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Body mass index does not predict prostate-specific antigen or percent free prostate-specific antigen in men undergoing prostate cancer screening

Georg Hutterer[a,b], *Paul Perrotte*[c], *Andrea Gallina*[a,d], *Jochen Walz*[a,f], *Claudio Jeldres*[a,c], *Miriam Traumann*[a,f], *Nazareno Suardi*[d], *Fred Saad*[c], *François Bénard*[c], *Luc Valiquette*[c], *Michael McCormack*[c], *Markus Graefen*[e], *Francesco Montorsi*[d], *Pierre I. Karakiewicz*[a,c,*]

[a]*Cancer Prognostics and Health Outcomes Unit, University of Montreal Health Center (CHUM), 1058, rue St-Denis, Montréal, Que., Canada H2X 3J4*
[b]*Department of Urology, Medical University Graz, Austria*
[c]*Department of Urology, University of Montreal, Que., Canada*
[d]*Department of Urology, Vita-Salute University San Raffaele, Milan, Italy*
[e]*Martini Clinic – Prostate Cancer Center, University Medical Centre Eppendorf, Hamburg, Germany*
[f]*Department of Urology, University Medical Centre Eppendorf, Hamburg, Germany*

ARTICLE INFO

Article history:
Received 15 November 2006
Received in revised form
19 December 2006
Accepted 4 January 2007
Available online 9 February 2007

Keywords:
Body mass index
Prostate cancer
Prostate-specific antigen

ABSTRACT

Objectives: Body mass index (BMI) may alter serum prostate specific antigen (PSA) and percent free PSA (%fPSA) and may mask the risk of prostate cancer. We investigated the relationship between BMI and PSA or %fPSA.

Materials and methods: Height, weight, PSA and %fPSA were assessed in 616 consecutive screened men without prostate cancer. Continuously coded and categorised BMI was studied. Statistical analyses consisted of ANOVA, linear regression, bivariate and partial correlations.

Results: Median age was 57 years. Median PSA was 1.0 and median %fPSA was 26. Median BMI was 25.8 kg/m^2. Neither continuously coded nor categorised BMI correlated with either PSA or %fPSA in unadjusted or age-adjusted analyses (all p values $\geqslant 0.3$).

Conclusions: Body mass index does not affect PSA or %fPSA in men without known prostate cancer, who undergo prostate cancer screening. Therefore, PSA or %fPSA-based screening or early detection efforts do not require an adjustment for BMI.

1. Introduction

Obesity is common in western countries.[1] According to the recent World Health Organization (WHO) criteria, more than 30% of adults in the United States are obese. Moreover, over 70% of Americans over 40 years of age are overweight (body mass index [BMI] $\geqslant 25$ kg/m^2).[2] Similarly, obesity is a growing problem in Western European countries.[3,4] Body mass index is implicated in various aspects of prostate cancer.[5–9] Those include the grade and stage of the disease, where obese men have more advanced and more aggressive disease.[10–12] Moreover, the rate of prostate specific antigen (PSA) recurrence

* *Corresponding author:* Address: Cancer Prognostics and Health Outcomes Unit, University of Montreal Health Center (CHUM), 1058, rue St-Denis, Montréal, Que., Canada H2X 3J4. Tel.: +1 514 890 8000x35336; fax: +1 514 412 7363.
E-mail address: pierre.karakiewicz@umontreal.ca (P.I. Karakiewicz).
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doi:10.1016/j.ejca.2007.01.005

after definitive therapy is reportedly higher in obese men.[10] Additionally, obese men are at higher risk of prostate cancer mortality.[5,13,14] Finally, several ecological studies demonstrated that prostate cancer is more prevalent in Western countries with higher fat intake than in Asia, where fat intake is lower.[15–19]

Despite the apparently abundant BMI literature, few studies addressed the direct relationship between BMI and prostate cancer detection,[5,7,8] as well as between BMI and PSA levels prior to prostate cancer diagnosis. The latter relationship is important, as same investigators indicated that elevated BMI may be associated with lower circulating serum PSA. Thus, men with high BMI may be excluded from screening or early detection based on spuriously low perceived risk of prostate cancer. Based on this hypothesis, we decided to examine the relationship between BMI and PSA, as well as between BMI and percent free PSA (%fPSA) in men without clinical evidence of prostate cancer.

2. Materials and methods

2.1. Patient population

Our cohort consisted of a total of 630 men without known prostate cancer, who participated in an annual prostate cancer screening event, the Prostate Cancer Awareness Days (PCAD). The PCAD are organised by a multidisciplinary group of urologists, oncologists, radiation oncologists, nurses, support group members and nutrition experts from the University of Montreal Health Center. The aim of the event is to educate, inform and raise public awareness about prostate cancer. The PSA and %fPSA (Hybritech, Beckmann-Coulter, Inc., Canada) values were measured in all participants. Similarly, in all men BMI was defined according to the WHO classification [weight (kg)/height squared (m^2)], where BMI between 18.5 and 24.99 kg/m^2 indicates normal weight.[20] Of 630 participants, all variables were available in 616 (97.8%), which represent the focus of this analysis.

