Surface Anthropometric Indices in Obesity-related Metabolic Diseases and Cancers

Chao-Yang Yang, PhD; Chien-Yu Peng, MS; Ying-Chieh Liu, PhD; Wen-Zhi Chen, PhD; Wen-Ko Chiou, PhD

Prof. Wen-Ko Chiou

Metabolic syndrome (MetS), cardiovascular diseases (CVD) and cancers such as colon cancer (CCa), prostate cancer (PCa) and breast cancer (BCa) have been recognized as obesity-initiated diseases. The development of obesity can cause changes in metabolic and hormonal conditions, which can result in the storage of excess energy in different forms in the human body. Existing anthropometric data are useful in the prognosis of these diseases. Although frequently studied, there is disagreement on the applicability, reliability and trends of weight, height, waist circumference (WC) and relevant indices. WC is generally accepted as a key marker in CVD and CCa risk assessment whereas more evidence of the usefulness of WC-CVD, WC-PCa and WC-BCa correlations is needed. The body mass index, which has been widely used as a determinant of obesity, has a strong connection with CCa risk in men and young women, but an inconsistent connection with BCa. Cross-referencing measurements, with indices such as the waist-to-height ratio (WHtR) and waist-to-hip ratio (WHR), enhances the association with diseases, e.g. WHtR-CVD and WHR-CCa, and connections are strong. This idea is further applied to multiple referencing. For example, the WHtR/WHR has been studied and found highly correlated with the MetS risk in Asia. In addition, latent issues (such as tools or techniques for surface anthropometric measurement), which could affect the prognosis of diseases, have been discussed. To this end, three-dimensional technology is suggested as a reliable tool for various anthropometric data collection and analysis in preventive medicine. *(Chang Gung Med J 2011;34:1-22)*

Key words: obesity, anthropometric indices, metabolic syndrome, cardiovascular diseases, cancer, measurement error

Obesity has been associated with negative health impacts, including metabolic syndrome (MetS), cardiovascular diseases (CVD) and some types of cancers.[1-7] During the development of these obesity-related diseases, metabolic and hormonal conditions are changed when excess energy is stored in different forms such as body fat (BF) and cholesterol. The major causative factor is thought to be hormones

From the Department of Industrial Design, Chang Gung University, Taoyuan, Taiwan.
Received: May 3, 2010; Accepted: Sep. 8, 2010
Correspondence to: Prof. Wen-Ko Chiou, Department of Industrial Design, Chang Gung University. 259, Wunhua 1st Rd., Gueishan Township, Taoyuan County 333, Taiwan (R.O.C.) Tel.: 886-3-2118800 ext. 5422; Fax: 886-3-2118500;
E-mail: wkchiu@mail.cgu.edu.tw

which mediate metabolic control (insulin and leptin), cell growth (insulin-like growth factor I, [IGF-I], and IGF-binding proteins) and reproduction (steroids and leptin).[8] Moreover, a diagnosis of MetS requires at least of 3 of 5 risk factors of CVD and diabetes including abdominal obesity, elevated fasting blood glucose, elevated blood pressure, hypertriglyceridemia, and low levels of high density lipoprotein.[9] Abdominal and visceral fat in particular have been implicated as major risk factors for MetS.[10,11]

Of the top 5 causes of cancer mortality in the United States, which are lung, colon, breast, prostate, and pancreas cancer, adiposity likely plays an important role in all but lung cancer.[12] Individuals with MetS have been found to have an elevated risk of developing colon cancer (CCa).[13-16] Breast cancer (BCa) and prostate cancer (PCa) are the most common cancers worldwide among women and men, respectivel.[17,18] Several meta-analyses have shown that body mass index (BMI) is associated with cancer risk in the colon, breast, and prostate.[19-24] However, the biological mechanisms linking obesity with increased cancer risk and mortality are not entirely consistent and many hypotheses have been generated to explain this association. For example, numerous epidemiological studies have shown that high serum levels of IGF-I correlate with increased cancer risks in PCa,[25-27] CCa[28-30] and premenopausal BCa.[31,32] There are significant associations of BMI with IGF-I levels and of all anthropometric variables, except body height (BH), with negative health outcomes.[33] Therefore, in this review, the development of CCa, PCa and BCa will be discussed in relation to surface anthropometric indices.

Recent research has suggested that the distribution of BF may affect the development of diseases. For example, adipose tissue in the thigh is protective against MetS,[34] and a high ratio of abdominal to thigh fat is most predictive of CVD.[35,36] However, the distribution of BF is difficult to measure directly through existing techniques. While BMI is the most commonly used fat-related risk index,[37] anthropometric indices of abdominal fat, such as waist circumference (WC) and waist-to-hip ratio (WHR), are better at explaining MetS, CVD and cancers relevant to adiposity.[8,38-40]

Body dimensions are related to growth, age and fitness in healthy subjects and have been used for centuries as indices for acute and long-term diseases in clinical medicine.[41] However, the need for accurate body measurements has increased as knowledge about their relationship with health risks is accumulating. Recently, three dimensional (3D) body scanning, which provides a detailed body shape, has been proposed as a sophisticated tool for accurately measuring obesity status, and allowing for the identification of those most at risk of MetS,[42-46] hypertension,[47] Type 2 diabetes[48,49] and CVD.[41,50] Body surface dimensions should not therefore be regarded as a primitive approach for describing BF distribution. 3D body scanning has a potential major role to play in both epidemiological studies of the risk of MetS and the monitoring of individual patients in response to treatment.[51] Although measuring body shape, including volumes and dimensions, can provide important information to investigators for research or clinical purposes, no single widely accepted technique can simultaneously measure the multiple variables that determine body shape.

Because of instrument imprecision and human inconsistencies, measurements are not free of error. In the measuring process, doctors play an important role in examinations of obesity and associated health risks.[52] Anthropometric studies have shown excellent reproducibility for body weight (BW), BH and derived BMI, but unsatisfactory reproducibility for WC and the WHR[52] in intra-observer and inter-measurer reproducibility of these measurements.[53-57] Serious measurement inaccuracy can influence results of health examinations and influence the diagnosis, and in this setting may result in health problems remaining undetected. If commissioners of health services are to be informed by these data, then it is important to address their reliability. External observation is recommended to improve validity.[57] By triangulating various anthropometry measurements, the chance of finding biologically true differences is increased.[58]

The main purpose of this review is to investigate the applicability of existing measurement techniques in assessing the risk of MetS, CVD, CCa, PCa and BCa. As with previous research,[5-8,59-63] this review commenced by looking at keywords such as obesity, CCa, PCa, BCa, CVD, MetS, BMI, WC and WHR, obesity-related diseases and surface anthropometrics. First, the background and present conditions of the diseases are introduced. Next, surface anthropometric indices with relationship to MetS, CVD, CCa, PCa and BCa are compared. Finally, latent issues and limitations, such as measurement errors of surface anthropometric indices, are reviewed; finally, the appropriateness of different techniques is addressed.

Surface anthropometric indices and MetS

The BMI is significantly correlated with adiposity[64,65] and can predict the BF percentage adequately when age and gender are considered.[66,67] However, the BMI is not a useful predictor of variables associated with MetS as it does not provide information on how BF is deployed.[68] There is no doubt that abdominal anthropometric indices contribute important information about abdominal obesity in relation to MetS. Several organizations advocate WC measurement as a component of the criteria for MetS.[68-72]

Table 1. Surface Anthropometric Indices and MetS in Different Regions

	Regions		Fat-related anthropometry				Description
	Asia	Others	BMI	WC	WHR	WHtR	
Lin et al., 2002[44]	Taiwan		†		†		Although BMI could be considered a marker of obesity, WHR was a better indicator of MetS disorders.
Hsieh et al., 2003[84]	Japan		†	†		†	WHtR had the highest correlation coefficient for both men and women and all ages.
Syed et al., 2009[85]	Pakistan		*		*		The combination of WHR and BMI increased the explanatory power of each index alone.
Lee et al., 2008[86]	Korea			†	†	†	WHR was less likely to be predictive for MetS risk factors compared with other anthropometry in men.
Kato et al., 2008[87]	Japan		*	*	*	*	The predictive power of WC was not less than those of the other indices and possibly was somewhat better.
Lear et al., 2002[78]	China	Europe		†			MetS risk factors significantly correlated with WC within each gender and ethnic cohort.
Perry et al., 2008[68]		Americans	*	†	†		Both WC and WHR were better correlates of MetS components than BMI. WHR appeared optimal for predicting components of MetS in white women.
Shen et al., 2006[70]		Americans		†			Among the three widely used weight-related anthropometric measures, WC had the highest cross-sectional correlation with components of MetS.
Bosy-Westphal et al., 2006[79]		Poland	†	†		†	WC and WHtR were the best predictors in both sexes. In stepwise multiple regression analyses, WHtR was the main predictor of MetS risk in both sexes combined.
Wannamethee et al., 2005[80]		British	†	†	†		BMI and WC were most strongly associated with MetS and insulin resistance in elderly men. WC could be used as a complementary measurement to identify MetS risks in normal-weight and overweight elderly persons.

Abbreviations: BMI: body mass index; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; WC: waist circumference; *: $0.01 < p \leq 0.1$, moderate correlation; †: $p \leq 0.01$, strong correlation.

However, significant clinical evidence has indicated that individual differences can affect MetS risk judgments. For example, overweight Asian individuals do not reach the cut-off point used in Western countries but still have a substantially higher risk of MetS than their leaner Asian counterparts and heavier Western counterparts.(73-75)

Recent research suggests that WC is a better index for assessing BF distribution(76) and prefer it to the WHR because of simplicity of measurement, ease of interpretation(77) and also the stronger relationship with MetS in the United States and Europe.(68,70,78-80) However, limitations of these indices have been emphasized by other investigators from a statistical point of view.(81,82) For example, short people may still face higher metabolic risks than tall people with similar WC;(80) obese and lean individuals can have equal values for the WHR; an increased WHR may indicate either increased visceral fat or reduced muscle mass as quantified by HC.(83) Accordingly, recent studies found that cross-referencing of the WHtR and WHR index results is a better index for assessing BF distribution and results in a stronger correlation with MetS in Asian.(44,73,74,84-86) However, a composite index generally has more measurement inaccuracy than either the WHtR or WHR alone.(87) This inaccuracy is generally considered to be a research limitation of sampling bias,(44,86) differential measuring definitions and human measurement errors.

