		7.7	(6.0–9.3)	3.5	(2.7–4.2)
Asthma	7.0	(5.8–8.2)	11.5	(9.7–13.4)	8.6	(7.7–9.6)
Sports activity						
≥1 h/week	56.9	(54.4–59.4)	42.6	(39.6–45.6)	51.7	(49.8–53.5)
Physical activity						
≥2.5 h/week	23.2	(21.3–25.2)	19.0	(16.8–21.2)	21.8	(20.3–23.2)

persons attended one of the 180 examination centres, and 914 were interviewed only. The net sample (n=7,988) permits representative cross-sectional analyses and time trend analyses for the age range 18–79 years in comparison with GNHIES98 (n=7,124) [12]. The data of the revisiting participants can be used for longitudinal analyses.

The cross-sectional and trend analyses are conducted with a weighting factor which corrects deviations in the sample from the population structure (correct as of 31 Dec 2010) with regard to age, sex, region, nationality, type of municipality and education [12]. A separate weighting factor was prepared for the examination part. Calculation of the weighting factor also considered re-participation probability of GNHIES98 participants based on a logistical regression model. A non-response analyses and a comparison of selected indicators with data from census statistics indicate a high level of representativity of the net sample for the residential population aged 18–19 years of Germany [12]. To take into account the weighting as well as the correlation of the participants within a community, the confidence intervals and p values were determined using STATA SE 12 survey procedures.

All participants were informed about the study objectives, and signed a written informed consent. The study protocol was approved by the ethics committee of Charité—Universitätsmedizin Berlin and the Federal Commissioner for Data Protection and Freedom of Information.

Measurement method

Cardiorespiratory fitness was measured using a standardised, submaximal cycle ergometer test. The methodology is described in detail in another paper in this edition [18]. To be included, participants had to give written informed consent, be aged 18–64 and be test-qualified according to a modified version of the Physical Activity Readiness—Questionnaire (PAR-Q) [19, 20]. Participants underwent an incremental exercise test following the test protocol recommended by the World Health Organisation, beginning at 25 watts (W) and increasing the workload by 25 W every two minutes [21]. The heart rate was recorded continuously throughout the test. The recovery period began at the end of the workload stage in which an individually calculated heart rate of 85% of the age-predicted maximum heart rate was exceeded. Participants also completed a health questionnaire. Body height and weight of the participants were measured without shoes and in light clothing, using standardised methods and calibrated instruments.

Definitions of variables

Cardiorespiratory fitness

Cardiorespiratory fitness was assessed on the basis of heart-rate data using the approach of "Physical Work Capacity" (PWC) [22, 23, 24]. PWC in watts was calculated by linear interpolation at the heart-rate thresholds of 130 and 150 ($PWC_{130,\ 150}$) beats per minute (bpm) [24], and at 75% of the age-predicted maximum heart rate ($PWC_{75\%}$) [25], the calculated PWC values were then divided by the participant's body weight. The method is described in detail in another paper in this edition [18]. Calculating $PWC_{130,\ 150}$ has the advantage that the results can be compared to the existing reference values for Germany for these thresholds [24, 26]. Gore et al. [27] have shown that in population studies, "variable" thresholds such as the $PWC_{75\%}$ produce more plausible results regarding age-group comparisons than "fixed" thresholds ($PWC_{130,\ 150}$); thus $PWC_{75\%}$ is used for the cross-sectional analyses by age and socioeconomic status. The age-predicted maximum heart rate, which was used to calculate $PWC_{75\%}$, was obtained with the formula 208 minus 0.7 times age [28]. In order to carry out an analysis by socioeconomic status, the continuous variable $PWC_{75\%}$ was converted into a binary variable to avoid questionable assumptions of linearity for the relationship between the socioeconomic status and cardiorespiratory fitness, which must be assumed if linear regression analysis is used. The sample was thus divided into two groups, 40 and 60%, by calculating quintiles. The top 40% of the $PWC_{75\%}$ distribution was defined as having a "high" level of cardiorespiratory fitness. The division was carried out separately for men and women. In each case, the upper limits of the

third quintile of $PWC_{75\%}$ were used as the cut-points, which was 1.60 W per kilogramme of body weight for men and 1.23 W per kilogramme for women.