2.2. Statistical methods

The relation between BMI and PSA, as well as between BMI and %fPSA was assessed in two ways. First, continuously coded BMI was tested in bivariate correlations, which specifically focused on the correlation between BMI and either PSA or %fPSA. Partial correlations adjusted for the effect of age. Subsequently, ANOVA models tested PSA and %fPSA means differences according to WHO–BMI categories. The results were, respectively, shown graphically in scatterplots and boxplots.

SPSS for Windows version 13.0 was used for statistical analyses. All tests were two-sided and $p < 0.05$ was considered statistically significant.

3. Results

Patient characteristics are shown in Table 1. Age ranged from 40 to 79 years (mean 58, median 57). Fig. 1 shows the age distribution of the entire cohort. Total PSA ranged from 0.1 to 26.0 ng/mL (mean 1.8, median 1.0), while %fPSA ranged from 5% to 71% (mean 27.2, median 26.0). BMI ranged from 16.8 to 48.8 kg/m^2 (mean 26.2, median 25.8). Of all participants, 40.3% were non-obese (BMI < 24.9 kg/m^2), 46.4% were overweight (BMI range 25.0–29.9 kg/m^2), 11.4% were obese (BMI range 30.0–34.9 kg/m^2) and 1.9% were severely obese (BMI > 35.0 kg/m^2). Fig. 2 shows the virtually normal distribution of continuously coded BMI of the entire cohort (Fig. 2a). Fig. 2b depicts the frequency distribution within the WHO–BMI categories.

Table 1 – Descriptive characteristics of the study cohort (N = 616)

Variable	N (%)
Total number of patients (%)	616 (100)
Age (years)	
Mean (median)	58 (57)
Range	40–79
<50	148 (24.0)
50–59	221 (35.9)
60–69	153 (24.8)
70–79	94 (15.3)
PSA (ng/mL)	
Mean (median)	1.8 (1.0)
Range	0.1–26.0
0–1	298 (48.4)
1.1–2	165 (26.8)
2.1–3	64 (10.4)
3.1–4	36 (5.8)
4.1–10	43 (7.0)
>10	10 (1.6)
%fPSA	
Mean (median)	27.2 (26.0)
Range	5–71
WHO–BMI (kg/m^2)	
Mean (median)	26.2 (25.8)
Range	16.8–48.8
Non-obese (BMI < 24.9)	248 (40.3)
Overweight (BMI 25–29.9)	286 (46.4)
Obese (BMI 30–34.9)	70 (11.4)
Severely obese (BMI > 35)	12 (1.9)

PSA, prostate specific antigen; %fPSA, percent free PSA; BMI, body mass index.

3.1. Association between continuously coded BMI versus PSA and %fPSA

Fig. 3 represents the scatterplots of the relation between continuously coded BMI and total PSA (Fig. 3a) or %fPSA (Fig. 3b). The majority of coordinates correspond to BMI values from 20 to 35 kg/m^2 and PSA values from 0 to 4 ng/mL.

The correlational analyses between continuously coded BMI and total PSA demonstrated a virtually non-existent relationship ($r = 0.005$), which was statistically indifferent from no correlation at all ($p = 0.9$). The partial correlation which adjusted for age was equally weak ($r = 0.003$; $p = 1.0$). The correlation between BMI and %fPSA ($r = -0.06$; $p = 0.1$) was also unimpressive. Finally, the partial correlation between BMI and %fPSA adjusted for age ($r = -0.06$; $p = 0.1$) failed to identify any correlation between these variables.

