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ORIGINAL CONTRIBUTIONS

Anthropometry in Relation to Prostate Cancer Risk in the Netherlands Cohort Study

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In the Netherlands Cohort Study, the authors investigated whether anthropometry is associated with prostate cancer risk. At baseline in 1986, 58,279 men aged 55–69 years completed a self-administered questionnaire on diet, anthropometry, and other risk factors for cancer. After 6.3 years of follow-up, 681 cases were available with complete data on height and weight at baseline, and for 523 cases, there were data for weight at age 20 years. In both age-adjusted and multivariate case-cohort analyses (adjusted for age, family history of prostate cancer, and socioeconomic status), height, body mass index (BMI; kg/m^2), and lean body mass (kg) at baseline were not associated with prostate cancer risk. The rate ratios of prostate cancer for men with a BMI at age 20 of less than 19, 19–20.9, 21–22.9, 23–24.9, and 25 or greater were 1.00 (reference), 1.06, 1.09, 1.39, and 1.33, respectively (p for trend = 0.02). For gain in BMI from age 20 years to age of the cohort at baseline, an inverse trend in risk was found (p for trend = 0.01), which did not persist after additional adjustment for BMI at age 20 (p for trend = 0.07). In subgroup analyses, no clear associations between anthropometry and advanced prostate cancer were found. Our findings suggest that body composition in young adulthood may already exert an effect on later risk of prostate cancer. *Am J Epidemiol* 2000;151:541–9.

anthropometry; cohort studies; prostatic neoplasms; questionnaires

Prostate cancer is one of the most frequently occurring types of cancer in Western countries, but up to now, very little has been known about the etiology of the disease. Body composition is one of several possible factors that might be related to prostate cancer risk (1, 2). Different epidemiologic studies have evaluated this possible relation but with inconclusive results. For height, weight, and body mass index (BMI), mostly positive or null associations have been reported, both in cohort and case-control studies, but inverse associations have also been observed (1, 2). A potential role of lean body mass (LBM) in prostate cancer etiology is also still questionable (3–5). One important drawback that probably contributes to a, thus far, fairly incomplete picture of anthropometry and prostate cancer is that the majority of previous studies did not evaluate this relation extensively.

Observed associations between anthropometry and prostate cancer are often explained by an interaction with hormonal levels (androgens), but mechanisms through insulin or growth factors have also been proposed (4–6). A hormonal etiology for prostate cancer seems plausible because the normal growth and functioning of the prostate is influenced by androgens. Increased testosterone has been implicated in prostate cancer carcinogenesis (7), and body mass appears to influence serum androgen concentrations (8–10). Because of the long induction period of cancer, a possible effect of body composition on prostate cancer

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Abbreviations: BMI, body mass index; CI, confidence interval; LBM, lean body mass; NLCS, Netherlands Cohort Study; RR, rate ratio; SHBG, sex hormone-binding globulin.

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risk might occur in an earlier stage of life. Only six studies (5, 6, 11–14) have reported some results on anthropometric measures early in life or change in anthropometric measures during lifetime in relation to prostate cancer risk. Some findings do, indeed, indicate an early effect of body composition, but data are too sparse to draw strong conclusions.

Here, we report our results on anthropometry and change in anthropometric measures during lifetime in relation to prostate cancer risk from the Netherlands Cohort Study (NLCS).

MATERIALS AND METHODS

The cohort

Because the study design has been described before (15), we will give only a brief outline. In September 1986, the NLCS was initiated. At baseline, 58,279 men aged 55–69 years completed a self-administered questionnaire on usual diet, lifestyle, personal and family history of cancer, anthropometry, demographic data, and other risk factors for cancer. The case-cohort approach (16) was used for data processing and analysis. For calculation of incidence rates of prostate cancer, the number of cancer cases diagnosed in the entire cohort was used as the numerator, while person-years at risk (denominator) were estimated using a random sample of 1,688 men (subcohort). Follow-up for incident prostate cancer was established by computerized record linkage with all nine cancer registries in the Netherlands and with the Dutch national database of pathology reports (PALGA) (17). The subcohort has been followed up biennially for vital status information, which involved personal mailings and (for nonrespondents) additional contacts with municipal population registries. Completeness of cancer follow-up was at least 96 percent (18), and no subcohort members have been lost to follow-up. After a follow-up period of 6.3 years (September 1986 to December 1992), 704 incident, microscopically or histologically confirmed, primary prostate cancer cases were detected.

Data collection and analysis

Information on height (cm), weight at baseline (kg), and weight at age 20 years (kg) was obtained by using a self-administered questionnaire. To minimize observer bias in coding and interpretation of the data, questionnaire data for all cases and subcohort members were key-entered twice and processed in a manner blinded with respect to case-subcohort status. Baseline BMI and BMI at age 20 years were calculated using baseline weight and weight at age 20, respectively, divided by height at baseline squared (kg/m^2). Change in BMI from age 20 years to baseline was calculated as BMI at baseline minus BMI at age 20. LBM (kg) was calculated as (2.447 – 0.09516 age (years) + 0.1074 height (cm) + 0.3362 weight (kg))/0.732, as described by Willett (19). All subjects with prevalent cancer other than skin cancer were excluded. Furthermore, all men with incomplete data on anthropometric measures at baseline were excluded, leaving 681 cases and 1,565 subcohort members for analyses. Complete data on BMI at age 20 years were available for 523 cases and 1,249 subcohort members.