Surface anthropometric indices and CVD

Studies have found that total fat as well as abdominal fat distribution play an approximately equal role in CVD.(88) Recently, a great quantity of data has confirmed the importance of central adiposity as a CVD risk factor,(89,90) with WC explaining a greater variance of the CVD risk factors than the BMI.(91)

Despite the strong association between central adiposity and CVD risks, employing anthropometric indices for CVD risk results in varied findings: (1) WC has a stronger correlation than the WHR with visceral fat(92) and CVD(89,93) (2) WC has been widely demonstrated to be a predictor of CVD risk factors in both genders(94-96) but, some studies have found a low correlation.(97) (3) In the Nurses' Health Study, both the WHR and WC accurately predicted coronary risk, especially in women.(94) (4) Researchers(98,99) have identified that the WHR is comparable to or more strongly associated with CVD than WC and the BMI whereas others(100,101) believe this is only true in women.

Among four anthropometric indices (BMI, WC, WHR and WHtR), the WHtR is the best discriminator of CVD risk factor for both genders(102-104) in Asia,(103,105) in Western countries,(106,107) and in Iran.(102) Further, the WHtR shows better CVD prediction than multiple uses of indices, e.g. cross referencing of the BMI and WC.(108) To sum up, waist-related indices are more precise than the BMI in predicting CVD in women whereas the WHtR is a more appropriate measure than the BMI and WC in men.

Surface anthropometric indices and CCa

The positive correlation between the BMI and the risk of CCa has been well studied and is generally accepted.(28) However, some studies have identified that gender differences could affect the diagnosis of CCa. For example, men with CCa show stronger correlation with a high BMI.(109-115) Some studies have found no association between the BMI and CCa in women.(110-118) One potential reason for the discrepancy is that men and women have different body shapes, i.e. the BW to BF distribution differs between genders. For example, heavier males tend to have larger abdomens whereas heavier females tend to have more gluteofemoral BF.(119) Age difference significantly affects the BMI-CCa association in women but not men, with the BMI tending to have a stronger association with CCa in young women.(120) On the contrary, WC and the WHR generally show better consistency in relation to CCa risk than the BMI,(19,121) especially in women.(118,119,122,123)

In summary, available epidemiologic evidence suggests that abdominal obesity is more predictive of CCa risk than overall obesity(109,116-119,121,124,125) for all ages, but with gender differences.(116,119,121,126) This tendency could be caused by different definitions of waist girth, i.e. standard(116,119,121) or one-inch above the navel.(126) This implies that different methods of waist measurement may have been used to predict CCa in different subjects or on different occasions.

Surface anthropometric indices and PCa

BW and its relationship with PCa is disputed. Some studies showed that overweight men have an increased risk of aggressive PCa,(127-136) while other

Table 2. Surface Anthropometric Indices and Cardiovascular Disease (CVD) by Gender

	Fat-related anthropometry				Description
	BMI	WC	WHR	WHtR	
Perry et al., 1998[93]			†_F		Higher BMI was not solely responsible for increases in CVD risk factors.
Bertsias et al., 2003[97]		†_F		†_M	WC in women and WHtR in men were strong indicators for abnormal serum lipids and lipoproteins.
Ho et al., 2001[100]	*_M	*	*_F		There were significant gender differences in the association between central or general obesity with CVD risk factors (WC_M, BMI, WC_F, WHR).
Mellati et al., 2009[102]	*	†	*	†	Area under curve of WHtR was the largest for most of the common CVD risk factors in both men and women.
Shahraki et al., 2008[221]		†_F	†_F		WC was better for predicting some CVD risk factors in young and middle-aged women; however, for older women, WHR was better.
Turcato et al., 2000[222]		†	*_F	†_F	WC was the anthropometric indicator of fat distribution most closely related to CVD risk factors in old age.
Maffeis et al., 2001[223]		†			Multivariate logistic regression analysis revealed that children with a WC above the 90th percentile for sex and age have a higher probability of having CVD risk factors.
Sharp et al., 2003[224]	*	†			Using more than one anthropometric measure in multiple regression did not improve predictions of risk over using a single predictor.
Rezende et al., 2006[225]	*	†			Most correlations between anthropometric indices and risk factors for CVD were significant, but weak. WC had the strongest correlation and was associated with the largest number of variables.
Botton et al., 2007[226]	*	*		*	The correlations between CVD risk factors and WC or WHtR were roughly similar.
Hara et al., 2002[227]		*		†	WHtR was the best predictor of CVD risk in children.

Abbreviations: M: male; F: female; BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; *: $0.01 < p \leq 0.1$, moderate correlation; †: $p \leq 0.01$, strong correlation.

studies concluded no association exists.[137-146] The correlation between the risk of total PCa incidence and BMI[147] has been further repudiated, as well as that for BH,[132,137,144,148-155] and body mass.[156] Additionally, there is little evidence for an association with central obesity.[22] Some studies found a direct relationship between PCa risk and the WHR,[157-159] whereas reports from the United States and Europe found no association.[149,152,153,160]

Apart from this inconsistency, indices have been found to be associated with PCa. Chan et al.[25] reported a strong positive association between levels

Table 3. Surface Anthropometric Indices and Colon Cancer (CCa) by Gender

	Fat-related anthropometry				Description
	BMI	WC	WHR	Others	
Adams et al., 2007[120]	†_M				BMI was related to CCa risk for young (aged 50-66 years) but not older (aged 67-71 years) women.
MacInnis et al., 2004[109]	*_M	†_M	†_M	†_BH_M †_FFM_M	Body size and composition might be related to risk of CCa in men through two different pathways, via an association with central adiposity (WC and WHR) and an association with non-adipose mass (BH and fat-free mass).
Moore et al., 2004[121]	*	*			The BMI effect was stronger for men than women. WC among women may be a stronger predictor of CCa risk than BMI.
MacInnis et al., 2006[116]	ns_F	*_F	†_F		Central adiposity measures of WHR and WC were positively associated with CCa risk.
Caan et al., 1998[126]	†	†_M ns_F	†_M †_F	†_BW	The association with BMI was stronger in certain age categories (only in men > 55 years and women < 70 years). WC was related in men only. When controlled for BMI, a WHR relationship was found for women.
Pischon et al., 2006[119]	*_M	†	†	†_BW_M	BW and BMI were statistically significantly associated with CCa risk in men but not in women. WC and WHR, indicators of abdominal obesity, were strongly associated with CCa risk in men and women.

Abbreviations: M: male; F: female; BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; BH: body height; ns: $p > 0.1$, not significant; *: $0.01 < p \le 0.1$, moderate correlation; †: $p \le 0.01$, strong correlation.

of plasma IGF-I in adults and PCa risk, and previous studies have also suggested a relationship between IGF-I and PCa,[161,162] suggesting that tall men may be exposed to higher levels of IGF-I and androgens during adolescence. Furthermore, serum prostate-specific antigen (PSA) has been widely used to detect PCa, and prostate volume and body surface area are significant factors for predicting PSA levels.[154]

Surface anthropometric indices and BCa

BCa is linked to reproductive and hormone-related factors, such as age at menarche, parity, age at menopause,[163] endogenous sex hormone levels,[164,165] and also exogenous estrogens and progestagens.[166] An increased BCa incidence occurs in parallel with increased frequency of type 2 diabetes and MetS.[167] Thus low levels of high density lipoprotein,[168] high blood glucose,[169] high triglycerides,[170] postmenopausal overweight,[171] abdominal obesity,[172] hypertension,[173] and high levels of insulin,[174] C-peptide[175] and IGF-I[166] are all associated with BCa risk.

Metabolic and hormonal factors have also been implicated in female BCa prognosis[176,177] and the relationship between body size and BCa risk has been investigated in numerous studies. Initially, studies focused on the association between body size consistency (i.e. BW[62,178-182] or BH[24,178,180,181,183]) and BCa. Recently, it has been postulated that enlarged body areas, such as the waist or hips, may play a key role in the development of BCa. Both WC and hip circumference (HC) are highly related to the risk, and also highly correlated to each other, so calculat-

Table 4. Surface Anthropometric Indices and Prostate Cancer (PCa)

	Fat-related anthropometry					Description
	BMI	WC	HC	WHR	Others	
Nilsen & Vatten, 1999(142)	ns				ns_BW	No variables (BW and BMI) displayed any consistent relation with the risk of PCa.
Putnam et al., 2000(143)	ns					BMI was only weakly and positively associated with PCa after adjustment for age.
Habel et al., 2000(144)	ns				ns_BW, BH	After adjusting for race, age, and birth year, there was no association between BH, BW, BM and PCa risk in the full cohort.
Friedenreich et al., 2004(152)	ns	ns	ns	ns	ns_BW ns_BH	All odds ratios estimated for current BW, BMI, WC, HC and WHR were close to null. No association was found between any measures of anthropometry including several derived measures of changes in weight over lifetime and PCa risk.
Dal Maso et al., 2004(153)	ns			ns	ns_BW ns_BH	BH, BW, BMI, WHR, and lean body mass 1 year before diagnosis/interview were not significantly associated with risk.
Ochiai et al., 2005(154)	ns				**_PV *_PSA ns_BW, ns_BH	Serum prostate-specific antigen (PSA) has been widely used to detect PCa. Multivariate analysis revealed that prostate volume and body surface area were significant factors for predicting the PSA level.
Lundqvist et al., 2007(155)	ns				ns_BH	No consistent associations were found for PCa either for BMI or height.
Hsing et al., 2000(157)	ns		†	†		This population-based case-control study revealed that higher levels of WHR and a smaller HC were significant risk factors for clinically overt PCa in China. These results suggested that BF distribution rather than overall obesity plays a role in PCa etiology. A larger HC was associated with a reduced risk of PCa independent of WHR.
Wallström et al., 2009(159)	ns			*		General adiposity, expressed as BMI or BF percentage, was not associated with PCa risk. WHR, a measure of central adiposity, was positively associated with PCa before age 65.
Hubbard et al., 2004(160)	ns	ns		ns		A greater WHR was associated with an increased, but not statistically significant, risk of PCa in both age-adjusted and multivariate-adjusted analyses. No associations were seen for WC.
Clarke & Whittemore, 2000(228)	ns					Overall, the data did not indicate that adiposity correlates with a higher risk of PCa.
MacInnis et al., 2003(229)	ns				ns_BF	No overall association was found between PCa and any anthropometric measurement (including BF and BMI).

Abbreviations: M: male; F: female; BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; BF: body fat; ns: $p > 0.1$, not significant; *: $0.01 < p \leq 0.1$, moderate correlation; †: $p \leq 0.01$, strong correlation.