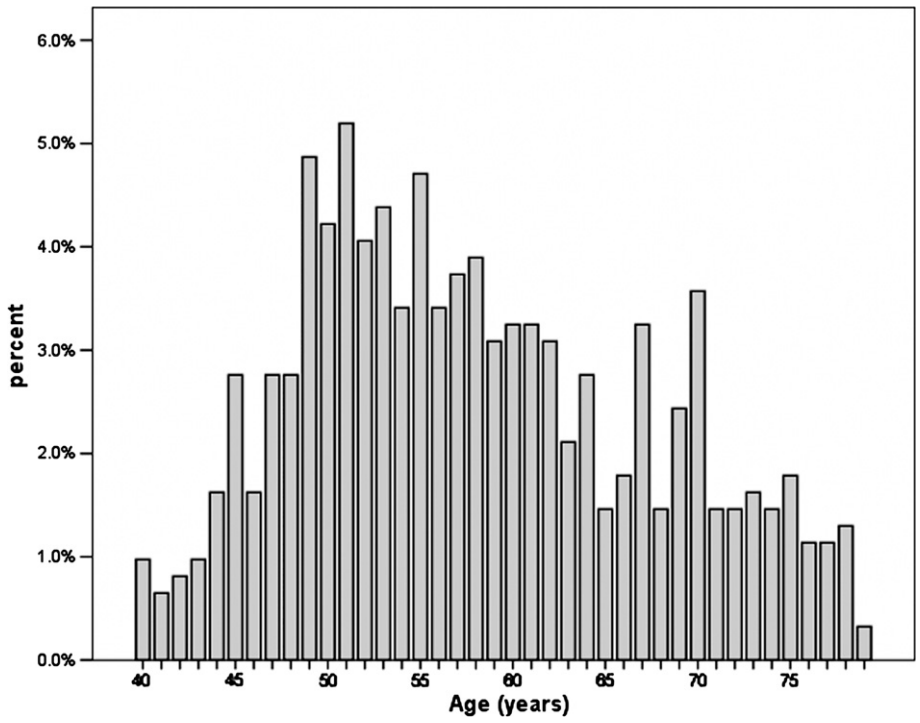

Fig. 1 – Age distribution of the study cohort (*N* = 616).

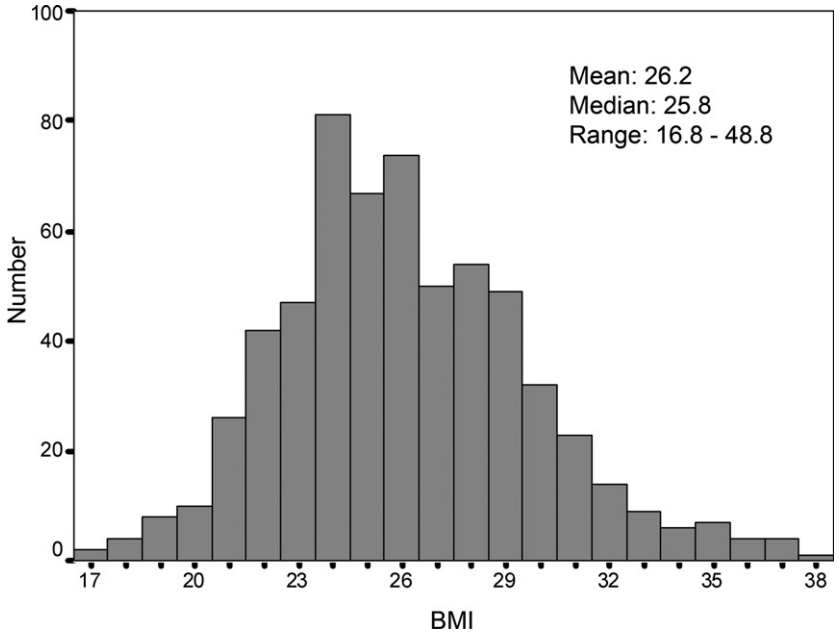

Fig. 2a – Frequency distribution of continuously coded body mass index (BMI) [kg/m^2].

3.2. *Association between categorically coded BMI versus PSA and %fPSA*

PSA and %fPSA means failed to demonstrate any statistically significant differences when they were categorised according to the WHO–BMI strata (ANOVA $p = 0.4$ and ANOVA $p = 0.2$). Fig. 4 represents the boxplots of PSA distribution (Fig. 4a) and %fPSA distribution (Fig. 4b) according to WHO–BMI categories. The means, medians and ranges are shown in Table 2.

Linear regression models, where categorically coded BMI predicted either PSA or %fPSA, failed to demonstrate statistically significant results with or without age adjustment (all p values $\geqslant 0.3$).