Mean values of anthropometric and potential confounding variables were compared between cases and subcohort members. Rate ratios of prostate cancer and 95 percent confidence intervals were computed using the GLIM statistical package (20). Exponentially distributed survival times were assumed in the follow-up period. Since standard software was not available, specific macros were developed to account for the additional variance introduced by using the subcohort instead of the entire cohort (21). Tests for trend were based on likelihood ratio tests; two-sided p values are used throughout this report. Age- and multivariate-adjusted analyses were conducted for categorized and continuous anthropometric variables. Variables included in the multivariate analyses were age (continuous), family history of prostate cancer (no, yes), and socioeconomic status (low, medium, high) because these were associated with prostate cancer risk in our study. Energy and fat intake were not related to prostate cancer risk in the NLCS and, therefore, are not considered as potential confounding variables. The same applies to vegetable and fruit consumption (22).

To evaluate whether results for baseline BMI were biased because of an influence of disease occurrence, we performed analyses with exclusion of cases detected in the first 2 years of follow-up. To investigate the hypothesis that latent and nonlatent or aggressive prostate tumors might have different etiologies, subgroup analyses were performed for continuous anthropometric variables within case subgroups of localized (T_{0-2}, M_0), and advanced (T_{3-4}, M_0; T_{0-4}, M_1) prostate tumors (using the TNM classification); well-differentiated, moderately differentiated, poorly differentiated, and undifferentiated prostate tumors; and latent and nonlatent tumors. Based on information from the pathology reports that have been obtained from PALGA, prostate cancer cases detected during transurethral prostate resections were coded as latent. Cases detected during surgical procedures used in cases of suspected cancer (biopsy, radical prostatectomy) were coded as nonlatent. Cases were excluded from these subgroup analyses when this additional information was unknown or unclear (38.8 percent).

RESULTS

In table 1, anthropometric variables are described for cases and subcohort members. The means of all anthropometric variables did not differ to a large extent between cases and subcohort members. Furthermore, when subcohort members with missing information for weight at age 20 years were compared with those who had mentioned their weight at age 20, no differences in mean height were found. However, subcohort members with missing information about weight at age 20 had a lower weight and BMI at baseline (76.4 kg and 24.6 kg/m^2, respectively) than did men with complete information (78.4 kg and 25.1 kg/m^2, respectively). These differences in mean weight and BMI were statistically significant. For cases, subjects with missing information about weight at age 20 years did not differ on baseline height, weight, and BMI from cases who had mentioned their weight at age 20 (data not shown). Also shown in table 1 are some potentially confounding variables. The mean age is somewhat higher among cases (63.8 years) than among controls (61.4 years). Furthermore, cases more often reported a positive family history of prostate cancer (4.3 vs. 2.6 percent) and are more highly educated than are subcohort members.

In table 2, age-adjusted as well as multivariate-adjusted rate ratios of prostate cancer are displayed for baseline height, BMI, and LBM. In both the age-adjusted and the multivariate analyses, height was not associated with prostate cancer risk. The rate ratios for BMI at baseline were slightly (but nonsignificantly) increased in the third and fourth categories, but the rate ratio was somewhat decreased in the highest category, and there was no trend in risk (p for trend = 0.73). For LBM, we found no association with prostate cancer risk. Results for BMI and LBM after exclusion of cases detected in the first 2 years of follow-up were essentially the same (data not shown). We also conducted analyses in which each exposure variable was adjusted for the others. The estimated rate ratios were essentially the same as those presented in table 2 (data not shown).

In table 3, results for BMI at age 20 years and gain in BMI from age 20 to cohort baseline age are displayed. For BMI at age 20, a significant positive trend in risk (p for trend = 0.02) was found. Men with a BMI at age 20 years of 25 or more had a rate ratio (RR) of 1.33 (95 percent confidence interval (CI): 0.81, 2.19) compared with men with a BMI at age 20 years of less than 19. For both subcohort members and cases, 9 percent of all men lost weight. The mean gain in weight (standard deviation) for subcohort members and cases was 12.1 (8.4) kg and 11.2 (7.1) kg, respectively. The mean gain in BMI (standard deviation) was 3.9 (2.6) kg/m^2 for subcohort members and 3.6 (2.2) kg/m^2 for cases. A significantly decreasing trend in risk was observed for an increase in BMI from age 20 years to cohort baseline age (p for trend = 0.03); however, after additional adjustment for BMI at age 20, the trend test was no longer statistically significant (p for trend = 0.07). Only in the two highest categories of gain in BMI were nonsignificant decreased RRs observed (0.83 and 0.67, respectively).