Socioeconomic status

Socioeconomic status was determined using an index which includes information on school education, vocational training, occupational status and net household income (weighted by household needs), and which enables a classification into low, intermediate and high status groups [29].

Statistical analysis

In order to present the descriptive data ($PWC_{130,\ 150,\ 75\%}$), mean values and percentages of cardiorespiratory fitness and relating 95% confidence intervals were calculated. Differences are considered to be statistically significant if the respective 95% confidence intervals do not overlap. Differences in cardiorespiratory fitness ($PWC_{75\%}$) by age group were calculated as the average, percental decrease per decade between the age groups 18–29 and 50–59. The association between socioeconomic status and cardiorespiratory fitness ($PWC_{75\%}$) was analysed using multivariate logistic regression analyses by adjusting for age.

The 18–29, 30–39, 40–49 and 50–64 age groups were used to adjust for age. All analyses were performed weighted; the numbers of observations were shown unweighted. Survey-design procedures were used to adjust for the cluster design of the survey by calculating wider confidence intervals compared to those calculated for simple randomised samples.

Study sample

The total DEGS1 sample for the 18–64 age group comprised 5,263 individuals, of whom 316 (6.0%) were classified as non-eligible cases, and 1,836 (34.9%) as test-unqualified based on PAR-Q. The reasons for exclusion are described in detailed in another paper in this issue [18]. In short, the most common contraindication was "prescribed drugs for high blood pressure or heart or breathing conditions". A total of 3030 test-qualified persons, 1,491 men and 1,549 women, underwent the cycle ergometer test.

Abstract · Zusammenfassung

Bundesgesundheitsbl 2013 · DOI 10.1007/s00103-013-1672-y

© Springer-Verlag Berlin Heidelberg 2013

J.D. Finger · S. Krug · A. Gößwald · S. Härtel · K. Bös

Cardiorespiratory fitness among adults in Germany. Results of the German Health Interview and Examination Survey for Adults (DEGS1)

Abstract

A high level of fitness is an indicator for a good health state. Therefore, cardiorespiratory fitness was examined in the cross-sectional German Health Interview Survey for Adults (DEGS1). Data from 3,030 test-qualified adults between 18 and 64 years old were assessed by means of a standardized submaximal cycle ergometer test. Test-qualified participants were significantly younger, more often men, less often obese and showed a better health state than those who were not test-qualified. The calculated physical work capacity at 75% of the age-predicted maximum heart rate (PWC75%) in watts per kg bodyweight was among men 1.52 and among women 1.15. PWC75% declines by 4.2% per age decade for men and 4.8% for women. A higher socioeconomic status (SES) is associated with better fitness among women. No significant association was observed between SES and fitness among men. These findings can be used to develop target-group specific health-promotion interventions in order to enhance cardiorespiratory fitness. It is planned to calculate updated PWC reference values based on the DEGS1 data.

Keywords

Cardiorespiratory fitness · PWC · Cycle ergometry · Adults · Health survey

Kardiorespiratorische Fitness bei Erwachsenen in Deutschland. Ergebnisse der Studie zur Gesundheit Erwachsener in Deutschland (DEGS1)

Zusammenfassung

Ein guter Fitnesszustand ist ein Indikator für einen positiven Gesundheitszustand. Daher wurde in der „Studie zur Gesundheit Erwachsener in Deutschland" (DEGS1) die kardiorespiratorische Fitness im Querschnitt untersucht. Es wurden Daten von 3030 testtauglichen Erwachsenen im Alter von 18 bis 64 Jahren mittels eines submaximalen Fahrradergometertests erhoben. Testtaugliche Teilnehmende sind signifikant jünger, häufiger männlich, weniger häufig adipös und weisen einen besseren Gesundheitszustand auf als testuntaugliche Personen. Die berechnete pulsbezogene Leistung bei 75% der maximalen Herzfrequenz ($PWC_{75\%}$) in Watt pro kg Körpergewicht beträgt bei Männern 1,52 und bei Frauen 1,15. Die $PWC_{75\%}$ nimmt pro Altersdekade um 4,2% bei Männern und um 4,8% bei Frauen ab. Bei Frauen ist ein höherer Sozialstatus (SES) mit einer besseren kardiorespiratorischen Fitness assoziiert. Bei Männern ist dagegen kein statistisch signifikanter Zusammenhang zwischen dem SES und der Fitness nachweisbar. Diese Erkenntnisse können genutzt werden, um zielgruppenspezifische Gesundheitsförderungsprogramme zur Steigerung der kardiorespiratorischen Fitness zu entwickeln. Es ist geplant auf Basis der DEGS1-Daten aktuelle PWC-Normwerte zu erstellen.