Table 5. Surface Anthropometric Indices and Pre- and Post-menopausal Breast Cancer (BCa)

	Fat-related anthropometry					Description
	BMI	WC	HC	WHR	Others	
Folsom et al., 2000[99]	†	†		*		
Rinaldi et al., 2006[184]	†_post	†_post	†_post			WC and HC were both highly related to BCa risk, and also highly correlated with each other, so that calculating the ratio between the two measures could have attenuated the associations with BCa risk.
Shu et al., 2001[190]	*_post ns_pre			*_pre ns_post	†_post_BH †_post_BW	WHR was positively associated with both pre- and post-menopausal BCa but after adjustment for BMI, WHR was only associated with an increased risk of premenopausal BCa.
Kaaks et al., 1998[199]	ns			†		WHR but not BMI appeared to be the more specific indicator of BCa risk.
Sonnenschein et al., 1999[200]		ns		*_pre ns_post		
Galanis et al., 1998[230]	*_post					The association between BMI and postmenopausal BCa incidence was strongest among women ≥ 65 years.
Tung et al., 1999[231]	*_post ns_pre				*_pre_BH ns_post_BH ns_BW	BH and BMI were risk markers for pre- and post-menopausal BCa risk, respectively.
Li et al., 2000[232]	*_post				*_post_BW	BW and BMI affected BCa risk.
Tian et al., 2007[233]	*_post ns_pre	*_post ns_pre		*_post ns_pre		The risk for BCa increased with larger anthropometric measures including BMI, WC and WHR in post-, but not premenopausal women.
Nemesure et al., 2009[234]	ns	*_post		*_post	*_BH ns_BW	WC was associated with BCa risk among postmenopausal women, but only in those who never used hormone replacement therapy (HRT). WC and WHR yielded a significantly increased BCa risk in older women, while suggesting a protective effect in young women.
Friedenreich et al., 2002[235]	ns	*_post	*_pre	†_post; ns_pre	ns_BH ns_BW	Effect modification with HRT was found for most variables assessed in postmenopausal women, with much stronger associations found among never-users compared with users.
Shin et al., 2009[236]	†			†	†_BW	High WHR was more strongly associated with BCa risk in both premenopausal and postmenopausal women than BW or BMI.
Montazeri et al., 2008[237]	*_post				†_BH; ns_BW	
Lahmann et al., 2004[238]	†_post	*_pre	*_pre		†_post_BH ns_pre_BH	Abdominal fat assessed as WHR or WC was not related to risk when adjusted for BMI in postmenopausal women.
Lahmann et al., 2003[239]	*	ns		ns	†_BH *_BW *_BF	BW, BH, BMI and BF were positively associated with risk of BCa (adjusted age), BF showed the strongest association with BCa.
Verla-Tebit & Chang-Claude, 2005[240]					*_pre_BW	Increased BW was protective against premenopausal BCa and this effect seemed more pronounced for women who were lean in adolescence and early adulthood.
Riza et al., 2009[241]					†_post_CC	Chest circumference (CC) as a measure of upper BF adiposity appeared to be a stronger determinant of mammographic patterns than BF distribution (measured as WHR). Larger CC may be used as a proxy for upper BF distribution to assess the association with breast density at post-menopausal ages.

Abbreviations: BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; BH: body height; BW: body weight; ns: $p > 0.1$, not significant; *: $0.01 < p \leq 0.1$, moderate correlation; †: $p \leq 0.01$, strong correlation; pre: pre-menopausal; post: post-menopausal.

ing the ratio between the two measures could accurately reflect the cancer risk.(184) Additionally, indicators such as BMI,(24,185,186) WC,(182,183,186,187) and the WHR,(183,186,188,189) have all been highly associated with BCa risk. Women with central adiposity may have a higher risk of BCa than those in which BF is mainly distributed subcutaneously over the hips, buttocks and lower extremities.(183)

However, this correlation is different in the menopause group according to body indices. For example, increased BW or BMI may confer an increased BCa risk in premenopausal and postmenopausal women.(24,183,190-194) During the premenopausal period, BCa risk is associated with general adiposity (i.e. higher BW and BMI), but has little association with central adiposity (i.e. WC and WHR), whereas postmenopausal women in both general and central adiposity groups face higher BCa risks.(183,190)

Correlations between the WHR and BCa have been further examined with discrepant associations in both pre- and postmenopausal women.(195-197) For example, the WHR and BCa are reported by some researchers to be strongly linked in both the postmenopausal(99,189,198,199) and premenopausal period(190,200) whereas others reported no significant association(184) in either premenopausal(180,185,201) or postmenopausal(182,185,189,202,203) groups.

Because of the discrepancy in the correlation with these body measurements, researchers are looking for better body indices for the prognosis of BCa. As greater upper or central BF distribution is associated with multiple hormonal and metabolic changes,(204) chest circumference (CC) appears to be a stronger determinant of mammographic patterns than BF distribution (measured as the WHR). It is widely accepted that mammographic parenchyma patterns are a strong independent risk factor for BCa,(205,206) so CC is possibly an efficient risk indicator.(194,205,207)

Limitations in body surface measurements

These anthropometric measures have the potential to assist in the assessment of obesity-related MetS, CVD, CCa, and BCa risk and are also easy to perform in clinical practice. However, some limitations, which can influence both risk prognosis and nutritional status interpretation, are little considered. These include human mechanical deviations and deviations between different measuring tools.

Although measurement criteria has improved, inter-measurer issues remain an important cause of deviation.(52) Circumference measurements have shown strong inter-measurer deviations.(52,53,208,209) Differences as large as 3 cm have been obtained in measurements in the same subject.(210) Expertise also affects the outcome, as differences in measurement of more than 1 cm have been found between expert and novices.(208,209,211) Differences can be caused by the

Table 6. Inter- and Intra-Measurer Estimates of Body Composition Measurement: Correlation Coefficient of Reliability and Technical Error of Measurement (TEM) from Published Studies

	WC	HC	WHR
Sebo et al., 2008(52)	Inter 0.92	Inter 0.72	Inter 0.51
Ulijaszek & Kerr, 1998(53)	Intra 0.97	Inter 0.94	
	Intra 0.97	Inter 0.89	
Adams et al., 2002(208)	TEM 0.6	TEM 1.6	
Sonnenschein et al., 1993(213)	Intra 0.89	Intra 0.81	Intra 0.74
Meunier & Yin, 2000(218)	Intra 0.99	Intra 0.99	
Rimm et al., 1990(220)	Intra 0.88_M, 0.88_F	Intra 0.89_M, 0.88_F	Intra 0.68_M, 0.78_F
Ferrario et al., 1995(242)	Intra 0.97	Inter 0.98	Intra 0.99
	Inter 0.99	Intra 0.91	Inter 0.94

Abbreviations: WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; TEM: technical error of measurement; Inter: inter-measurer; Intra: intra-measurer; M: male; F: female.

pressure applied on subject's body while measuring, difficulty in using the instruments and the accuracy in locating the exact point of measurement of the body part.[209] For example, remaining in physical contact with subjects during application of the measuring tape may be difficult when subjects are oversized and measurers can over-manipulate the area to be measured.[96,212] Human anthropometry requires specific manipulation especially in circumference measurements; to this end, researchers have suggested that training for measurers is necessary, including definitions of measuring location and proficiency in methods.

A tape measure is considered a routine health risk assessment tool for collecting circumference measurements. However the traditional methods of determining body shape are time consuming, prone to human error[211,213-215] and show inter-measurer differences in measurements of the same subject.[210] Multiple measurements must be performed under time constraints by interviewers, clinicians and researchers in a variety of settings and hence, negate the method's value as simple and quick.[216] To efficiently reduce anthropometric measurement deviations, researchers have begun to use 3D technology in this domain.[41,217] The technology not only enhances the quality of length and circumference measurement but also provides detailed information on difficult-to-assess measurements such as body volume.[216-218] Reliable 3D anthropometry is being substituted for the traditional tape measure to improve risk management of obesity-relevant diseases.[42-46]

Three-dimensional surface anthropometry

The results of traditional measurements are widely dependent on the measurer's skill and measurement tools. Widely accepted techniques/tools are needed to measure multiple body sizes. A digitized optical method and computer to generate 3D photonic images of objects was developed decades ago, and has been used for whole-body surface anthropometric measurements in humans.[219] A 3D scan requires only a few seconds and can be used on people with various body sizes without contact with the body.[44] This method reduces human error and the data can incorporate computer-aided design and rapid prototyping.[41] This newly developed, noninvasive, whole body imaging technology could be an important frontline tool in preventing, classifying and monitoring the treatment of diseases.[41,50,217]

Conclusions

This paper has reviewed the literature on the use of body anthropometry in the prognosis of the risk of MetS, CVD, CCa, PCa and BCa in a clinical setting. As a result, efficient assessment of the risk of these diseases is illustrated by the relationships among body measurements (BW, BH, WC and HC), indices (BMI, WHtR and WHR) and diseases in existing studies (as shown in the Fig. 1). WC has a high correlation with the risk of MetS and CCa, but remains controversial in CVD. Indices and composite measurements, generally perform better as follows: (1) the BMI shows a strong connection with CCa in men and young women; (2) the WHtR is generally accepted as a CVD predictor; (3) the WHR is strongly related to the risk of both MetS and CCa. Through cross-referencing the existing indices and measurements, researchers have identified a strong correlation between the WHtR/WHR composite and MetS, whereas use of BMI/WC and BMI/WHR composites is still controversial in the prediction of CCa in women. On the other hand, body anthropometry still shows no consistent outcomes in correlation with PCa and BCa.

In conclusion, previous research has shown the great necessity of precise body measurements (especially in WC) and has brought attention to the following. (1) Latent issues such as deviations among existing indices. Individual differences in subjects in daily life (e.g. jobs, exercise and clothing) are also recognized variables affecting the efficiency of risk assessment. (2) Physical movement such as breathing (expansion and contraction of the rib cage and abdomen) could cause measuring deviation in different conditions (arm position, relaxed or tight posture).[96,218] (3) Composite measurements may lower the chance of missed prognoses (especially in CVD) through cross-referencing body parts, but higher accuracy is required.[54,55,213,220] (4) 3D technology has demonstrated reliable results, but still is not widely applied in the frontline of disease risk assessment.