In table 4, rate ratios are displayed for continuous anthropometric variables in case subgroups of localized and advanced prostate tumors. No association was found between height and localized or advanced tumors. Baseline BMI and LBM were also not associated with either localized or advanced prostate tumors.

TABLE 1. Description of anthropometric variables and potential confounders in prostate cancer cases and subcohort members, Netherlands Cohort Study, 1986–1992

	Anthropometric variables (mean (SD*))					
	Height at baseline (cm)	Weight at baseline (kg)	BMI* at baseline (kg/m^2)	LBM* at baseline (kg)	Weight at age 20 years† (kg)	BMI at age 20 years† (kg/m^2)
Cases (n = 681)	176.3 (6.7)	77.8 (9.2)	25.0 (2.5)	56.7 (4.9)	68.0 (8.3)	21.9 (2.4)
Subcohort (n = 1,565)	176.6 (6.8)	78.0 (9.8)	25.0 (2.7)	57.1 (5.2)	67.9 (8.4)	21.8 (2.5)

	Potentially confounding variables (mean (SD))				
	Age (years)	Positive family history of prostate cancer (% yes)	Highest educational level‡ (%)		
			Low	Medium	High
Cases (n = 681)	63.8 (3.8)	4.3	46.3	33.2	19.7
Subcohort (n = 1,565)	61.4 (4.2)	2.6	48.1	33.8	17.4

* SD, standard deviation; BMI, body mass index; LBM, lean body mass.

† Based on 523 cases and 1,249 subcohort members.

‡ There was missing information for 0.9% (cases) and 0.7% (subcohort members); low is defined as primary school with/without lower-level vocational education, medium as secondary school or medium level vocational education, and high as university or higher level vocational education.

TABLE 2. Rate ratios and 95% confidence intervals for prostate cancer according to anthropometric variables, Netherlands Cohort Study, 1986–1992

Anthropometric variables	Age adjusted			Multivariate adjusted		
	No. of cases/ person-years in subcohort	RR*	95% CI*	No. of cases/ person-years in subcohort	RR†	95% CI
Height at baseline (cm)						
<170‡	100/1,287	1.00		99/1,262	1.00	
170–174	155/2,272	0.92	0.67, 1.27	154/2,259	0.90	0.65, 1.24
175–179	214/2,703	1.12	0.83, 1.52	210/2,690	1.08	0.79, 1.47
180–184	142/1,888	1.03	0.74, 1.43	142/1,879	0.98	0.70, 1.37
185–189	50/913	0.83	0.54, 1.26	50/907	0.78	0.51, 1.19
≥190	20/307	0.97	0.53, 1.77	20/307	0.96	0.52, 1.75
		p for trend, 0.88			*p* for trend, 0.60	
Height continuous, 5-cm increment		1.00	0.94,1.08		0.99	0.92, 1.06
BMI* at baseline (kg/m²)						
<22‡	63/1,047	1.00		63/1,047	1.00	
22–23	167/2,218	1.21	0.85, 1.74	164/2,211	1.20	0.84, 1.73
24–25	237/3,012	1.28	0.91, 1.80	236/2,980	1.35	0.95, 1.90
26–27	151/1,988	1.22	0.84, 1.75	150/1,976	1.26	0.87, 1.83
≥28	63/1,106	0.85	0.55, 1.29	62/1,091	0.89	0.58, 1.37
		p for trend, 0.38			*p* for trend, 0.73	
BMI continuous, 2-kg/m² increment		0.98	0.91, 1.05		1.00	0.92, 1.07
LBM* at baseline (kg)						
<52‡	108/1,367	1.00		108/1,361	1.00	
52–54.9	148/1,959	0.99	0.72, 1.36	145/1,940	0.98	0.71, 1.35
55–57.9	168/2,150	1.07	0.78, 1.46	166/2,131	1.07	0.79, 1.47
58–60.9	138/1,863	1.05	0.76, 1.44	138/1,851	1.05	0.76, 1.45
≥61	119/2,031	0.96	0.69, 1.33	118/2,022	0.95	0.69, 1.33
		p for trend, 0.92			*p* for trend, 0.95	
LBM continuous 2-kg increment		0.99	0.96, 1.03		1.00	0.96, 1.03

* RR, rate ratio; CI, confidence interval; BMI, body mass index; LBM, lean body mass.
† RRs adjusted for age, family history of prostate cancer, and socioeconomic status.
‡ Reference category.

In contrast, for BMI at age 20 years, a significant increase in risk of localized prostate tumors was found (RR per increment of 2 kg/m^2 = 1.18, 95 percent CI: 1.04, 1.35). No association between BMI at age 20 years and advanced prostate tumors was shown. The overall negative association between gain in BMI and prostate cancer risk was more pronounced for localized prostate tumors (RR = 0.87, 95 percent CI: 0.74, 1.02 per increment of 2 kg/m^2). Table 5 shows continuous anthropometric variables evaluated in case subgroups by differentiation grade of the tumor. Some associations were noted in different subgroups; however, anthropometric measures showed no consistent association with one specific subgroup of prostate cancer tumors. For both latent and nonlatent tumors, no clear associations were observed (data not shown).