Schlüsselwörter

Kardiorespiratorische Fitness · PWC · Fahrradergometrie · Erwachsene · Gesundheitssurvey

This complies with a participation rate of 57.2% in relation to the total sample and 97.4% in relation to the sample of test-qualified persons (n=3,111). There were 11.9% of participants who terminated the test before reaching the allocated target heart rate. It was possible to calculate PWC_{130} for 2,843 participants (93.8%), $PWC_{75\%}$ for 2,827 (93.3%), and PWC_{150} for 1,586 (52.3%).

Results

Participants

The test-qualified compared to the test-unqualified participants in the 18–64 age group were significantly younger, more often men than women, had a better health state, were less likely to be obese and were more physically active (**Tab. 1**).

Tab. 2 Mean values and 95% confidence intervals (***95%CI***) of Physical Work Capacity (***PWC***) in watts/kg bodyweight by sex and age group

	Age group	18–29		30–39		40–49		50–64[a]		Total	
		n	mean (95%CI)	n	mean (95%CI)	n	mean (95%CI)	n	mean (95%CI)	n	mean (95%CI)
Sex											
Women	PWC_{130}	373	0.97 (0.92–1.01)	271	1.04 (1.00–1.09)	406	1.10 (1.06–1.14)	402	1.05 (1.00–1.09)	1452	1.04 (1.01–1.06)
	PWC_{150}	357	1.38 (1.33–1.43)	253	1.45 (1.40–1.50)	175	1.55 (1.49–1.61)	–	–	785	1.44 (1.40–1.47)
	$PWC_{75\%}$	367	1.24 (1.20–1.29)	267	1.20 (1.15–1.25)	403	1.15 (1.11–1.20)	410	0.98 (0.94–1.03)	1447	1.15 (1.13–1.18)
Men	PWC_{130}	404	1.34 (1.30–1.39)	288	1.41 (1.35–1.46)	348	1.41 (1.35–1.46)	351	1.41 (1.37–1.46)	1391	1.39 (1.36–1.41)
	PWC_{150}	393	1.79 (1.73–1.84)	273	1.84 (1.78–1.90)	135	1.77 (1.68–1.85)	–	–	801	1.80 (1.76–1.84)
	$PWC_{75\%}$	395	1.65 (1.60–1.70)	283	1.58 (1.53–1.64)	344	1.46 (1.41–1.51)	358	1.34 (1.30–1.39)	1380	1.52 (1.50–1.55)
Total	PWC_{130}	777	1.17 (1.13–1.20)	559	1.24 (1.19–1.28)	754	1.26 (1.22–1.29)	753	1.23 (1.19–1.27)	2843	1.22 (1.20–1.24)
	PWC_{150}	750	1.60 (1.56–1.64)	526	1.66 (1.61–1.71)	310	1.66 (1.60–1.72)	–	–	1586	1.63 (1.60–1.66)
	$PWC_{75\%}$	762	1.46 (1.43–1.50)	550	1.41 (1.36–1.45)	747	1.31 (1.27–1.35)	768	1.17 (1.13–1.20)	2827	1.35 (1.32–1.37)

Physical Work Capacity (***PWC***), calculated at the heart-rate thresholds of 130 and 150 beats per minute as well as at 75% of individual maximum heart rate (208–0.7 * age [28]) [a]In the age group 50–64, the heart-rate threshold of 150 beats per minute was not reached in the context of a submaximal exercise test, since maximum heart rate decreases with increasing age.