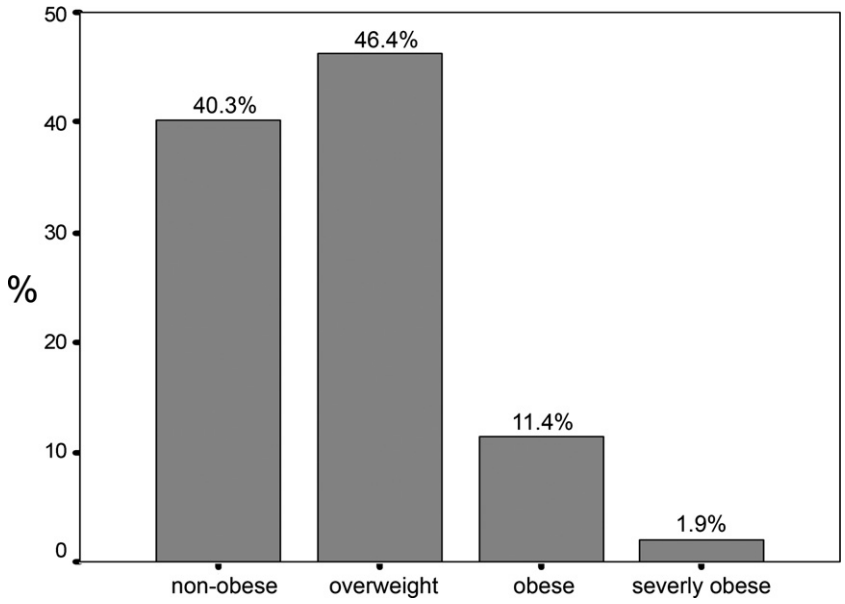

Fig. 2b – Distribution of categorically coded body mass index (BMI).

4. Discussion

Elevated BMI is implicated as a risk factor in several cancers, including prostate cancer.[5–9,21] The adverse effects of elevated BMI have been suggested throughout the span of the natural history of treated prostate cancer. Ecological studies suggested that obesity predisposes to higher incidence of prostate cancer.[5,7] Obesity was also shown to represent a risk factor for higher prevalence of prostate cancer on needle biopsy and for the presence of higher grade of prostate cancer, when the diagnosis was made.[10,11] Moreover, obese men are at a higher risk of harboring higher grade and higher stage prostate cancer at the time of definitive therapy.[10] Obese men reportedly also have a higher risk of positive surgical margins after radical prostatectomy and higher risk of biochemical recurrence after definitive therapy.[9] Finally, obesity represents a risk factor for prostate cancer mortality.[5,13,14]

Despite this apparently abundant evidence favouring the implication of BMI as an adverse prostate cancer risk factor, several investigators questioned the importance of BMI. For example, in 2005 Freedland and colleagues reported that elevated BMI does not predispose to baseline higher PSA levels.[22] This report appeared despite prior reports from the same investigators, where BMI represented a significant predictor of adverse pathological outcomes at radical prostatectomy.[9] Similarly, in a careful and detailed statistical analysis of the effect of BMI on biochemical recurrence, Mallah and colleagues showed that BMI does not improve the ability to predict the rate of biochemical recurrence.[23] Lack of added value related to the consideration of BMI in prediction of biochemical recurrence after radical prostatectomy was also reported in a European series of patients.[24] Hence, the clinical significance of BMI remains controversial.

Equally important controversy also exists with respect to the effect of BMI on PSA at the time of initial evaluation of men without an established prostate cancer diagnosis. Baillargeon and colleagues studied a cohort of 2779 men without evidence of prostate cancer and found that obese men had lower PSA levels, which could mask the presence of prostate cancer.[25] In another study of 3341 men, the same investigators found that BMI categories were related to statistically significant PSA means differences.[26] Despite statistical significance, the actual PSA means were strikingly similar across BMI strata and were, respectively, 1.17, 1.17, 1.07 and 0.96 for BMI categories <25, 25–29, 30–39 and 35+.[26] Finally, in 1565 men, the same group reported no statistically significant PSA differences across BMI strata.[27]

Taken together, these observations indicate that the majority of published data support the tenet that elevated BMI is an adverse factor, which predisposes to prostate cancer, increases the risk of adverse prostate cancer variants and increases the risk of prostate cancer mortality.[5,10,11,13,14] However, some well-established investigators either question the clinical significance of BMI or report contradictory results from different cohorts.[8,26–28] The lack of consensus regarding the role of BMI suggests that BMI may have different effects in different populations.[8,22,27] This applies to Thompson et al.'s studies, where different findings were reported for two similar but not exactly the same cohorts.[25,26] Similarly, in 2005 Freedland and colleagues reported lower PSA in obese men from a cohort of 787 men from Palo Alto, California.[8] Conversely, in a report addressing a larger, combined and more contemporary cohort of 1414 men from Palo Alto and San Francisco, California, the same investigators reported no effect between BMI and PSA.[22]

These reports suggest that many variables can modify the relationship between BMI and various prostate cancer outcomes. As shown above, these variables may relate to population differences. Methodological issues may also confound this relationship. For example, Mallah and colleagues, as well as Chun and colleagues assessed the effect of BMI on biochemical recurrence and despite BMI's independent predictor status, they found that BMI did not improve the predictive ability of established biochemical recurrence risk factors.[23,24]