Acknowledgements

The author would like to thank Miss Judy Perry and Mrs. Judy Siirila for their revision of the manuscript and Dr. Jen-Der Lin for his assistance with the

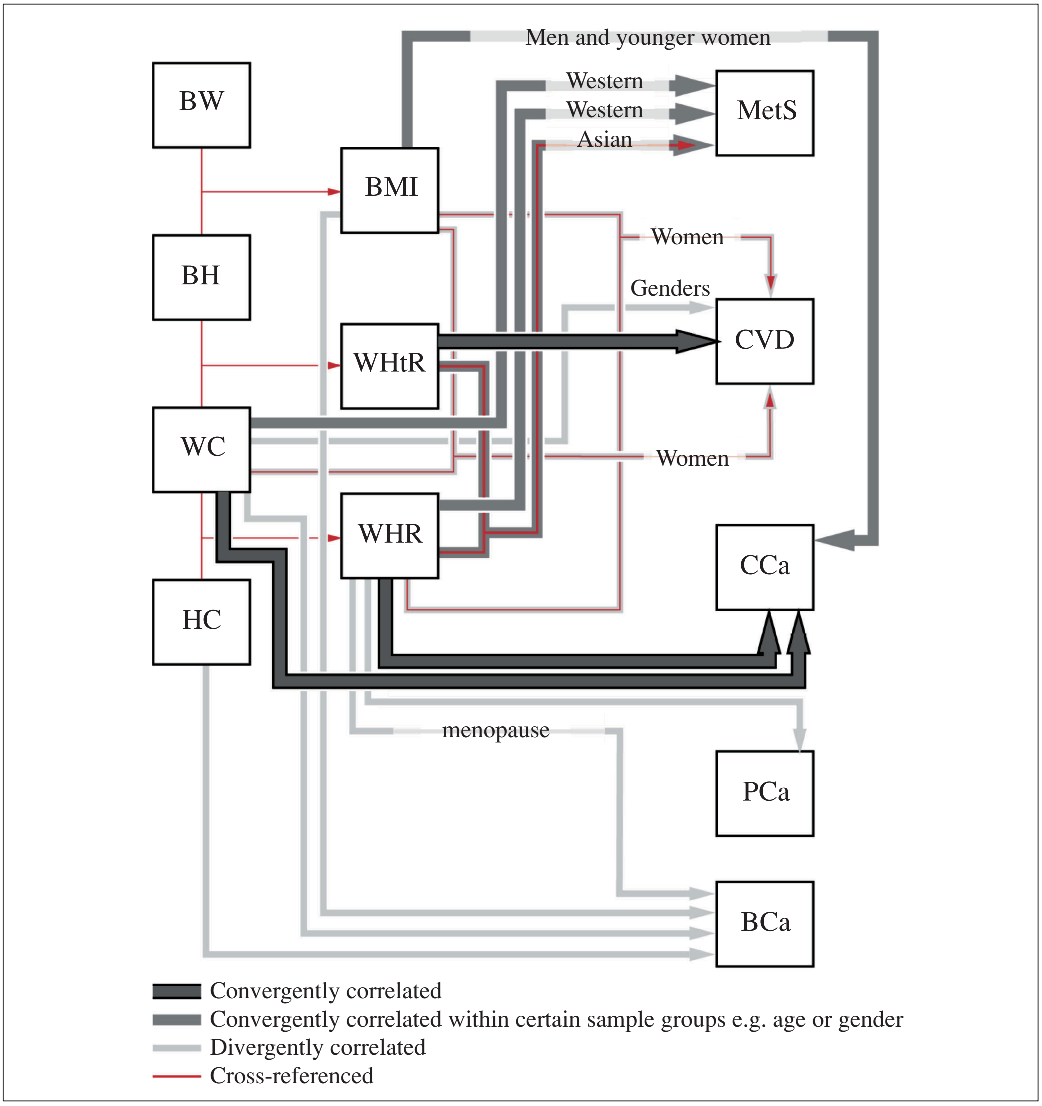

Fig. 1 Demonstration of the relationships among measurements, indices and diseases. Dark gray lines with black outlines indicate connections found in common by researchers; gray lines represent strong connections in certain demographic groups; lighter gray lines show connections still considered controversial; red thin lines demonstrate cross-reference connections. Abbreviations used: BW: body weight; BH: body height; WC: waist circumference; HC: hip circumference; BMI: body mass index; WHtR: waist-to-height ratio; WHR: waist-to-hip ratio; MetS: metabolic syndrome; CVD: cardiovascular disease; CCa: colon cancer; PCa: prostate cancer; BCa: breast cancer.

content. This research was supported by grants (NSC 89-2745-p-182-002) from the National Science Council of Taiwan, and Chang Gung Memorial Hospital (Contract No. CMRPG33008) and we thank them for financially supporting this research.

Appendices

The appendices, Table 1-6, are inserted in previous sections. In the appendices, the major references are compared with respect to demographics, fat measurements/indices and findings. The references were retrieved from a Medline search of scientific publications between 1998 and 2009 using the following keywords: obesity, CCa, PCa, BCa, CVD, MetS, BMI, WC, WHR and WHtR.

REFERENCES

1. Manson JE, Willett WC, Stampfer MJ, Colditz GA, Hunter DJ, Hankinson SE, Hennekens CH, Speizer FE. Body weight and mortality among women. N Engl J Med 1995;333:677-85.
2. Institute NHLaB, National Institutes of Health. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. Obes Res 1998;6:51S-209S.
3. Calle EE, Thun MJ, Petrelli JM, Rodriguez C, Heath CW Jr. Body-mass index and mortality in a prospective cohort of U.S. adults. N Engl J Med 1999;341:1097-105.
4. National Task Force on the Prevention Treatment of Obesity. Overweight, obesity, and health risk. Arch Intern Med 2000;160:898-904.
5. Irigaray P, Newby JA, Lacomme S, Belpomme D. Overweight/obesity and cancer genesis: more than a biological link. Biomed Pharmacother 2007;61:665-78.
6. Renehan A, Tyson M, Egger M, Heller RF, Zwahlen M. Body-mass index and incidence of cancer: a systematic review and meta-analysis of prospective observational studies. Lancet 2008;371:569-78.
7. Fader AN, Arriba LN, Frasure HE, von Gruenigen VE. Endometrial cancer and obesity: epidemiology, biomarkers, prevention and survivorship. Gynecol Oncol 2009;114:121-7.
8. Anderson A, Caswell S. Obesity management: an opportunity for cancer prevention. Surgeon 2009;7:282-5.
9. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, Gordon DJ, Krauss RM, Savage PJ, Smith SC Jr, Spertus JA, Costa F; American Heart Association; National Heart, Lung, and Blood Institute. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation 2005;112:2735-52.
10. Kissebah AH, Vydelingum N, Murray R, Evans DJ, Hartz AJ, Kalkhoff RK, Adams PW. Relation of body fat distribution to metabolic complications of obesity. J Clin Endocrinol Metab 1982;54:254-60.
11. Björntorp P. Abdominal obesity and the development of noninsulin-dependent diabetes mellitus. Diabetes Metab Rev 1988;4:615-22.
12. Giovannucci E, Michaud D. The role of obesity and related metabolic disturbances in cancers of the colon, prostate, and pancreas. Gastroenterology 2007;132:2208-25.
13. Trevisan M, Liu J, Muti P, Misciagna G, Menotti A, Fucci F. Risk Factors and Life Expectancy Research Group. Markers of insulin resistance and colorectal cancer mortality. Cancer Epidemiol Biomarkers Prev 2001;10:937-41.
14. Colangelo LA, Gapstur SM, Gann PH, Dyer AR, Liu K. Colorectal cancer mortality and factors related to the insulin resistance syndrome. Cancer Epidemiol Biomarkers Prev 2002;11:385-91.
15. Ahmed RL, Schmitz KH, Anderson KE, Rosamond WD, Folsom AR. The metabolic syndrome and risk of incident colorectal cancer. Cancer 2006;107:28-36.
16. Bowers K, Albanes D, Limburg P, Pietinen P, Taylor PR, Virtamo J, Stolzenberg-Solomon R. A prospective study of anthropometric and clinical measurements associated with insulin resistance syndrome and colorectal cancer in male smokers. Am J Epidemiol 2006;164:652-64.
17. Parkin DM, Pisani P, Ferlay J. Estimates of the worldwide incidence of 25 major cancers in 1990. Int J Cancer 1999;80:827-41.
18. Jemal A, Siegel R, Ward E, Murray T, Xu J, Thun MJ. Cancer Statistics, 2007. CA Cancer J Clin 2007;57:43-66.
19. Larsson SC, Wolk A. Obesity and colon and rectal cancer risk: a meta-analysis of prospective studies. Am J Clin Nutr 2007;86:556-65.
20. Bergstrom A, Pisani P, Tenet V, Wolk A, Adami HO. Overweight as an avoidable cause of cancer in Europe. Int J Cancer 2001;91:421-30.
21. Kubo A, Corley DA. Body mass index and adenocarcinomas of the esophagus or gastric cardia: a systematic review and meta-analysis. Cancer Epidemiol Biomarkers Prev 2006;15:872-8.
22. MacInnis RJ, English DR. Body size and composition and prostate cancer risk: systematic review and meta-regression analysis. Cancer Causes Control 2006;17:989-1003.
23. Ursin G, Longnecker MP, Haile RW, Greenland S. A meta-analysis of body mass index and risk of premenopausal breast cancer. Epidemiology 1995;6:137-41.
24. van den Brandt PA, Spiegelman D, Yaun SS, Adami HO, Beeson L, Folsom AR, Fraser G, Goldbohm RA, Graham S, Kushi L, Marshall JR, Miller AB, Rohan T, Smith-Warner SA, Speizer FE, Willett WC, Wolk A, Hunter DJ. Pooled analysis of prospective cohort studies on height, weight, and breast cancer risk. Am J Epidemiol 2000;152:514-27.
25. Chan JM, Stampfer MJ, Giovannucci E, Gann PH, Ma J, Wilkinson P, Hennekens CH, Pollak M. Plasma insulin-like growth factor-I and prostate cancer risk: a prospective study. Science 1998;279:563-6.
26. Chan JM, Stampfer MJ, Ma J, Gann P, Gaziano JM, Pollak M, Giovannucci E. Insulin-like growth factor-I (IGF-I) and IGF binding protein-3 as predictors of advanced-stage prostate cancer. J Natl Cancer Inst 2002;94:1099-106.