DISCUSSION

In our study, we observed no clear associations between height, BMI, and LBM and prostate cancer risk. For BMI at age 20 years, a significant positive trend in risk was observed. In contrast, for a gain in BMI from age 20 to baseline age of the cohort, a significant inverse trend in risk was found. After correction for the absolute BMI at age 20 years, the trend test was no longer statistically significant. In subgroup analyses, these observed associations for overall prostate cancer risk were found mainly in the subgroup of localized prostate tumors. We found no evidence that anthropometric variables were more strongly related to advanced prostate tumors, poorly and undifferentiated tumors, or nonlatent tumors.

TABLE 3. Rate ratios and 95% confidence intervals for prostate cancer according to anthropometric variables at age 20 years, Netherlands Cohort Study, 1986–1992

Anthropometric variables	Age adjusted			Multivariate adjusted		
	No. of cases/ person-years in subcohort	RR*,†	95% CI*	No. of cases/ person-years in subcohort	RR†	95% CI
BMI* at age 20 years (kg/m²)						
<19‡	57/908	1.00		57/902	1.00	
19 to 20.9	124/1,909	1.10	0.75, 1.62	122/1,902	1.06	0.72, 1.56
21 to 22.9	178/2,552	1.13	0.79, 1.64	176/2,536	1.09	0.76, 1.58
23 to 24.9	119/1,521	1.34	0.91, 1.99	119/1,496	1.39	0.93, 2.06
≥25	45/598	1.34	0.82, 2.20	44/598	1.33	0.81, 2.19
		p for trend, 0.04			*p* for trend, 0.02	
BMI at age 20 years continuous, 2-kg/m² increment		1.07	0.98, 1.17		1.08	0.99, 1.18
Change in BMI from age 20 years to baseline (kg/m²)						
−9.2 to <0	47/668	1.19	0.77, 1.84	47/668	1.19	0.74, 1.90§
0 to 1.9‡	122/1,876	1.00		120/1,857	1.00	
2 to 3.9	179/2,104	1.31	0.97, 1.76	176/2,104	1.32	0.98, 1.79§
4 to 5.9	113/1,537	0.99	0.72, 1.37	113/1,512	1.04	0.74, 1.47§
6 to 7.9	43/852	0.78	0.51, 1.18	43/852	0.83	0.53, 1.31§
≥8	19/451	0.61	0.35, 1.08	19/441	0.67	0.36, 1.23§
		p for trend, 0.01			*p* for trend, 0.07¶	
Gain in BMI from age 20 years to baseline continuous, 2-kg/m² increment		0.91	0.83, 0.99		0.93	0.84, 1.03§

* RR, rate ratio; CI, confidence interval; BMI, body mass index.
† RRs adjusted for age, family history of prostate cancer, and socioeconomic status.
‡ Reference category.
§ Additional adjustment for BMI at age 20 years.
¶The test for trend applies to weight gain categories only.

TABLE 4. Rate ratios and 95% confidence intervals for prostate cancer according to anthropometric variables in subgroups of localized (T_{0-2}, M_0) and advanced (T_{3-4}, M_0, T_{0-4}, M_1) prostate tumors, Netherlands Cohort Study, 1986–1992

Anthropometric variables	Localized tumors (*n* = 239)		Advanced tumors (*n* = 226)	
	RR*,†	95% CI*	RR†	95% CI
Height at baseline (continuous 5-cm increment)	0.99	0.89, 1.10	0.98	0.88, 1.10
BMI* at baseline (continuous 2-kg/m² increment)	0.96	0.86, 1.06	1.01	0.90, 1.13
LBM* at baseline (continuous 2-kg increment)	0.98	0.93, 1.03	1.00	0.94, 1.06
BMI at age 20 years (continuous 2-kg/m² increment)	1.18	1.04, 1.35	1.03	0.91, 1.18
Gain in BMI from age 20 years to baseline (continuous, 2-kg/m² increment)	0.87	0.74, 1.02‡	0.93	0.80, 1.08‡

* RR, rate ratio; CI, confidence interval; BMI, body mass index; LBM, lean body mass.
† Adjusted for age, family history of prostate cancer, and socioeconomic status.
‡ Additional adjustment for BMI at age 20 years.