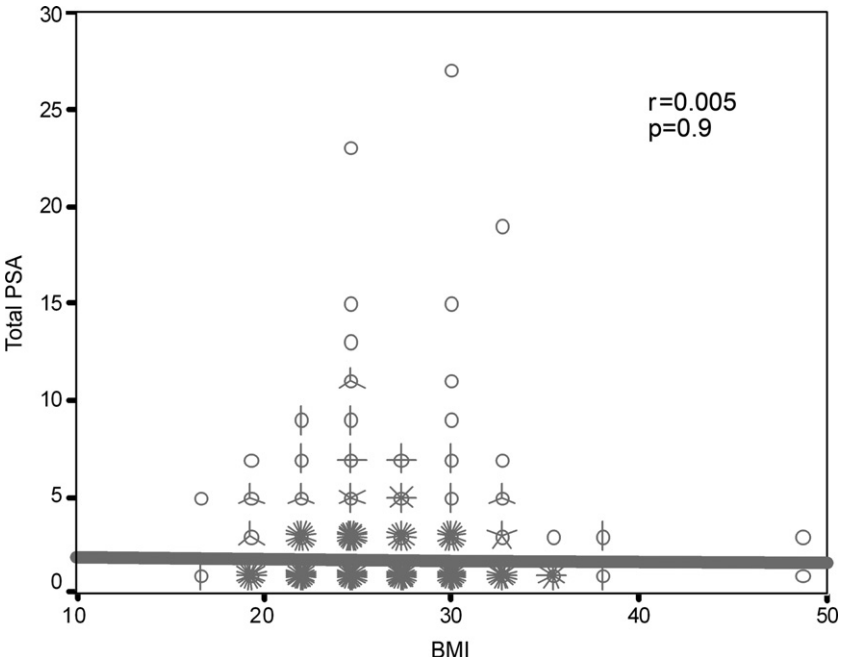

Fig. 3a – Scatterplot of the relation between continuously coded body mass index (BMI) and total prostate specific antigen (PSA) values. Pearson correlation coefficient (*r*) and its significance (*p*) are shown. Multiple observations are depicted as sunflowers, where each petal corresponds to one individual observation.

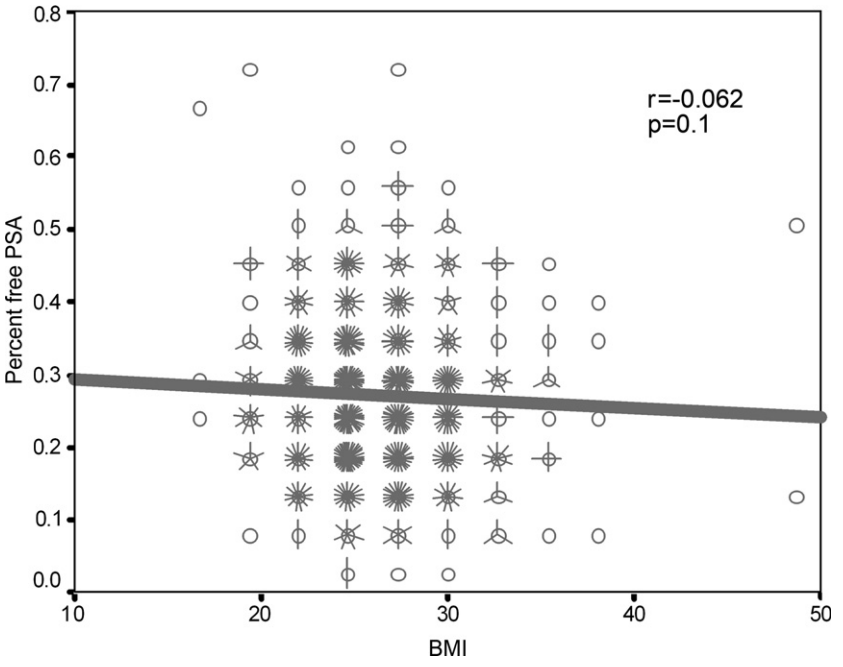

Fig. 3b – Scatterplot of the relation between continuously coded body mass index (BMI) and percent free PSA (%fPSA) values. Pearson correlation coefficient (*r*) and its significance (*p*) are shown. Multiple observations are depicted as sunflowers, where each petal corresponds to one individual observation.

The results of Mallah and colleagues and Chun and colleagues are particularly interesting as they question the clinical significance of a marker, despite its independent predictor status. Taken together, Krystal et al.'s, Freedland et al.'s, Thompson et al.'s, Mallah et al.'s and Chun et al.'s findings question the importance and clinical significance of BMI.