Tab. 3 Mean values for heart rate-based performance at 75% of maximum heart rate ($PWC_{75\%}$) in watts/kg bodyweight, percentage values for high cardiorespiratory fitness (***CRF***) and 95% confidence intervals (***95%CI***) by sex, age group and socioeconomic status (***SES***)

Age group	18–29			30–44			45–64			Total		
		$PWC_{75\%}$	High CRF		$PWC_{75\%}$	High CRF		$PWC_{75\%}$	High CRF		$PWC_{75\%}$	High CRF
	n	mean (95%CI)	% (95%CI)	n	mean (95%CI)	% (95%CI)	n	mean (95% CI)	% (95%CI)	n	mean (95%CI)	% (95%CI)
Women												
SES low	69	1.18 (1.08–1.28)	36 (24–48)	37	0.99 (0.88–1.11)	28 (8–47)	54	0.95 (0.82–1.07)	15 (2–28)	160	1.07 (1.00–1.13)	28 (20–36)
SES middle	231	1.20 (1.15–1.25)	50 (43–57)	287	1.18 (1.14–1.22)	45 (39–51)	358	0.98 (0.92–1.03)	24 (18–31)	876	1.12 (1.09–1.15)	39 (35–43)
SES high	66	1.49 (1.38–1.60)	71 (58–84)	143	1.33 (1.27–1.39)	60 (50–70)	194	1.14 (1.08–1.20)	35 (26–43)	405	1.28 (1.23–1.33)	52 (45–59)
Men												
SES low	75	1.68 (1.53–1.83)	57 (43–70)	56	1.45 (1.30–1.60)	35 (20–50)	67	1.43 (1.30–1.56)	39 (24–54)	198	1.53 (1.45–1.62)	44 (36–52)
SES middle	262	1.64 (1.57–1.70)	51 (44–59)	246	1.54 (1.48–1.60)	40 (33–47)	293	1.32 (1.28–1.36)	20 (15–25)	801	1.50 (1.47–1.54)	37 (33–41)
SES high	56	1.66 (1.52–1.80)	50 (35–66)	141	1.54 (1.46–1.62)	39 (28–50)	175	1.53 (1.43–1.62)	42 (33–52)	372	1.56 (1.51–1.61)	43 (36–49)
SES—no data	3			10			4			17		

$PWC_{75\%}$ heart rate-based performance at the pulse threshold, 75% of maximum heart rate (208–0.7•age [28]) in watts/kg bodyweightHigh cardiorespiratory fitness (***CRF***), defined as the quantile 100–60% (upper 40%) of distribution of $PWC_{75\%}$ in watts/kg bodyweight, dichotomised variables were calculated separately for women and men.

Cardiorespiratory fitness, sex and age

Men have an average PWC of 1.39 W per kg body weight at 130 bpm and 1.80 W per kg at 150 bpm. The corresponding PWC values for women are 1.04 and 1.44 (**Tab. 2**). While PWC_{130} and PWC_{150} do not significantly differ by age group for men and women, $PWC_{75\%}$ is lower for men and women in older age groups than in younger age groups (**Fig. 1**). The reduction in $PWC_{75\%}$ between the age groups 18–29 and 50–59 is on average 4.2% per decade for men and 4.8% for women.

Cardiorespiratory fitness and socioeconomic status

Women of high socioeconomic status in all age groups show a significantly better fitness than women of low status (**Tab. 3**). These differences are greater for women in the age groups 30–44 and 18–29 than in the 45–64 group (**Fig. 2**). In men, only in the 45–64 age group can it be observed that men with high socioeconomic status have a significantly higher mean value than men with intermediate socioeconomic status.