The results from the NLCS are not likely to be influenced by selection bias, given the high completeness of follow-up of cases and subcohort person years (18, 23). All of the anthropometric measures are self-

TABLE 5. Rate ratios and 95% confidence intervals for prostate cancer according to anthropometric variables in subgroups on differentiation grade, Netherlands Cohort Study, 1986–1992

Anthropometric variables	Well differentiated (n = 194)		Moderately differentiated (n = 247)		Poorly differentiated/ undifferentiated (n = 174)	
	RR*,†	95% CI*	RR†	95% CI	RR*	95% CI
Height at baseline (continuous 5-cm increment)	0.94	0.84, 1.06	0.98	0.89, 1.08	1.07	0.95, 1.21
BMI* at baseline (continuous 2-kg/m² increment)	0.92	0.82, 1.04	1.02	0.93, 1.13	1.01	0.89, 1.14
LBM* at baseline (continuous 2-kg increment)	0.94	0.89, 1.00	1.00	0.95, 1.06	1.03	0.97, 1.10
BMI at age 20 years (continuous 2-kg/m² increment	1.09	0.94, 1.26	1.15	1.01, 1.31	0.97	0.83, 1.13
Gain in BMI from age 20 years to baseline continuous, 2-kg/m² increment)	0.77	0.65, 0.92‡	0.97	0.83, 1.13‡	0.68	0.58, 0.81†

* RR, rate ratio; CI, confidence interval; BMI, body mass index; LBM, lean body mass.
† Adjusted for age, family history of prostate cancer, and socioeconomic status.
‡ Additional adjustment for BMI at age 20 years.

reported, and misclassification of exposure is a potential source of bias. Weight at age 20 years was used to calculate BMI at age 20, and misclassification of BMI at age 20 might have occurred because weight at age 20 is difficult to remember. However, misclassification is expected to be nondifferential, and therefore, a possible effect on the risk estimates should be toward the null value. When we compared the mean self-reported height and weight at baseline in the subcohort with the mean height and weight of a representative sample of Dutch men aged 50–69 years in 1985–1988 (24), these measures were comparable. Finally, residual confounding of the effect measures cannot be excluded, although we considered several potential confounding factors.

For 20 and 23 percent of cases and subcohort members, respectively, data regarding BMI at age 20 years were missing. Cases with and those without information regarding BMI at age 20 years did not differ in baseline anthropometric measures, but subcohort members with missing information had a lower weight and BMI at baseline than did subcohort members with complete information. Because of these missing data, our positive association with regard to BMI at age 20 needs to be interpreted carefully. One case-control study reported no association between BMI 20 years prior to the interview and prostate cancer (25). In another case-control study, risk estimates for prostate cancer were nonsignificantly increased in association with BMI at ages 25 and 45 years (14). In contrast to these findings, Giovannucci et al. (5) found no association between BMI at age 21 years and overall prostate cancer risk, but an inverse association between BMI at age 21 and advanced prostate cancer risk was reported; the rate ratio for men with a BMI of 26 or more versus less than 20 at age 21 years was 0.53. For obesity at ages 5 and 10 years, based on self-reported assessments using pictograms of body size, a reduced risk was also noted. An explanation that was given for this decreased risk is that if obesity is related to the hormonal milieu, low testosterone and insulin-like growth factor I levels and higher estrogen levels may lower the risk of prostate cancer. In another cohort study (6) and a case-control study (11), no clear associations were seen for BMI at a younger age (20 or 25 years) and prostate cancer risk. In general, obesity has been reported to be inversely associated with plasma testosterone levels (5, 8–10, 26), and lower testosterone levels may be related to a lower prostate cancer risk (7). Therefore, the suggested positive association observed in our study is somewhat unexpected. However, obesity also shows an inverse relation with sex hormone-binding globuline (SHBG), and SHBG is hypothesized to have an inverse association with prostate cancer risk (27). Because SHBG binds to testosterone and lower levels of SHBG may lead to higher levels of bioavailable testosterone, this might be a pathway explaining our observed positive association between BMI at age 20 years and prostate cancer risk. Our results, which indicated an inverse trend in risk when evaluating gain in BMI from age 20 years to cohort baseline age (55–69 years) are not in concordance with this hypothesis, however. Nevertheless, it might be plausible that different hormones or hormone levels are involved at different stages in prostate cancer development. The prostate resides in a multihormonal environment, and a number of growth-regulatory pathways with complex interactions are involved in epithelial proliferation (28). The exact role of hormones in the development of prostate cancer remains poorly understood

(29). Therefore, studies providing insight into possible mechanisms of action of hormones in relation to prostate growth and prostate cancer are needed. In two cohort studies, no association between change in BMI from age 25 years to cohort baseline age (≥65 years) (6) or change in BMI from college years to years after college (13) and prostate cancer risk was found. However, in one of these cohort studies, percent change in BMI from age 50 years to cohort baseline age (≥65 years) showed a positive trend in risk (p for trend = 0.04), although none of the rate ratios were statistically significant (6). Obviously, misclassification because of a poor memory of BMI at earlier ages may have influenced results in different studies.