27. Stattin P, Rinaldi S, Stenman UH, Riboli E, Hallmans G, Bergh A, Kaaks R. Plasma prolactin and prostate cancer risk: a prospective study. Int J Cancer 2001;92:463-5.
28. Giovannucci E. Insulin, insulin-like growth factors and colon cancer: a review of the evidence. J Nutr 2001;131:3109S-20S.
29. Ma J, Pollak M, Giovannucci E, Chan JM, Tao Y, Hennekens C, Stampfer MJ. A prospective study of plasma levels of insulin-like growth factor I (IGF-I) and IGF-binding protein-3, and colorectal cancer risk among men. Growth Horm IGF Res 2000;10:28S-9S.
30. Ma J, Pollak MN, Giovannucci E, Chan JM, Tao Y, Hennekens CH, Stampfer MJ. Prospective study of colorectal cancer risk in men and plasma levels of insulin-like growth factor I (IGF-I) and IGF-binding protein-3. J Natl Cancer Inst 1999;91:620-5.
31. Allen NE, Roddam AW, Allen DS, Fentiman IS, Dos Santos Silva I, Peto J, Holly JM, Key TJ. A prospective study of serum insulin-like growth factor-I (IGF-I), IGF-II, IGF-binding protein-3 and breast cancer risk. Br J Cancer 2005;92:1283-7.
32. Renehan AG, Harvie M, Howell A. Insulin-like growth factor (IGF)-I, IGF binding protein-3, and breast cancer risk: eight years on. Endocr Relat Cancer 2006;13:273-8.
33. Faupel-Badger JM, Berrigan D, Ballard-Barbash R, Potischman N. Anthropometric correlates of insulin-like growth factor 1 (IGF-1) and IGF binding protein-3 (IGFBP-3) levels by race/ethnicity and gender. Ann Epidemiol 2009;19:841-9.
34. Kahn HS, Austin H, Williamson DF, Arensberg D. Simple anthropometric indices associated with ischemic heart disease. J Clin Epidemiol 1996;49:1017-24.
35. Smith DA, Ness EM, Herbert R, Schechter CB, Phillips RA, Diamond JA, Landrigan PJ. Abdominal diameter index: a more powerful anthropometric measure for prevalent coronary heart disease risk in adult males. Diabetes Obes Metab 2005;7:370-80.
36. Snijder MB, Visser M, Dekker JM, Goodpaster BH, Harris TB, Kritchevsky SB, De Rekeneire N, Kanaya AM, Newman AB, Tylavsky FA, Seidell JC; Health ABC Study. Low subcutaneous thigh fat is a risk factor for unfavourable glucose and lipid levels, independently of high abdominal fat. The Health ABC Study. Diabetologia 2005;48:301-8.
37. Hu FB, Willett WC, Li T, Stampfer MJ, Colditz GA, Manson JE. Adiposity as compared with physical activity in predicting mortality among women. N Engl J Med 2004;351:2694-703.
38. Larsson SC, Andersson SO, Johansson JE, Wolk A. Diabetes mellitus, body size and bladder cancer risk in a prospective study of Swedish men. Eur J Cancer 2008;44:2655-60.
39. Wilson PW, D'Agostino RB, Sullivan L, Parise H, Kannel WB. Overweight and obesity as determinants of cardiovascular risk: the Framingham experience. Arch Intern Med 2002;162:1867-72.
40. Yusuf S, Hawken S, Ounpuu S, Bautista L, Franzosi MG, Commerford P, Lang CC, Rumboldt Z, Onen CL, Lisheng L, Tanomsup S, Wangai P Jr, Razak F, Sharma AM, Anand SS; INTERHEART Study Investigators. Obesity and the risk of myocardial infarction in 27,000 participants from 52 countries: a case-control study. Lancet 2005;366:1640-9.
41. Wang J, Gallagher D, Thornton JC, Yu W, Horlick M, Pi-Sunyer FX. Validation of a 3-dimensional photonic scanner for the measurement of body volumes, dimensions, and percentage body fat. Am J Clin Nutr 2006;83:809-16.
42. Lin JD, Chiou WK, Chang HY, Liu FH, Weng HF, Liu TH. Association of hematological factors with components of the metabolic syndrome in older and younger adults. Aging Clin Exp Res 2006;18:477-84.
43. Lin JD, Chiou WK, Weng HF, Fang JT, Liu TH. Application of three-dimensional body scanner: observation of prevalence of metabolic syndrome. Clin Nutr 2004;23:1313-23.
44. Lin JD, Chiou WK, Weng HF, Tsai YH, Liu TH. Comparison of three-dimensional anthropometric body surface scanning to waist-hip ratio and body mass index in correlation with metabolic risk factors. J Clin Epidemiol 2002;55:757-66.
45. Chiou WK, Lin JD, Weng HF, Ou YC, Liu TH, Fang JT. Correlation of the dysmetabolic risk factors with different anthropometric measurements. Endocr J 2005;52: 139-48.
46. Lin JD, Chiou WK, Chang HY, Liu FH, Weng HF. Serum uric acid and leptin levels in metabolic syndrome: a quandary over the role of uric acid. Metabolism 2007;56:751-6.
47. Chiu C, Hsu KH, Hsu PL, Hsu CI, Lee PC, Chiou WK, Liu TH, Chuang YC, Hwang CJ. Mining three-dimensional anthropometric body surface scanning data for hypertension detection. IEEE Trans Inf Technol Biomed 2007;11:264-73.
48. Chuang YC, Hsu KH, Hwang CJ, Hu PM, Lin TM, Chiou WK. Waist-to-thigh ratio can also be a better indicator associated with type 2 diabetes than traditional anthropometrical measurements in Taiwan population. Ann Epidemiol 2006;16:321-31.
49. Su CT, Yang CH, Hsu KH, Chiu WK. Data mining for the diagnosis of type II diabetes from three-dimensional body surface anthropometrical scanning data. Comput Math Appl 2006;51:1075-92.
50. Wells JC, Treleaven P, Cole TJ. BMI compared with 3-dimensional body shape: the UK National Sizing Survey. Am J Clin Nutr 2007;85:419-25.
51. Wells JC, Cole T, Treleaven P. Age-variability in body shape associated with excess weight: the UK National Sizing Survey. Obesity 2008;16:435-41.
52. Sebo P, Beer-Borst S, Haller DM, Bovier PA. Reliability

of doctors' anthropometric measurements to detect obesity. Prev Med 2008;47:389-93.
53. Ulijaszek SJ, Kerr DA. Anthropometric measurement error and the assessment of nutritional status. Br J Nutr 1999;82:165-77.
54. Nordhamn K, Södergren E, Olsson E, Karlström B, Vessby B, Berglund L. Reliability of anthropometric measurements in overweight and lean subjects: consequences for correlations between anthropometric and other variables. Int J Obes Relat Metab Disord 2000;24:652-7.
55. Chen MM, Lear SA, Gao M, Frohlich JJ, Birmingham CL. Intraobserver and interobserver reliability of waist circumference and the waist-to-hip ratio. Obes Res 2001;9:651.
56. Moreno LA, Joyanes M, Mesana MI, González-Gross M, Gil CM, Sarría A, Gutierrez A, Garaulet M, Perez-Prieto R, Bueno M, Marcos A; AVENA Study Group. Harmonization of anthropometric measurements for a multicenter nutrition survey in Spanish adolescents. Nutrition 2003;19:481-6.
57. Wang J, Thornton JC, Bari S, Williamson B, Gallagher D, Heymsfield SB, Horlick M, Kotler D, Laferrère B, Mayer L, Pi-Sunyer FX, Pierson RN Jr. Comparisons of waist circumferences measured at 4 sites. Am J Clin Nutr 2003;77:379-84.
58. Harris EF, Smith RN. Accounting for measurement error: a critical but often overlooked process. Arch Oral Biol 2009;54:107S-17S.
59. Giovannucci E, Liu Y, Platz EA, Stampfer MJ, Willett WC. Risk factors for prostate cancer incidence and progression in the health professionals follow-up study. Int J Cancer 2007;121:1571-8.
60. Buschemeyer WC 3rd, Freedland SJ. Obesity and prostate cancer: epidemiology and clinical implications. Eur Urol 2007;52:331-43.
61. Landau-Ossondo M, Rabia N, Jos-Pelage J, Marquet LM, Isidore Y, Saint-Aimé C, Martin M, Irigaray P, Belpomme D; ARTAC international research group on pesticides. Why pesticides could be a common cause of prostate and breast cancers in the French Caribbean Island, Martinique. an overview on key mechanisms of pesticide-induced cancer. Biomed Pharmacother 2009;63:383-95.
62. Carmichael AR, Bates T. Obesity and breast cancer: a review of the literature. Breast 2004;13:85-92.
63. Pichard C, Plu-Bureau G, Neves-E Castro M, Gompel A. Insulin resistance, obesity and breast cancer risk. Maturitas 2008;60:19-30.
64. Craig P, Samaras K, Freund J, Culton N, Halavatau V, Campbell L. BMI inaccurately reflects total body and abdominal fat in Tongans. Acta Diabetol 2003;40:282S-5S.
65. Shiwaku K, Anuurad E, Enkhmaa B, Nogi A, Kitajima K, Yamasaki M, Yoneyama T, Oyunsuren T, Yamane Y. Predictive values of anthropometric measurements for multiple metabolic disorders in Asian populations. Diabetes Res Clin Pract 2005;69:52-62.
66. Baumgartner RN, Heymsfield SB, Roche AF. Human body composition and the epidemiology of chronic disease. Obes Res 1995;3:73-95.
67. Seidell JC, Visscher TL. Body weight and weight change and their health implications for the elderly. Eur J Clin Nutr 2000;54:33S-9S.
68. Perry A, Wang X, Kuo YT. Anthropometric correlates of metabolic syndrome components in a diverse sample of overweight/obese women. Ethn Dis 2008;18:163-8.
69. Asayama K, Dobashi K, Hayashibe H, Kodera K, Uchida N, Nakane T, Araki T, Nakazawa S. Threshold values of visceral fat measures and their anthropometric alternatives for metabolic derangement in Japanese obese boys. Int J Obes Relat Metab Disord 2002;26:208-13.
70. Shen W, Punyanitya M, Chen J, Gallagher D, Albu J, Pi-Sunyer X, Lewis CE, Grunfeld C, Heshka S, Heymsfield SB. Waist circumference correlates with metabolic syndrome indicators better than percentage fat. Obesity 2006;14:727-36.
71. Chuang SY, Pan WH. Predictability and implications of anthropometric indices for metabolic abnormalities in children: nutrition and health survey in Taiwan elementary children, 2001-2002. Asia Pac J Clin Nutr 2009;18:272-9.
72. Hirschler V, Aranda C, Calcagno Mde L, Maccalini G, Jadzinsky M. Can waist circumference identify children with the metabolic syndrome? Arch Pediatr Adolesc Med 2005;159:740-4.
73. Feng Y, Hong X, Li Z, Zhang W, Jin D, Liu X, Zhang Y, Hu FB, Wei LJ, Zang T, Xu X, Xu X. Prevalence of metabolic syndrome and its relation to body composition in a Chinese rural population. Obesity 2006;14:2089-98.
74. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157-63.
75. Wells JC, Cole TJ, Bruner D, Treleaven P. Body shape in American and British adults: between-country and inter-ethnic comparisons. Int J Obes 2008;32:152-9.
76. Allison DB, Paultre F, Goran MI, Poehlman ET, Heymsfield SB. Statistical considerations regarding the use of ratios to adjust data. Int J Obes Relat Metab Disord 1995;19:644-52.
77. Pouliot MC, Després JP, Lemieux S, Moorjani S, Bouchard C, Tremblay A, Nadeau A, Lupien PJ. Waist circumference and abdominal sagittal diameter: best simple anthropometric indexes of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. Am J Cardiol 1994;73:460-8.
78. Lear SA, Chen MM, Frohlich JJ, Birmingham CL. The relationship between waist circumference and metabolic risk factors: cohorts of European and Chinese descent. Metabolism 2002;51:1427-32.