After adjusting for age, higher socioeconomic status is associated with higher cardiorespiratory fitness in women. Compared to women of low status, the odds ratios for high fitness are 1.9 (95% CI, 1, 2–3, 1; p<0.001) for intermediate-status women, and 3.7 for high-status women (2.2–6.2; p<0.001). Compared to their low-status counterparts, intermediate-status women are almost twice as likely to show a high fitness, and high-status women ap-

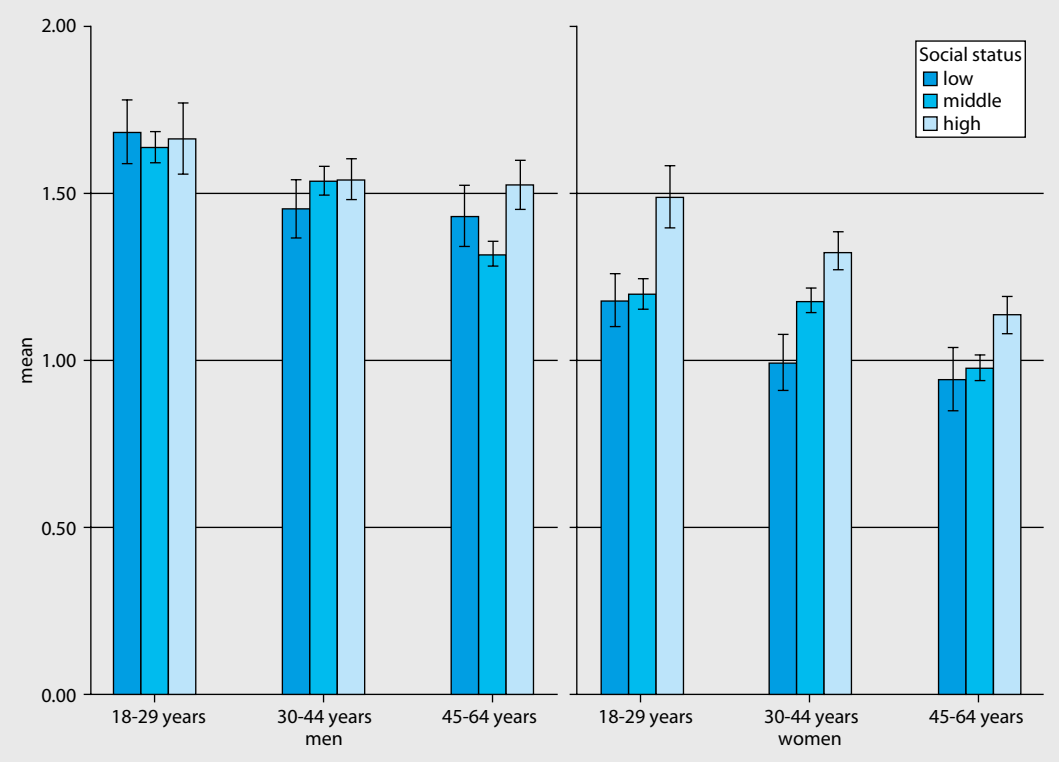

Fig. 2 ◀ Physical work capacity at 75% of maximum heart rate, in watts per kg body weight for men and women by socioeconomic status and age (mean values with 95% confidence intervals, n=2,827)

proximately three and a half times more likely. The corresponding odds ratios for men are 0.7 (0.5–1.1; p=0.1) and 1.1 (0.7–1.7; p=0.8). There is thus no significant association between socioeconomic status and fitness in men.

Discussion

As expected, the results of the DEGS1 nationwide cross-sectional study show that cardiorespiratory fitness is lower in women than in men, and is lower among older people than younger people among both men and women. Women of high socioeconomic status are fitter than those of low and intermediate status; in the 30–44 age group, fitness level increases with increasing socioeconomic status. There is no statistically significant association between fitness and socioeconomic status in men.

Sex and age differences

Sex-specific differences in cardiorespiratory fitness have already been examined in detail, and are partly the result of lower muscle mass in women than in men. Rost et al. [26] estimate that women's maximum endurance capacity is approximately 20% lower than that of men; based on the DEGS1 data, $PWC_{75\%}$ is approximately 24% lower. Also, men indicate to be more often physically active than women [30], which is another possible explanation for the sex-specific differences in cardiorespiratory fitness.

There is also detailed evidence of existing age differences in cardiorespiratory fitness, which might be partly attributable to a lower participation of older people in physical activity [30], and to aging processes leading to physical limitations which is a limiting factor for physical fitness in higher age groups [1].