Based on this controversy, our objective was to further explore the importance of BMI in men without prostate cancer diagnosis. The rationale for our analyses stemmed from Baillargeon's paper, where the authors suggested that BMI may falsely lower PSA levels and may undermine the indication for biopsy.[25] Therefore, our analysis tested the relation be-

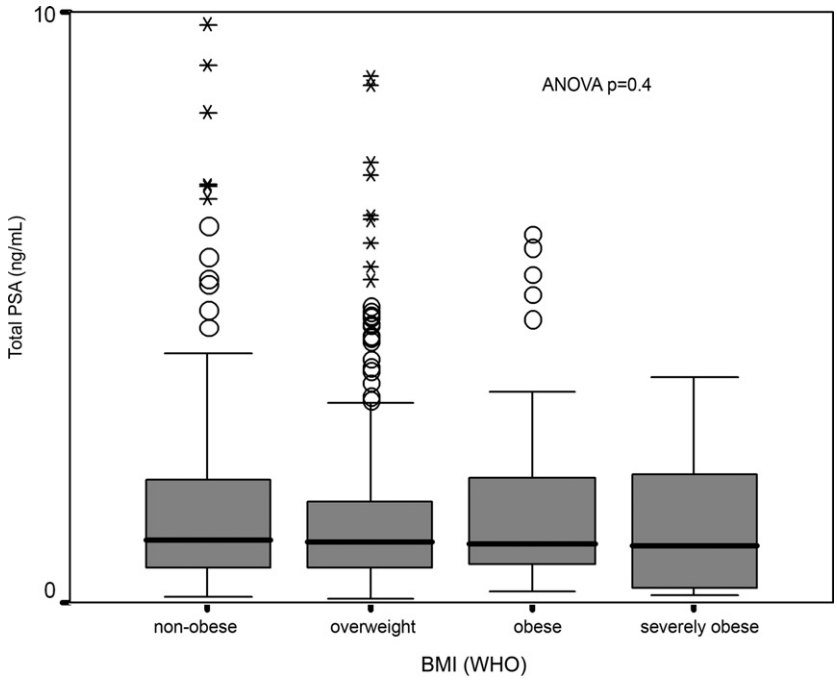

Fig. 4a – Boxplots of the distribution of total PSA according to World Health Organization (WHO) body mass index (BMI) categories. For each boxplot the solid line represents the median. The boxes represent the 25th to 75th percentiles. The whiskers show the spread from the 2.5th to the 97.5th percentile. Finally, the open circles represent outliers and the asterisks identify the extremes.

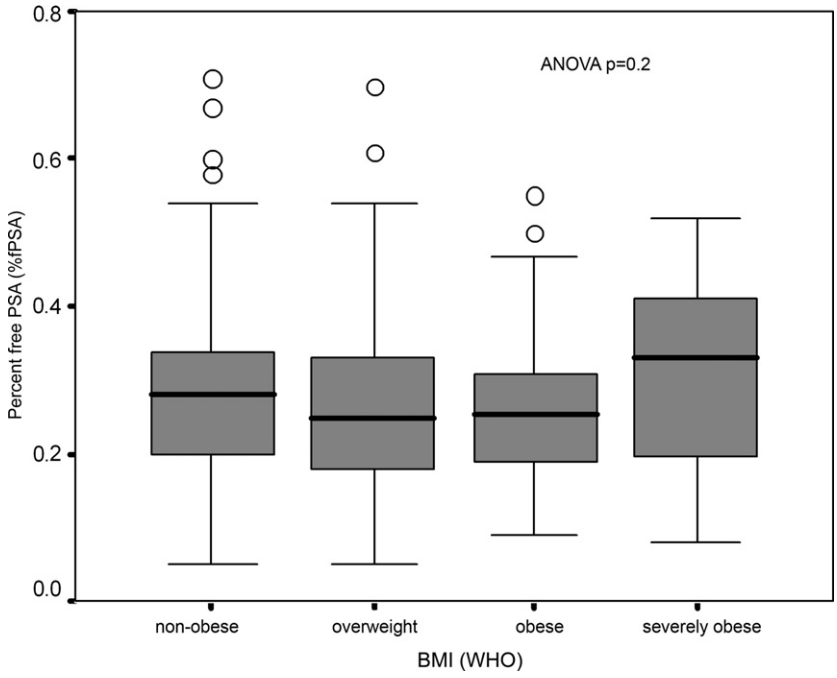

Fig. 4b – Boxplots of the distribution of %fPSA according to World Health Organization (WHO) body mass index (BMI) categories. For each boxplot the solid line represents the median. The boxes represent the 25th to 75th percentiles. The whiskers show the spread from the 2.5th to the 97.5th percentile. Finally, the open circles represent outliers and the asterisks identify the extremes.

tween BMI and PSA, as well as %fPSA. Despite different BMI coding schemes, we were unable to demonstrate that BMI was statistically significantly related to either PSA or %fPSA prior to prostate cancer diagnosis. The consideration of continuously coded BMI or categorised BMI did not change these results. Moreover, age had no effect on these correlations. Our