According to the results from one study, it has been suggested that lean body mass may be associated with prostate cancer risk and not the fat tissue. In that study, a positive association was observed between the area of muscle in the arm, but not with area of fat in the arm, and prostate cancer risk (3). The authors speculated that increased muscle development might reflect overproduction of sex hormone, since this is a pathway explaining their observed association. We found no association between estimated LBM and prostate cancer risk, and in another case-control study, no association between fat-free mass and prostate cancer was observed (30). In a retrospective cohort study among 135,006 Swedish construction workers, a significant positive trend (p for trend = 0.002) in risk was observed between calculated LBM (using the same equation as in our study) and prostate cancer incidence (4). The age-adjusted risk estimate for men with an LBM of more than 62 compared with one of less than 55 was 1.17 (95 percent CI: 1.04, 1.32). A disadvantage of the calculated measure is that the assumption of a constant water proportion in LBM may not hold. Depending on the state of hydration and the relative components of LBM, the proportion of water varies (4, 19). Sometimes, other measures were used to estimate the distribution of fat in the body. No clear associations were found between waist circumference and prostate cancer risk in three studies (5, 31, 32). In the Health Professionals Follow-Up Study, among 47,781 men, an inverse association was noted between hip circumference and prostate cancer. The risk estimate for men in the fifth versus those in the first quintile was 0.85 (95 percent CI: 0.68, 1.06), and the trend test was statistically significant (p for trend = 0.04) (5). In one case-control study, no clear associations were observed with hip or thigh circumference and biacromial breadth (31). However, in the latter case-control study, significant differences between cases and controls were found for the waist-to-thigh ratio (p = 0.03), with the cases having a higher ratio than the controls. This was not confirmed in a later case-control study by the same authors (30). In that study, the only anthropometric measures that consistently differed between cases and controls were indexes of upper body robustness, as assessed by biacromial, bideltoid, and biacromial-to-standing height ratio measures (30). In one cohort study, the waist-to-hip ratio was not related to overall prostate cancer risk (5).

Our results of no association between height and prostate cancer risk are in accordance with results from other cohort studies (3, 6, 13, 33, 34) and case-control studies (14, 25, 30–32, 35–42). Nevertheless, there were four cohort studies (4, 5, 43, 44) and two case-control studies (45, 46) in which positive associations with increasing height were indicated. In three of these studies (4, 43, 44), the trend test was statistically significant. In one case-control study (31), the sitting-to-standing height ratio was significantly higher for cases than for controls. Previous analyses from our study showed a strong positive association between height and breast cancer risk (47). Because we do not expect the determinants of adult height (e.g., childhood energy intake) to differ greatly between men and women in our cohort, the absence of variation in these determinants cannot explain our finding of no association between height and prostate cancer risk. The observed positive association between height and prostate cancer risk in some studies might be explained by the fact that tallness could be the result of higher levels of insulin-like growth factor I and testosterone, which might influence prostate cancer risk (4, 5). In the Health Professionals Follow-Up Study (5), one of the prospective studies in which a positive association between height and prostate cancer risk was found, an inverse association with preadult obesity was observed. Both attained height and childhood obesity may be related to the preadult hormonal milieu. Because of scarcity of data, more studies on preadult exposures in relation to risk of prostate cancer are needed.

The vast majority of previous epidemiologic studies on anthropometry and prostate cancer reported results on indices of body mass index, as an indicator of adiposity. As in our study, in most cohort studies no clear associations were observed (3, 5, 13, 33, 43, 48, 49). However, in four cohort studies (4, 6, 34, 50), positive associations were indicated. Case-control studies mostly reported null associations (25, 30–32, 36–40, 51–56), but positive associations were also observed (12, 35, 45, 46). Because of the inverse association between obesity and plasma testosterone levels (5, 8–10, 26), one should expect BMI to be inversely related to risk of prostate cancer. However, the inverse association between BMI and SHBG, as described

above, might explain the positive associations observed in some studies. Inconsistencies in reported results can partly be explained by the fact that the evaluated range in BMI differed between the various studies. Another important drawback of several of the published studies is that only correction for age was reported (3, 4, 12, 13, 25, 33, 34, 45, 46, 49, 51–54, 56). In addition, in several case-control studies, only a comparison of mean BMI between cases and controls was reported, and no risk estimates were computed (31, 32, 36–40). Furthermore, if BMI in case-control studies was measured at the time of diagnosis, disease may have affected this measure, leading to biased results.

Finally, we found no evidence of anthropometric measures being more strongly associated with advanced, poorly and undifferentiated, or nonlatent prostate tumors. There were only a few other studies (5, 6, 11, 25, 43) in which case subgroups were evaluated. Results between these studies were not very consistent and do not permit definitive conclusions.

In conclusion, our results indicate an effect of early BMI (BMI at age 20 years) and change in BMI from age 20 to baseline age. Thus far, evidence for an effect of early weight and weight gain during lifetime is too limited to draw conclusions yet, and more research is also warranted to reveal potential mechanisms. Furthermore, the effect of timing of changes in anthropometric measures during lifetime also need attention in future studies on anthropometry and prostate cancer risk. We found no association between height, BMI, and LBM at baseline and risk of prostate cancer.