79. Bosy-Westphal A, Geisler C, Onur S, Korth O, Selberg O, Schrezenmeir J, Miller MJ. Value of body fat mass vs anthropometric obesity indices in the assessment of metabolic risk factors. Int J Obes 2006;30:475-83.
80. Wannamethee SG, Shaper AG, Morris RW, Whincup PH. Measures of adiposity in the identification of metabolic abnormalities in elderly men. Am J Clin Nutr 2005;81:1313-21.
81. Seidell JC, Pérusse L, Després JP, Bouchard C. Waist and hip circumferences have independent and opposite effects on cardiovascular disease risk factors: the Quebec Family Study. Am J Clin Nutr 2001;74:315-21.
82. Kronmal RA. Spurious correlation and the fallacy of the ratio standard revisited. J R Stat Soc A Stat 1993;156:379-92.
83. Molarius A, Seidell JC. Selection of anthropometric indicators for classification of abdominal fatness: a critical review. Int J Obes Relat Metab Disord 1998;22:719-27.
84. Hsieh SD, Yoshinaga H, Muto T. Waist-to-height ratio, a simple and practical index for assessing central fat distribution and metabolic risk in Japanese men and women. Int J Obes Relat Metab Disord 2003;27:610-6.
85. Syed S, Hingorjo MR, Charania A, Qureshi MA. Anthropometric and metabolic indicators in hypertensive patients. J Coll Physicians Surg Pak 2009;19:421-7.
86. Lee K, Song YM, Sung J. Which obesity indicators are better predictors of metabolic risk? healthy twin study. Obesity 2008;16:834-40.
87. Kato M, Takahashi Y, Inoue M, Tsugane S, Kadowaki T, Noda M; JPHC Study Group. Comparisons between anthropometric indices for predicting the metabolic syndrome in Japanese. Asia Pac J Clin Nutr 2008;17:223-8.
88. Ledoux M, Lambert J, Reeder BA, Després JP. Correlation between cardiovascular disease risk factors and simple anthropometric measures. Canadian Heart Health Surveys Research Group. CMAJ 1997;157:46S-53S.
89. Hsieh SD, Yoshinaga H. Abdominal fat distribution and coronary heart disease risk factors in men-waist/height ratio as a simple and useful predictor. Int J Obes Relat Metab Disord 1995;19:585-9.
90. Hsieh SD, Yoshinaga H. Waist-height ratio as a simple and useful predictor of coronary heart disease risk factors in women. Intern Med 1995;34:1147-52.
91. Lear SA, Toma M, Birmingham CL, Frohlich JJ. Modification of the relationship between simple anthropometric indices and risk factors by ethnic background. Metabolism 2003;52:1295-301.
92. Rankinen T, Kim SY, Pérusse L, Després JP, Bouchard C. The prediction of abdominal visceral fat level from body composition and anthropometry: ROC analysis. Int J Obes Relat Metab Disord 1999;23:801-9.
93. Perry AC, Applegate EB, Allison MD, Jackson ML, Miller PC. Clinical predictability of the waist-to-hip ratio in assessment of cardiovascular disease risk factors in overweight, premenopausal women. Am J Clin Nutr 1998;68:1022-7.
94. Rexrode KM, Carey VJ, Hennekens CH, Walters EE, Colditz GA, Stampfer MJ, Willett WC, Manson JE. Abdominal adiposity and coronary heart disease in women. JAMA 1998;280:1843-8.
95. Wang Z, Hoy WE. Waist circumference, body mass index, hip circumference and waist-to-hip ratio as predictors of cardiovascular disease in Aboriginal people. Eur J Clin Nutr 2004;58:888-93.
96. Wang J. Waist circumference: a simple, inexpensive, and reliable tool that should be included as part of physical examinations in the doctor’s office. Am J Clin Nutr 2003;78:902-3.
97. Bertsias G, Mammas I, Linardakis M, Kafatos A. Overweight and obesity in relation to cardiovascular disease risk factors among medical students in Crete, Greece. BMC Public Health 2003;3:3.
98. Walker SP, Rimm EB, Ascherio A, Kawachi I, Stampfer MJ, Willett WC. Body size and fat distribution as predictors of stroke among US men. Am J Epidemiol 1996;144:1143-50.
99. Folsom AR, Kushi LH, Anderson KE, Mink PJ, Olson JE, Hong CP, Sellers TA, Lazovich D, Prineas RJ. Associations of general and abdominal obesity with multiple health outcomes in older women: the Iowa Women’s Health Study. Arch Intern Med 2000;160:2117-28.
100. Ho SC, Chen YM, Woo JL, Leung SS, Lam TH, Janus ED. Association between simple anthropometric indices and cardiovascular risk factors. Int J Obes Relat Metab Disord. 2001;25:1689-97.
101. Weisell RC. Body mass index as an indicator of obesity. Asia Pac J Clin Nutr 2002;8:681S-4S.
102. Mellati AA, Mousavinasab SN, Sokhanvar S, Kazemi SA, Esmailli MH, Dinmohamadi H. Correlation of anthropometric indices with common cardiovascular risk factors in an urban adult population of Iran: data from Zanjan Healthy Heart Study. Asia Pac J Clin Nutr 2009;18:217-25.
103. Ho SY, Lam TH, Janus ED; Hong Kong Cardiovascular Risk Factor Prevalence Study Steering Committee. Waist to stature ratio is more strongly associated with cardiovascular risk factors than other simple anthropometric indices. Ann Epidemiol 2003;13:683-91.
104. Lee CM, Huxley RR, Wildman RP, Woodward M. Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. J Clin Epidemiol 2008;61:646-53.
105. Aekplakorn W, Kosulwat V, Suriyawongpaisal P. Obesity indices and cardiovascular risk factors in Thai adults. Int J Obes 2006;30:1782-90.
106. Dalton M, Cameron AJ, Zimmet PZ, Shaw JE, Jolley D, Dunstan DW, Welborn TA; AusDiab Steering Committee. Waist circumference, waist-hip ratio and body mass index and their correlation with cardiovascu-