The observed magnitude of sex-related differences in cardiorespiratory fitness is in DEGS1 approximately the same as this reported in similar population studies [27, 31, 32]. However, it is difficult to compare the age-related fitness differences observed in DEGS1 with the results of other studies because the assessment strategies and sample distributions are different. Gore et al. [27] report on the basis of the Australian health survey that $PWC_{75\%}$ decreases on average by 8.1% per decade for men and 9.8% for women between the age groups 18–29 and 70–79. In DEGS1, this decline is also slightly lower for men than for women, but the average per decade decline for both sexes is only about half of that observed in the Australian survey.

Socioeconomic differences

In men, cardiorespiratory fitness may be improved by fulfilling strenuous physical work tasks, which is mainly performed by men of low socioeconomic status [33, 34]. However, high-status men are more likely to exercise in their leisure time than those of intermediate and low status [30, 33, 35, 36], which may lead to an improved cardiorespiratory fitness among high-status men. One hypothesis may be that the two factors, strenuous physical work and leisure-time physical activity counterbalance each other, so that in DEGS1 no significant differences in cardiorespiratory fitness can be observed between high- and low-status men. However, other studies show that cardiorespiratory fitness among men improves with increasing socioeconomic status [37], which was in DEGS1 only the case in the age group 45–64.

In Germany, the positive association between socioeconomic status and leisure-time physical activity is stronger for women than for men [35]. More-

over, women are less likely than men to have physically demanding jobs [33]; thus strenuous work activity appears to be a less important factor for women than for men. These two aspects may explain why there is a significant association between socioeconomic status and cardiorespiratory fitness in women, but not so in men.

When interpreting these results, it should be borne in mind however that physical fitness is not only influenced by behavioural and structural factors, but also determined by genetic components [1].

The DEGS1 cross-sectional data does not allow for drawing causal inference upon findings of this analysis. Also cohort effects may lead to misleading conclusions when interpreting cross-sectional information by socioeconomic status, since the German society has significantly changed over recent decades as regard education, occupation and income opportunities between people of differing age cohorts [38].

Qualifying the PWC values in the research context

When the PWC values are compared with the reference values published by Rost and Hollmann [24, 26] (PWC_{130}: men 1.50, women 1.25; PWC_{150}: men 2.00, women 1.60; mean dispersion ±0.4), the DEGS1 values for both variables lay within the given boundaries of the mean dispersion for men and women. However, the point estimates observed by Rost and Hollmann tend to be higher than those observed in DEGS1. Rost and Hollmann discussed their PWC values in 1982, noting that they were lower than those calculated in 1957 by Dransfeld and Mellerowicz [39]. The trend towards a decreasing PWC over time seems thus to be continuing. Increasing media consumption and the abolition of physical activity in daily life due to the technological progress may have contributed to a reduced physical fitness state within the population. Furthermore, the increased proportion of overweight individuals may have resulted in a lower PWC, as PWC is standardised to bodyweight as part of the PWC concept [24]. It is however questionable whether the study results are comparable over time, since it is likely that sampling effects compromise the comparability of the results.

Internal and external validity of results

During the DEGS1 exercise test also capillary blood lactate was measured, which is considered to be a more robust indicator of aerobic endurance capacity than heart rate [40]. Heart-rate and lactate values will be compared in further studies, both to each other and to self-reported physical activity, to obtain more information about the internal validity of the measurement parameters.

The DEGS1 cardiorespiratory fitness results can be generalised to the test-qualified adult population aged 18–64. The weighting factor used in DEGS1, which is based on the population structure of the German "microcensus", reduces the likelihood of sampling effects. As the probability of exclusion from the test increases with age, there is likely to be greater selection bias in older than younger age groups.

The levels of self-reported physical activity differ significantly between test-qualified and test-unqualified DEGS1 participants; it can therefore be assumed that test-unqualified individuals have on average a lower cardiorespiratory fitness than those who are test-qualified.

Conclusion

As expected, men have a better cardiorespiratory fitness than women, and younger persons a better fitness than older persons. A consideration of socioeconomic status may help to understand why some persons are fitter than others, and thus to develop target group-specific health-promotion programmes to enhance cardiorespiratory fitness. The PWC values measured in DEGS1 tend to be lower than those reported by Rost and Hollmann. It is planned to use the DEGS1 PWC values to calculate updated PWC reference values for Germany. During the DEGS1 exercise test also blood-lactate parameters were measured, which will be analysed in future studies.