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REFERENCES

1. Giles G, Ireland P. Diet, nutrition and prostate cancer. Int J Cancer 1997;(Suppl. 10):13–17.
2. Kolonel LN. Nutrition and prostate cancer. Cancer Causes Control 1996;7:83–94.
3. Severson RK, Grove JS, Nomura AM, et al. Body mass and prostatic cancer: a prospective study. BMJ 1988;297:713–15.
4. Andersson SO, Wolk A, Bergstrom R, et al. Body size and prostate cancer: a 20-year follow-up study among 135,006 Swedish construction workers. J Natl Cancer Inst 1997;89: 385–9.
5. Giovannucci E, Rimm EB, Stampfer MJ, et al. Height, body weight, and risk of prostate cancer. Cancer Epidemiol Biomarkers Prev 1997;6:557–63.
6. Cerhan JR, Torner JC, Lynch CF, et al. Association of smoking, body mass, and physical activity with risk of prostate cancer in the Iowa 65+ Rural Health Study (United States). Cancer Causes Control 1997;8:229–38.
7. Ross RK, Henderson BE. Do diet and androgens alter prostate cancer risk via a common etiologic pathway? J Natl Cancer Inst 1994;86:252–4.
8. Dai WS, Kuller LH, LaPorte RE, et al. The epidemiology of plasma testosterone levels in middle-aged men. Am J Epidemiol 1981;114:804–16.
9. Vermeulen A, Kaufman JM, Giagulli VA. Influence of some biological indexes on sex hormone-binding globulin and androgen levels in aging or obese males. J Clin Endocrinol Metab 1996;81:1821–6.
10. Wu AH, Whittemore AS, Kolonel LN, et al. Serum androgens and sex hormone-binding globulins in relation to lifestyle factors in older African-American, white, and Asian men in the United States and Canada. Cancer Epidemiol Biomarkers Prev 1995;4:735–41.
11. Andersson SO, Baron J, Wolk A, et al. Early life risk factors for prostate cancer: a population-based case-control study in Sweden. Cancer Epidemiol Biomarkers Prev 1995;4:187–92.
12. Ilic M, Vlajinac H, Marinkovic J. Case-control study of risk factors for prostate cancer. Br J Cancer 1996;74:1682–6.
13. Whittemore AS, Paffenbarger RS Jr, Anderson K, et al. Early precursors of site-specific cancers in college men and women. J Natl Cancer Inst 1985;74:43–51.
14. Key TJ, Silcocks PB, Davey GK, et al. A case-control study of diet and prostate cancer. Br J Cancer 1997;76:678–87.
15. Van den Brandt PA, Goldbohm RA, Van't Veer P, et al. A large-scale prospective cohort study on diet and cancer in the Netherlands. J Clin Epidemiol 1990;43:285–95.
16. Prentice RL. A case-cohort design for epidemiologic cohort studies and disease prevention trials. Biometrika 1986;73: 1–11.
17. Van den Brandt PA, Schouten LJ, Goldbohm RA, et al. Development of a record linkage protocol for use in the Dutch Cancer Registry for Epidemiological Research. Int J Epidemiol 1990;19:553–8.
18. Goldbohm RA, Van den Brandt PA, Dorant E. Estimation of the coverage of Dutch municipalities by cancer registries and PALGA based on hospital discharge data. Tijdschr Soc Gezondheidsz 1994;72:80–4.
19. Willett W. Anthropometric measures and body composition. In: Willett W, ed. Nutritional epidemiology. New York, NY: Oxford University Press, 1990:217–44.
20. Baker J. GLIM 3.77 reference manual. Oxford, England: Numerical Algorithms Group, 1985.
21. Volovics A, Van den Brandt PA. Methods for the analyses of case-cohort studies. Biom J 1997;2:195–214.
22. Schuurman AG, Goldbohm RA, Dorant E, et al. Vegetable and fruit consumption and prostate cancer risk: a cohort study in the Netherlands. Cancer Epidemiol Biomarkers Prev 1998;7: 673–80.
23. Van den Brandt PA, Van't Veer P, Goldbohm RA, et al. A prospective cohort study on dietary fat and the risk of postmenopausal breast cancer. Cancer Res 1993;53:75–82.
24. Netherlands Central Bureau of Statistics. Statistical yearbook of the Netherlands 1990. The Hague, the Netherlands: SDU Publishers, 1990.
25. Andersson SO, Baron J, Bergstrom R, et al. Lifestyle factors and prostate cancer risk: a case-control study in Sweden. Cancer Epidemiol Biomarkers Prev 1996;5:509–13.