lar disease risk factors in Australian adults. J Intern Med 2003;254:555-63.
107. Schneider HJ, Glaesmer H, Klotsche J, Böhler S, Lehnert H, Zeiher AM, März W, Pittrow D, Stalla GK, Wittchen HU; DETECT Study Group. Accuracy of anthropometric indicators of obesity to predict cardiovascular risk. J Clin Endocrinol Metab 2007;92:589-94.
108. Zhu S, Heshka S, Wang Z, Shen W, Allison DB, Ross R, Heymsfield SB. Combination of BMI and waist circumference for identifying cardiovascular risk factors in whites. Obes Res 2004;12:633-45.
109. MacInnis RJ, English DR, Hopper JL, Haydon AM, Gertig DM, Giles GG. Body size and composition and colon cancer risk in men. Cancer Epidemiol Biomarkers Prev 2004;13:553-9.
110. Terry P, Giovannucci E, Bergkvist L, Holmberg L, Wolk A. Body weight and colorectal cancer risk in a cohort of Swedish women: relation varies by age and cancer site. Br J Cancer 2001;85:346-9.
111. Terry PD, Miller AB, Rohan TE. Obesity and colorectal cancer risk in women. Gut 2002;51:191-4.
112. Lin J, Zhang SM, Cook NR, Rexrode KM, Lee IM, Buring JE. Body mass index and risk of colorectal cancer in women (United States). Cancer Causes Control 2004;15:581-9.
113. Ford ES. Body mass index and colon cancer in a national sample of adult US men and women. Am J Epidemiol 1999;150:390-8.
114. Murphy TK, Calle EE, Rodriguez C, Kahn HS, Thun MJ. Body mass index and colon cancer mortality in a large prospective study. Am J Epidemiol 2000;152:847-54.
115. Shimizu N, Nagata C, Shimizu H, Kametani M, Takeyama N, Ohnuma T, Matsushita S. Height, weight, and alcohol consumption in relation to the risk of colorectal cancer in Japan: a prospective study. Br J Cancer 2003;88:1038-43.
116. MacInnis RJ, English DR, Hopper JL, Gertig DM, Haydon AM, Giles GG. Body size and composition and colon cancer risk in women. Int J Cancer 2006;118:1496-500.
117. Martínez ME, Giovannucci E, Spiegelman D, Hunter DJ, Willett WC, Colditz GA. Leisure-time physical activity, body size, and colon cancer in women. Nurses' Health Study Research Group. J Natl Cancer Inst 1997;89:948-55.
118. Bostick RM, Potter JD, Kushi LH, Sellers TA, Steinmetz KA, McKenzie DR, Gapstur SM, Folsom AR. Sugar, meat, and fat intake, and non-dietary risk factors for colon cancer incidence in Iowa women (United States). Cancer Causes Control 1994;5:38-52.
119. Pischon T, Lahmann PH, Boeing H, Friedenreich C, Norat T, Tjønneland A, Halkjaer J, Overvad K, Clavel-Chapelon F, Boutron-Ruault MC, Guernec G, Bergmann MM, Linseisen J, Becker N, Trichopoulou A, Trichopoulos D, Sieri S, Palli D, Tumino R, Vineis P, Panico S, Peeters PH, Bueno-de-Mesquita HB, Boshuizen HC, Van Guelpen B, Palmqvist R, Berglund G, Gonzalez CA, Dorronsoro M, Barricarte A, Navarro C, Martinez C, Quirós JR, Roddam A, Allen N, Bingham S, Khaw KT, Ferrari P, Kaaks R, Slimani N, Riboli E. Body size and risk of colon and rectal cancer in the European Prospective Investigation Into Cancer and Nutrition (EPIC). J Natl Cancer Inst 2006;98:920-31.
120. Adams KF, Leitzmann MF, Albanes D, Kipnis V, Mouw T, Hollenbeck A, Schatzkin A. Body mass and colorectal cancer risk in the NIH-AARP cohort. Am J Epidemiol 2007;166:36-45.
121. Moore LL, Bradlee ML, Singer MR, Splansky GL, Proctor MH, Ellison RC, Kreger BE. BMI and waist circumference as predictors of lifetime colon cancer risk in Framingham Study adults. Int J Obes Relat Metab Disord 2004;28:559-67.
122. Russo A, Franceschi S, La Vecchia C, Dal Maso L, Montella M, Conti E, Giacosa A, Falcini F, Negri E. Body size and colorectal-cancer risk. Int J Cancer 1998;78:161-5.
123. Giovannucci E, Colditz GA, Stampfer MJ, Willett WC. Physical activity, obesity, and risk of colorectal adenoma in women (United States). Cancer Causes Control 1996;7:253-63.
124. Giovannucci E, Ascherio A, Rimm EB, Colditz GA, Stampfer MJ, Willett WC. Physical activity, obesity, and risk for colon cancer and adenoma in men. Ann Intern Med 1995;122:327-34.
125. Larsson SC, Rutegård J, Bergkvist L, Wolk A. Physical activity, obesity, and risk of colon and rectal cancer in a cohort of Swedish men. Eur J Cancer 2006;42:2590-7.
126. Caan BJ, Coates AO, Slattery ML, Potter JD, Quesenberry CP Jr, Edwards SM. Body size and the risk of colon cancer in a large case-control study. Int J Obes Relat Metab Disord 1998;22:178-84.
127. Lew EA, Garfinkel L. Variations in mortality by weight among 750,000 men and women. J Chronic Dis 1979;32:563-76.
128. Snowdon DA, Phillips RL, Choi W. Diet, obesity, and risk of fatal prostate cancer. Am J Epidemiol 1984;120:244-50.
129. Thompson MM, Garland C, Barrett-Connor E, Khaw KT, Friedlander NJ, Wingard DL. Heart disease risk factors, diabetes, and prostatic cancer in an adult community. Am J Epidemiol 1989;129:511-7.
130. Chyou PH, Nomura AM, Stemmermann GN. A prospective study of weight, body mass index and other anthropometric measurements in relation to site-specific cancers. Int J Cancer 1994;57:313-7.
131. 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.
132. Cerhan JR, Torner JC, Lynch CF, Rubenstein LM, Lemke JH, Cohen MB, Lubaroff DM, Wallace RB. 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.
133. Veierød MB, Laake P, Thelle DS. Dietary fat intake and risk of prostate cancer: a prospective study of 25,708 Norwegian men. Int J Cancer 1997;73:634-8.
134. 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.
135. Littman AJ, White E, Kristal AR. Anthropometrics and prostate cancer risk. Am J Epidemiol 2007;165:1271-9.
136. Rodriguez C, Freedland SJ, Deka A, Jacobs EJ, McCullough ML, Patel AV, Thun MJ, Calle EE. Body mass index, weight change, and risk of prostate cancer in the Cancer Prevention Study II Nutrition Cohort. Cancer Epidemiol Biomarkers Prev 2007;16:63-9.
137. Giovannucci E, Rimm EB, Stampfer MJ, Colditz GA, Willett WC. Height, body weight, and risk of prostate cancer. Cancer Epidemiol Biomarkers Prev 1997;6:557-63.
138. Mills PK, Beeson WL, Phillips RL, Fraser GE. Cohort study of diet, lifestyle, and prostate cancer in Adventist men. Cancer 1989;64:598-604.
139. Greenwald P, Damon A, Kirmss V, Polan AK. Physical and demographic features of men before developing cancer of the prostate. J Natl Cancer Inst 1974;53:341-6.
140. Whittemore AS, Paffenbarger RS Jr, Anderson K, Lee JE. Early precursors of site-specific cancers in college men and women. J Natl Cancer Inst 1985;74:43-51.
141. Le Marchand L, Kolonel LN, Wilkens LR, Myers BC, Hirohata T. Animal fat consumption and prostate cancer: a prospective study in Hawaii. Epidemiology 1994;5:276-82.
142. Nilsen TI, Vatten LJ. Anthropometry and prostate cancer risk: a prospective study of 22,248 Norwegian men. Cancer Causes Control 1999;10:269-75.
143. Putnam SD, Cerhan JR, Parker AS, Bianchi GD, Wallace RB, Cantor KP, Lynch CF. Lifestyle and anthropometric risk factors for prostate cancer in a cohort of Iowa men. Ann Epidemiol 2000;10:361-9.
144. Habel LA, Van Den Eeden SK, Friedman GD. Body size, age at shaving initiation, and prostate cancer in a large, multiracial cohort. Prostate 2000;43:136-43.
145. Schuurman AG, Goldbohm RA, Dorant E, van den Brandt PA. Anthropometry in relation to prostate cancer risk in the Netherlands Cohort Study. Am J Epidemiol 2000;151:541-9.
146. Gapstur SM, Gann PH, Colangelo LA, Barron-Simpson R, Kopp P, Dyer A, Liu K. Postload plasma glucose concentration and 27-year prostate cancer mortality (United States). Cancer Causes Control 2001;12:763-72.
147. Nomura AM. Body size and prostate cancer. Epidemiol Rev 2001;23:126-31.
148. Andersson SO, Baron J, Bergström R, Lindgren C, Wolk A, Adami HO. Lifestyle factors and prostate cancer risk: a case-control study in Sweden. Cancer Epidemiol Biomarkers Prev 1996;5:509-13.
149. Demark-Wahnefried W, Conaway MR, Robertson CN, Mathias BJ, Anderson EE, Paulson DF. Anthropometric risk factors for prostate cancer. Nutr Cancer 1997;28:302-7.
150. Andersson SO, Wolk A, Bergström R, Adami HO, Engholm G, Englund A, Nyrén O. Body size and prostate cancer: a 20-year follow-up study among 135006 Swedish construction workers. J Natl Cancer Inst 1997;89:385-9.
151. Hebert PR, Ajani U, Cook NR, Lee IM, Chan KS, Hennekens CH. Adult height and incidence of cancer in male physicians (United States). Cancer Causes Control 1997;8:591-7.
152. Friedenreich CM, McGregor SE, Courneya KS, Angyalfi SJ, Elliott FG. Case-control study of anthropometric measures and prostate cancer risk. Int J Cancer 2004;110:278-83.
153. Dal Maso L, Zucchetto A, La Vecchia C, Montella M, Conti E, Canzonieri V, Talamini R, Tavani A, Negri E, Garbeglio A, Franceschi S. Prostate cancer and body size at different ages: an Italian multicentre case-control study. Br J Cancer 2004;90:2176-80.
154. Ochiai A, Fritsche HA, Babaian RJ. Influence of anthropometric measurements, age, and prostate volume on prostate-specific antigen levels in men with a low risk of prostate cancer. Urology 2005;66:819-23.
155. Lundqvist E, Kaprio J, Verkasalo PK, Pukkala E, Koskenvuo M, Söderberg KC, Feychting M. Co-twin control and cohort analyses of body mass index and height in relation to breast, prostate, ovarian, corpus uteri, colon and rectal cancer among Swedish and Finnish twins. Int J Cancer 2007;121:810-8.
156. Bianchini F, Kaaks R, Vainio H. Overweight, obesity, and cancer risk. Lancet Oncol 2002;3:565-74.
157. Hsing AW, Deng J, Sesterhenn IA, Mostofi FK, Stanczyk FZ, Benichou J, Xie T, Gao YT. Body size and prostate cancer: a population-based case-control study in China. Cancer Epidemiol Biomarkers Prev 2000;9:1335-41.
158. Hsing AW, Chua S Jr, Gao YT, Gentzschein E, Chang L, Deng J, Stanczyk FZ. Prostate cancer risk and serum levels of insulin and leptin: a population-based study. J Natl Cancer Inst 2001;93:783-9.
159. Wallström P, Bjartell A, Gullberg B, Olsson H, Wirfält E. A prospective Swedish study on body size, body composition, diabetes, and prostate cancer risk. Br J Cancer 2009;100:1799-805.
160. Hubbard JS, Rohrmann S, Landis PK, Metter EJ, Muller DC, Andres R, Carter HB, Platz EA. Association of prostate cancer risk with insulin, glucose, and anthropometry in the Baltimore longitudinal study of aging. Urology 2004;63:253-8.
161. Mantzoros CS, Tzonou A, Signorello LB, Stampfer M,