Table 2 – Descriptive PSA and %fPSA statistics according to WHO–BMI categories

	PSA (ng/mL)			%fPSA		
	Mean	Median	Range	Mean	Median	Range
Non-obese (BMI < 24.9 kg/m^2)	1.8	1.1	0.1–23.9	28.0	28.0	5–71
Overweight (BMI 25–29.9 kg/m^2)	1.6	1.0	0.1–26.0	26.6	25.0	5–70
Obese (BMI 30–34.9 kg/m^2)	2.1	1.0	0.2–18.3	26.1	25.5	9–55
Severely obese (BMI > 35 kg/m^2)	1.4	1.0	0.1–3.8	30.8	33.0	8–52
ANOVA	$p = 0.4$			$p = 0.2$		

BMI, body mass index; PSA, prostate specific antigen; %fPSA:, percent free PSA.

data corroborate those of Kristal and colleagues, who despite a statistically significant trend failed to demonstrate clinically meaningful differences in PSA according to BMI strata.[26] Our findings also confirm those of Thompson and colleagues, where no statistically significant relationship between BMI and PSA was found.[27] The data convincingly indicate that obesity does not affect PSA levels prior to prostate cancer diagnosis. In consequence, BMI characteristics are not likely to mask the biochemical indication for biopsy in obese men, by virtue of decreasing the levels of circulating PSA or by increasing %fPSA levels. Therefore, BMI distribution should not affect the rate or the type of early detection or screening efforts.

It should also be emphasised that some investigators found an association between BMI and serum PSA. For example, in 2006 Ahn and colleagues reported data from 2032 Korean men aged 20–39 years of age who underwent a routine hospital health checkup and found that in this cohort BMI correlated inversely with serum PSA levels.[28] Recently, Barqawi and colleagues reported data from the 2003 Prostate Cancer Awareness Week national screening program, a U.S. study including 4458 men. The authors demonstrated that men with BMI of 30 kg/m^2 or more had significantly lower PSA levels across all age groups.[29] Finally, in 2006 Fowke and colleagues explored the relationship between BMI and PSA in a prospective cohort study including 149 Caucasian and 150 African American men, aged 40–79 years.[30] This group of investigators reported decreasing trends in PSA and %fPSA levels with a greater BMI among both Caucasian and African American men. Therefore, the association between BMI and PSA may vary according to population characteristics.

Some limitations apply to our findings. These are related to the nature of our population. Specifically, our findings only apply to populations where BMI distributions are similar to the one that we observed. Conversely, different BMI distributions may be associated with different risks on prostate cancer incidence, pathology and biology. The BMI distribution of our cohort was comparable to that of Thompson and colleagues.[27]

The fact that BMI represents only one of several measures of body fat might represent another limitation. Other measures include lean body mass, waist-to-hip-ratio and waist circumference.[31] These alternative coding schemes may represent a better way to quantify the effect of body fat on prostate cancer characteristics. In consequence, studies relying on these alternative definitions may show different results.

The effect of BMI may also be small in populations with low prostate cancer prevalence, such as in Asian men. Conversely, it might be substantially higher in higher risk populations such as among African Americans. For example, higher intake of animal fat in African-American may predispose to higher BMI and to a higher rate of prostate cancer.[32] Our study addressed white French-Canadians, whose gene pool may differ from English speaking Canadians or from men from the United States. This distinctive feature represents a strength of the study. It demonstrates that the lack of BMI effect may transcend several ethnic backgrounds.[22,27] Finally, Testosteron may affect the relationship between BMI and PSA as well as %fPSA. Unfortunately, this information was not available in our population.

In conclusion, our data indicate that BMI has little if any effect on PSA distribution. They imply that obese men are not at lower risk of having abnormal PSA or %fPSA values than their non-obese counterparts. In consequence, prostate cancer screening or detection strategies may be applied to obese and non-obese men using the same approach.

Conflict of interest statement

None declared.

Acknowledgments

Pierre I. Karakiewicz is partially supported by the Fonds de la Recherche en Santé du Québec, the CHUM Foundation, the Department of Surgery and Les Urologues Associés du CHUM.