Corresponding address

J.D. Finger
Department of Epidemiology and Health Monitoring, Robert Koch Institute
General-Pape-Str. 62–66, 12101 Berlin
Germany
FingerJ@rki.de

Funding of the study. The study was financed by the Robert Koch Institute and the Federal Ministry of Health.

Conflict of interest. On behalf of all authors, the corresponding author states that there are no conflicts of interest.

References

1. Hollmann W, Strüder HK (2009) Sportmedizin: Grundlagen von körperlicher Aktivität, Training und Präventivmedizin. Schattauer, Stuttgart
2. Shephard RJ (1994) Aerobic fitness and health. Human Kinetics Publishers, Champaign
3. O'Donovan G, Owen A, Bird SR et al (2005) Changes in cardiorespiratory fitness and coronary heart disease risk factors following 24 weeks of moderate- or high-intensity exercise of equal energy cost. J Appl Physiol 98:1619–1625
4. Blair SN, Cheng Y, Scott Holder J (2001) Is physical activity or physical fitness more important in defining health benefits? Med Sci Sports Exerc 33:S379–S399
5. Caspersen CJ, Powell KE, Christenson GM (1985) Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 100:126–131
6. American College of Sports Medicine (2006) ACSM's guidelines for exercise testing and prescription. Lippincott Williams & Wilkins, Philadelphia
7. Kodama S, Saito K, Tanaka S et al (2009) Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women. JAMA 301:2024–2035
8. LaMonte MJ, Barlow CE, Jurca R et al (2005) Cardiorespiratory fitness is inversely associated with the incidence of metabolic syndrome. A prospective study of men and women. Circulation 112:505–512
9. Fogelholm M (2010) Physical activity, fitness and fatness: relations to mortality, morbidity and disease risk factors. A systematic review. Obes Rev 11:202–221
10. Lee D, Sui X, Ortega F et al (2011) Comparisons of leisure-time physical activity and cardiorespiratory fitness as predictors of all-cause mortality in men and women. Br J Sports Med 45:504–510
11. Gößwald A, Lange M, Kamtsiuris P, Kurth BM (2012) DEGS: German Health Interview and Examination Survey for Adults. A nationwide cross-sectional and longitudinal study within the framework of health monitoring conducted by the Robert Koch-Institute. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 55:775–780