26. Meikle AW, Bishop DT, Stringham JD, et al. Relationship between body mass index, cigarette smoking, and plasma sex steroids in normal male twins. Genet Epidemiol 1989;6: 399–412.
27. Gann PH, Hennekens CH, Ma J, et al. Prospective study of sex hormone levels and risk of prostate cancer. J Natl Cancer Inst 1996;88:1118–26.
28. Griffiths K, Eaton CL, Davies P. Prostatic cancer: aetiology and endocrinology. Horm Res 1989;32 (Suppl. 1):38–43.
29. Pienta KJ, Goodson JA, Esper PS. Epidemiology of prostate cancer: molecular and environmental clues. Urology 1996; 48:676–83.
30. Demark Wahnefried W, Conaway MR, Robertson CN, et al. Anthropometric risk factors for prostate cancer. Nutr Cancer 1997;28:302–7.
31. Demark-Wahnefried W, Paulson DF, Robertson CN, et al. Body dimension differences in men with or without prostate cancer. J Natl Cancer Inst 1992;84:1363–4.
32. Whittemore AS, Kolonel LN, Wu AH, et al. Prostate cancer in relation to diet, physical activity, and body size in blacks, whites, and Asians in the United States and Canada. J Natl Cancer Inst 1995;87:652–61.
33. Greenwald P, Damon A, Kirmss V, et al. Physical and demographic features of men before developing cancer of the prostate. J Natl Cancer Inst 1974;53:341–6.
34. Thune I, Lund E. Physical activity and the risk of prostate and testicular cancer: a cohort study of 53,000 Norwegian men. Cancer Causes Control 1994;5:549–56.
35. Talamini R, La Vecchia C, Decarli A, et al. Nutrition, social factors and prostatic cancer in a Northern Italian population. Br J Cancer 1986;53:817–21.
36. Graham S, Haughey B, Marshall J, et al. Diet in the epidemiology of carcinoma of the prostate gland. J Natl Cancer Inst 1983;70:687–92.
37. Ross RK, Shimizu H, Paganini Hill A, et al. Case-control studies of prostate cancer in blacks and whites in southern California. J Natl Cancer Inst 1987;78:869–74.
38. Walker AR, Walker BF, Tsotetsi NG, et al. Case-control study of prostate cancer in black patients in Soweto, South Africa. Br J Cancer 1992;65:438–41.
39. Honda GD, Bernstein L, Ross RK, et al. Vasectomy, cigarette smoking, and age at first sexual intercourse as risk factors for prostate cancer in middle-aged men. Br J Cancer 1988;57: 326–31.
40. Kolonel LN, Yoshizawa CN, Hankin JH. Diet and prostatic cancer: a case-control study in Hawaii. Am J Epidemiol 1988; 127:999–1012.
41. Wynder EL, Mabuchi K, Whitmore WF Jr. Epidemiology of cancer of the prostate. Cancer 1971;28:344–60.
42. Talamini R, Franceschi S, La Vecchia C, et al. Diet and prostatic cancer: a case-control study in northern Italy. Nutr Cancer 1992;18:277–86.
43. Le Marchand L, Kolonel LN, Wilkens LR, et al. Animal fat consumption and prostate cancer: a prospective study in Hawaii. Epidemiology 1994;5:276–82.
44. Hebert PR, Ajani U, Cook NR, et al. Adult height and incidence of cancer in male physicians (United States). Cancer Causes Control 1997;8:591–7.
45. Hayes RB, de Jong FH, Raatgever J, et al. Physical characteristics and factors related to sexual development and behaviour and the risk for prostatic cancer. Eur J Cancer Prev 1992;1:239–45.
46. Fincham SM, Hill GB, Hanson J, et al. Epidemiology of prostatic cancer: a case-control study. Prostate 1990;17:189–206.
47. Van den Brandt PA, Dirx MJ, Ronckers CM, et al. Height, weight change, and postmenopausal breast cancer risk: The Netherlands Cohort Study. Cancer Causes Control 1997;8: 39–47.
48. Thompson MM, Garland C, Barrett-Connor E, et al. Heart disease risk factors, diabetes, and prostatic cancer in an adult community. Am J Epidemiol 1989;129:511–17.
49. Mills PK, Beeson WL, Phillips RL, et al. Cohort study of diet, lifestyle, and prostate cancer in Adventist men. Cancer 1989; 64:598–604.
50. Gronberg H, Damber L, Damber JE. Total food consumption and body mass index in relation to prostate cancer risk: a case-control study in Sweden with prospectively collected exposure data. J Urol 1996;155:969–74.
51. Ghadirian P, Lacroix A, Maisonneuve P, et al. Nutritional factors and prostate cancer: a case-control study of French Canadians in Montreal, Canada. Cancer Causes Control 1996; 7:428–36.
52. Yu H, Harris RE, Wynder EL. Case-control study of prostate cancer and socioeconomic factors. Prostate 1988;13:317–25.
53. Pawlega J, Rachtan J, Dyba T. Dietary factors and risk of prostate cancer in Poland. Results of case-control study. Neoplasma 1996;43:61–3.
54. West DW, Slattery ML, Robison LM, et al. Adult dietary intake and prostate cancer risk in Utah: a case-control study with special emphasis on aggressive tumors. Cancer Causes Control 1991;2:85–94.
55. Mettlin C, Selenskas S, Natarajan N, et al. Beta-carotene and animal fats and their relationship to prostate cancer risk. A case-control study. Cancer 1989;64:605–12.
56. Rohan TE, Howe GR, Burch JD, et al. Dietary factors and risk of prostate cancer: a case-control study in Ontario, Canada. Cancer Causes Control 1995;6:145–54.