REFERENCES

1. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States,1999–2004. *JAMA* 2006;**295**:1549–55.
2. Fontaine KR, Heo M, Allison DB. Obesity and prostate cancer screening in the USA. *Public Health* 2005;**119**:694–8.
3. Seidell JC. Obesity in Europe: scaling an epidemic. *Int J Obes Relat Metab Disord* 1995;**19**(Suppl.):51–4.
4. Pietinen P, Vatiainen E, Maennistoe S. Trends in body mass index and obesity among adults in Finland from 1972 to 1992. *Int J Obes Relat Metab Disord* 1996;**20**:114–20.
5. 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.
6. 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.
7. Engeland A, Tretli S, Bjorge T. Height, body mass index, and prostate cancer: a follow-up of 950,000 Norwegian men. *Br J Cancer* 2003;**89**:1237–42.
8. Freedland SJ, Terris MK, Platz EA, Presti Jr JC. Body mass index as a predictor of prostate cancer: development versus detection on biopsy. *Urology* 2005;**66**:108–13.
9. Freedland SJ, Aronson WJ, Kane CJ, et al. Impact of obesity on biochemical control after radical prostatectomy for clinically localized prostate cancer: a report by the Shared Equal Access Regional Cancer Hospital database study group. *J Clin Oncol* 2004;**22**:446–53.
10. Amling CL, Riffenburgh RH, Sun L, et al. Pathologic variables and recurrence rates as related to obesity and race in men with prostate cancer undergoing radical prostatectomy. *J Clin Oncol* 2004;**22**:439–45.
11. 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.
12. Putnam SD, Cerhan JR, Parker AS, et al. Lifestyle and anthropometric risk factors for prostate cancer in a cohort of Iowa men. *Ann Epidemiol* 2000;**10**:361–9.
13. Rodriguez C, Patel AV, Calle EE, Jacobs EJ, Chao A, Thun MJ. Body mass index, height, and prostate cancer mortality in two large cohorts of adult men in the United States. *Cancer Epidemiol Biomarkers Prev* 2001;**10**:345–53.
14. Calle EE, Rodriguez C, Walker-Thurmond K, Thun MJ. Overweight, obesity, and mortality from cancer in a prospectively studied cohort of U.S. adults. *N Engl J Med* 2003;**348**:1625–38.
15. Parkin DM, Muir CS. Cancer incidence in five continents comparability and quality of data. *IARC Sci Publ* 1992;**120**:45–173.
16. 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.
17. Ross RK, Shimizu H, Paganini-Hill A, Honda G, Henderson BE. Case–control studies of prostate cancer in blacks and whites in southern California. *J Natl Cancer Inst* 1987;**78**:869–74.
18. West DW, Slattery ML, Robison LM, French TK, Mahoney AW. 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.
19. 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.
20. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. *World Health Organ Tech Rep Ser* 1995;**854**:1–452.
21. Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults 1999–2000. *JAMA* 2002;**288**:1723–7.
22. Freedland SJ, Platz EA, Presti Jr JC, et al. Obesity, serum prostate specific antigen and prostate size: implications for prostate cancer detection. *J Urol* 2006;**175**:500–4.
23. Mallah KN, DiBlasio CJ, Rhee AC, Scardino PT, Kattan MW. Body mass index is weakly associated with, and not a helpful predictor of, disease progression in men with clinically localized prostate carcinoma treated with radical prostatectomy. *Cancer* 2005;**103**:2030–4.
24. Chun FK et al. Body mass index does not improve the ability to predict biochemical recurrence after radical prostatectomy. *Eur J Cancer* 2006. doi:10.1016/j.ejca.2006.08.037.
25. Baillargeon J, Pollock BH, Kristal AR, et al. The association of body mass index and prostate-specific antigen in a population-based study. *Cancer* 2005;**103**:1092–5.
26. Kristal AR, Chi C, Tangen CM, Goodman PJ, Etzioni R, Thompson IM. Associations of demographic and lifestyle characteristics with prostate-specific antigen (PSA) concentration and rate of PSA increase. *Cancer* 2006;**106**:320–8.
27. Thompson IM, Leach R, Troyer D, Pollock B, Naylor S, Higgins B. Relationship of body mass index and prostate specific antigen in a population-based study. *Urol Oncol* 2004;**22**:127–31.
28. Ahn JO, Ku JH. Relationship between serum prostate-specific antigen levels and body mass index in healthy younger men. *Urology* 2006;**68**:570–4.
29. Barqawi AB, Golden BK, O'Donnell C, Brawer MK, Crawford ED. Observed effect of age and body mass index on total and complexed PSA: analysis from a national screening program. *Urology* 2005;**65**:708–12.
30. Fowke JH, Signorello LB, Chang SS, et al. Effects of obesity and height on prostate-specific antigen (PSA) and percentage of free PSA levels among African-American and Caucasian men. *Cancer* 2006;**107**:2361–7.
31. Cox BD, Whichelow M. Ratio of waist circumference to height is better predictor of death than body mass index. *BMJ* 1996;**313**:1487.
32. Hayes RB, Ziegler RG, Gridley G, et al. Dietary factors and risks for prostate cancer among blacks and whites in the United States. *Cancer Epidemiol Biomarkers Prev* 1999;**8**:25–34.