12. Kamtsiuris P, Lange M, Hoffmann R et al (2013) The first wave of the German Health Interview and Examination Survey for Adults (DEGS1). Sampling design, response, sample weights, and representativeness. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 56:620–630
13. Kurth BM (2012) Das RKI-Gesundheitsmonitoring—was es enthält und wie es genutzt werden kann. Public Health Forum 20(76):4.e1–4.e3
14. Kurth BM, Lange C, Kamtsiuris P, Hölling H (2009) Health monitoring at the Robert Koch-Institute. Status and perspectives. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 52:557–570
15. Scheidt-Nave C, Kamtsiuris P, Gößwald A et al (2012) German health interview and examination survey for adults (DEGS)—design, objectives and implementation of the first data collection wave. BMC Public Health 12:730
16. Gößwald A, Lange M, Dölle R, Hölling H (2013) The first wave of the German Health Interview and Examination Survey for Adults (DEGS1). Participant recruitment, fieldwork, and quality management. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 56:611–619
17. Robert Koch-Institut (RKI) (2009) DEGS: Studie zur Gesundheit Erwachsener in Deutschland. Projektbeschreibung. Beiträge zur Gesundheitsberichterstattung des Bundes. RKI, Berlin
18. Finger JD, Gößwald A, Härtel S et al (2013) Measurement of cardiorespiratory fitness in the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 56:885–893
19. Canadian Society for Exercise Physiology (2012) Physical Activity Readiness Questionnaire—PAR-Q (revised 2002) http://csep.ca/cmfiles/publications/parq/par-q.pdf. Accessed 30 Nov 2012
20. Deutsche Gesellschaft für Sportmedizin und Prävention (DGSP) (2012) PAR-Q-Fragebogen (deutsche Fassung) http://www.dgsp.de/downloads/allgemein/Eingangsfragebogen.pdf. Accessed 30 Nov 2012
21. Lange Andersen K, Shephard R, Denolin H et al (1971) Fundamentals of exercise testing. World Health Organisation, Geneva
22. Astrand I (1958) The physical work capacity of workers 50–64 years old. Acta Physiol Scand 42:73–86
23. Wahlund H (1948) Determinants of the physical work capacity. A physiological and clinical study with special reference to standardization of cardio-pulmonary functional test. Acta Med Scand 215(Suppl):83–98
24. Rost R, Hollmann W (1982) Belastungsuntersuchungen in der Praxis. Thieme, Stuttgart
25. Miyashita M, Mutoh Y, Yoshioka N, Sadamoto T (1985) PWC75% HRmax: a measure of aerobic work capacity. Sports Med 2:159
26. Rost R (ed) (2001) Lehrbuch der Sportmedizin. Deutscher Ärzte-Verlag, Cologne
27. Gore CJ, Booth ML, Bauman A, Owen N (1999) Utility of pwc75% as an estimate of aerobic power in epidemiological and population-based studies. Med Sci Sports Exerc 31:348
28. Tanaka H, Monahan KD, Seals DR (2001) Age-predicted maximal heart rate revisited. J Am Coll Cardiol 37:153–156
29. Lampert T, Kroll L, Müters S, Stolzenberg H (2013) Measurement of socioeconomic status in the German Health Interview and Examination Survey for Adults (DEGSS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 56:631–636
30. Krug S, Jordan S, Mensink GBM et al (2013) Physical Activity. Results of the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 56:765–771
31. Wang CY, Haskell WL, Farrell SW et al (2010) Cardiorespiratory fitness levels among US adults 20–49 years of age: findings from the 1999–2004 National Health and Nutrition Examination Survey. Am J Epidemiol 171:426–435
32. Batcho CS, Thonnard JL, Nielens H (2012) PWC 75%/kg, a fitness index not linked to resting heart rate: testing procedure and reference values. Arch Phys Med Rehabil 93:1196–1200
33. Finger JD, Tylleskär T, Lampert T, Mensink GBM (2012) Physical activity patterns and socioeconomic position: the German National Health Interview and Examination Survey 1998 (GNHIES98) BMC Public Health 12:1079
34. He XZ, Baker DW (2005) Differences in leisure time, household, and work related physical activity by race, ethnicity, and education. J Genl Intern Med 20:259–266
35. Lampert T, Mensink GBM, Müters S (2012) Physical and sporting activity among adults in Germany. Results from the "German Health Update 2009" survey. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 55:102–110
36. Lindström M, Hanson BS, Östergren PO (2001) Socioeconomic differences in leisure-time physical activity: the role of socioeconomic participation and socioeconomic capital in shaping health related behaviour. Soc Sci Med 52:441–451
37. Lakka TA, Kauhanen J, Salonen TJ (1996) Conditioning leisure-time physical activity and cardiorespiratory fitness in sociodemographic groups of middle-aged men in eastern Finland. Int J Epidemiol 25:86–93
38. Lampert T, Kroll LE (2009) Die Messung des sozioökonomischen Status in sozialepidemiologischen Studien. In: Richter M, Hurrelmann K (eds) Gesundheitliche Ungleichheit. Grundlagen, Probleme, Perspektiven, 2. aktualisierte Aufl. VS Verlag für Sozialwissenschaften, Wiesbaden, pp 309–334
39. Dransfeld B, Mellerowicz H (1957) Untersuchungen über das Verhalten der Herzschlagfrequenz während und nach körperlichen Leistungen. Eur J Appl Physiol Occup Physiol 16:464–471
40. Löllgen H, Fahrenkrog U, Völker K et al (2010) Allgemeine Aspekte der Ergometrie. In: Löllgen H, Erdmann E, Gitt AK (eds) Ergometrie. Belastungsuntersuchungen in Klinik und Praxis. Springer Medizinverlag, Heidelberg, pp 21–60