Trichopoulos D, Adami HO. Insulin-like growth factor 1 in relation to prostate cancer and benign prostatic hyperplasia. Br J Cancer 1997;76:1115-8.
162. Wolk A, Mantzoros CS, Andersson SO, Bergström R, Signorello LB, Lagiou P, Adami HO, Trichopoulos D. Insulin-like growth factor 1 and prostate cancer risk: a population-based, case-control study. J Natl Cancer Inst 1998;90:911-5.
163. Kelsey JL, Gammon MD. The epidemiology of breast cancer. CA Cancer J Clin 1991;41:146-65.
164. Kaaks R, Rinaldi S, Key TJ, Berrino F, Peeters PH, Biessy C, Dossus L, Lukanova A, Bingham S, Khaw KT, Allen NE, Bueno-de-Mesquita HB, van Gils CH, Grobbee D, Boeing H, Lahmann PH, Nagel G, Chang-Claude J, Clavel-Chapelon F, Fournier A, Thiébaut A, González CA, Quirós JR, Tormo MJ, Ardanaz E, Amiano P, Krogh V, Palli D, Panico S, Tumino R, Vineis P, Trichopoulou A, Kalapothaki V, Trichopoulos D, Ferrari P, Norat T, Saracci R, Riboli E. Postmenopausal serum androgens, oestrogens and breast cancer risk: the European prospective investigation into cancer and nutrition. Endocr Relat Cancer 2005;12:1071-82.
165. Kaaks R, Berrino F, Key T, Rinaldi S, Dossus L, Biessy C, Secreto G, Amiano P, Bingham S, Boeing H, Bueno de Mesquita HB, Chang-Claude J, Clavel-Chapelon F, Fournier A, van Gils CH, Gonzalez CA, Gurrea AB, Critselis E, Khaw KT, Krogh V, Lahmann PH, Nagel G, Olsen A, Onland-Moret NC, Overvad K, Palli D, Panico S, Peeters P, Quirós JR, Roddam A, Thiebaut A, Tjønneland A, Chirlaque MD, Trichopoulou A, Trichopoulos D, Tumino R, Vineis P, Norat T, Ferrari P, Slimani N, Riboli E. Serum sex steroids in premenopausal women and breast cancer risk within the European Prospective Investigation into Cancer and Nutrition (EPIC). J Natl Cancer Inst 2005;97:755-65.
166. Campagnoli C, Clavel-Chapelon F, Kaaks R, Peris C, Berrino F. Progestins and progesterone in hormone replacement therapy and the risk of breast cancer. J Steroid Biochem Mol Biol 2005;96:95-108.
167. Xue F, Michels KB. Diabetes, metabolic syndrome, and breast cancer: a review of the current evidence. Am J Clin Nutr 2007;86:823S-35S.
168. Furberg AS, Veierød MB, Wilsgaard T, Bernstein L, Thune I. Serum high-density lipoprotein cholesterol, metabolic profile, and breast cancer risk. J Natl Cancer Inst 2004;96:1152-60.
169. Muti P, Quattrin T, Grant BJ, Krogh V, Micheli A, Schünemann HJ, Ram M, Freudenheim JL, Sieri S, Trevisan M, Berrino F. Fasting glucose is a risk factor for breast cancer: a prospective study. Cancer Epidemiol Biomarkers Prev 2002;11:1361-8.
170. Potischman N, McCulloch CE, Byers T, Houghton L, Nemoto T, Graham S, Campbell TC. Associations between breast cancer, plasma triglycerides, and cholesterol. Nutr Cancer 1991;15:205-15.
171. Marmot M, Atinmo T, Byers T, Chen J, Hirohata T, Jackson A, James WPT, Kolonel LN, Kumanyika S, Leitzmann C, Mann J, Powers HJ, Reddy KS, Riboli E, Rivera JA, Schatzkin A, Seidell, JC, Shuker DE, Uauy R, Willett W, Zeisel SH. Food, nutrition, physical activity, and the prevention of cancer: a global perspective. Washington: World Cancer Research Fund/American Institute for Cancer Research, 2007:227-38.
172. Connolly BS, Barnett C, Vogt KN, Li T, Stone J, Boyd NF. A meta-analysis of published literature on waist-to-hip ratio and risk of breast cancer. Nutr Cancer 2002;44:127-38.
173. Soler M, Chatenoud L, Negri E, Parazzini F, Franceschi S, la Vecchia C. Hypertension and hormone-related neoplasms in women. Hypertension 1999;34:320-5.
174. Hirose K, Toyama T, Iwata H, Takezaki T, Hamajima N, Tajima K. Insulin, insulin-like growth factor-I and breast cancer risk in Japanese women. Asian Pac J Cancer Prev 2003;4:239-46.
175. Verheus M, Peeters PH, Rinaldi S, Dossus L, Biessy C, Olsen A, Tjønneland A, Overvad K, Jeppesen M, Clavel-Chapelon F, Téhard B, Nagel G, Linseisen J, Boeing H, Lahmann PH, Arvaniti A, Psaltopoulou T, Trichopoulou A, Palli D, Tumino R, Panico S, Sacerdote C, Sieri S, van Gils CH, Bueno-de-Mesquita BH, González CA, Ardanaz E, Larranaga N, Garcia CM, Navarro C, Quirós JR, Key T, Allen N, Bingham S, Khaw KT, Slimani N, Riboli E, Kaaks R. Serum C-peptide levels and breast cancer risk: results from the European Prospective Investigation into Cancer and Nutrition (EPIC). Int J Cancer 2006;119:659-67.
176. Goodwin PJ, Ennis M, Pritchard KI, Trudeau ME, Koo J, Madarnas Y, Hartwick W, Hoffman B, Hood N. Fasting insulin and outcome in early-stage breast cancer: results of a prospective cohort study. J Clin Oncol 2002;20:42-51.
177. Rock CL, Demark-Wahnefried W. Can lifestyle modification increase survival in women diagnosed with breast cancer? J Nutr 2002;132:3504S-7S.
178. Tretli S. Height and weight in relation to breast cancer morbidity and mortality. a prospective study of 570,000 women in Norway. Int J Cancer 1989;44:23-30.
179. Le Marchand L, Kolonel LN, Earle ME, Mi MP. Body size at different periods of life and breast cancer risk. Am J Epidemiol 1988;128:137-52.
180. Swanson CA, Coates RJ, Schoenberg JB, Malone KE, Gammon MD, Stanford JL, Shorr IJ, Potischman NA, Brinton LA. Body size and breast cancer risk among women under age 45 years. Am J Epidemiol 1996;143:698-706.
181. Trentham-Dietz A, Newcomb PA, Storer BE, Longnecker MP, Baron J, Greenberg ER, Willett WC. Body size and risk of breast cancer. Am J Epidemiol 1997;145:1011-9.
182. Morimoto LM, White E, Chen Z, Chlebowski RT, Hays

J, Kuller L, Lopez AM, Manson J, Margolis KL, Muti PC, Stefanick ML, McTiernan A. Obesity, body size, and risk of postmenopausal breast cancer: the Women's Health Initiative (United States). Cancer Causes Control 2002;13:741-51.
183. Friedenreich CM. Review of anthropometric factors and breast cancer risk. Eur J Cancer Prev 2001;10:15-32.
184. Rinaldi S, Key TJ, Peeters PH, Lahmann PH, Lukanova A, Dossus L, Biessy C, Vineis P, Sacerdote C, Berrino F, Panico S, Tumino R, Palli D, Nagel G, Linseisen J, Boeing H, Roddam A, Bingham S, Khaw KT, Chloptios J, Trichopoulou A, Trichopoulos D, Tehard B, Clavel-Chapelon F, Gonzalez CA, Larrañaga N, Barricarte A, Quirós JR, Chirlaque MD, Martinez C, Monninkhof E, Grobbee DE, Bueno-de-Mesquita HB, Ferrari P, Slimani N, Riboli E, Kaaks R. Anthropometric measures, endogenous sex steroids and breast cancer risk in postmenopausal women: a study within the EPIC cohort. Int J Cancer 2006;118:2832-9.
185. Franceschic S, Favero A, La Vecchia C, Barón AE, Negri E, Dal Maso L, Giacosa A, Montella M, Conti E, Amadori D. Body size indices and breast cancer risk before and after menopause. Int J Cancer 1996;67:181-6.
186. Palmer JR, Adams-Campbell LL, Boggs DA, Wise LA, Rosenberg L. A prospective study of body size and breast cancer in black women. Cancer Epidemiol Biomarkers Prev 2007;16:1795-802.
187. Huang Z, Hankinson SE, Colditz GA, Stampfer MJ, Hunter DJ, Manson JE, Hennekens CH, Rosner B, Speizer FE, Willett WC. Dual effects of weight and weight gain on breast cancer risk. JAMA 1997;278:1407-11.
188. Borugian MJ, Sheps SB, Kim-Sing C, Olivotto IA, Van Patten C, Dunn BP, Coldman AJ, Potter JD, Gallagher RP, Hislop TG. Waist-to-hip ratio and breast cancer mortality. Am J Epidemiol 2003;158:963-8.
189. Hall IJ, Newman B, Millikan RC, Moorman PG. Body size and breast cancer risk in black women and white women: the Carolina Breast Cancer Study. Am J Epidemiol 2000;151:754-64.
190. Shu XO, Jin F, Dai Q, Shi JR, Potter JD, Brinton LA, Hebert JR, Ruan Z, Gao YT, Zheng W. Association of body size and fat distribution with risk of breast cancer among Chinese women. Int J Cancer 2001;94:449-55.
191. Tehard B, Clavel-Chapelon F. Several anthropometric measurements and breast cancer risk: results of the E3N cohort study. Int J Obes 2006;30:156-63.
192. Cold S, Hansen S, Overvad K, Rose C. A woman's build and the risk of breast cancer. Eur J Cancer 1998;34:1163-74.
193. Abrahamson PE, Gammon MD, Lund MJ, Flagg EW, Porter PL, Stevens J, Swanson CA, Brinton LA, Eley JW, Coates RJ. General and abdominal obesity and survival among young women with breast cancer. Cancer Epidemiol Biomarkers Prev 2006;15:1871-7.
194. Lovegrove JA. Obesity, body fat distribution and breast cancer. Nutr Res Rev 2002;15:389-412.
195. Okobia MN, Bunker CH, Zmuda JM, Osime U, Ezeome ER, Anyanwu SN, Uche EE, Ojukwu J, Kuller LH. Anthropometry and breast cancer risk in Nigerian women. Breast J 2006;12:462-6.
196. Männistö S, Pietinen P, Pyy M, Palmgren J, Eskelinen M, Uusitupa M. Body-size indicators and risk of breast cancer according to menopause and estrogen-receptor status. Int J Cancer 1996;68:8-13.
197. Ng EH, Gao F, Ji CY, Ho GH, Soo KC. Risk factors for breast carcinoma in Singaporean Chinese women. Cancer 1997;80:725-31.
198. Bruning PF, Bonfrèr JM, Hart AA, van Noord PA, van der Hoeven H, Collette HJ, Battermann JJ, de Jong-Bakker M, Nooijen WJ, de Waard F. Body measurements, estrogen availability and the risk of human breast cancer: a case-control study. Int J Cancer 1992;51:14-9.
199. Kaaks R, Van Noord PA, Den Tonkelaar I, Peeters PH, Riboli E, Grobbee DE. Breast-cancer incidence in relation to height, weight and body-fat distribution in the Dutch "DOM" cohort. Int J Cancer 1998;76:647-51.
200. Sonnenschein E, Toniolo P, Terry MB, Bruning PF, Kato I, Koenig KL, Shore RE. Body fat distribution and obesity in pre- and postmenopausal breast cancer. Int J Epidemiol 1999;28:1026-31.
201. Huang Z, Willett WC, Colditz GA, Hunter DJ, Manson JE, Rosner B, Speizer FE, Hankinson SE. Waist circumference, waist: hip ratio, and risk of breast cancer in the Nurses' Health Study. Am J Epidemiol 1999;150:1316-24.
202. Lapidus L, Helgesson O, Merck C, Björntorp P. Adipose tissue distribution and female carcinomas. a 12-year follow-up of participants in the population study of women in Gothenburg, Sweden. Int J Obes 1988;12:361-8.
203. Muti P, Stanulla M, Micheli A, Krogh V, Freudenheim JL, Yang J, Schünemann HJ, Trevisan M, Berrino F. Markers of insulin resistance and sex steroid hormone activity in relation to breast cancer risk: a prospective analysis of abdominal adiposity, sebum production, and hirsutism (Italy). Cancer Causes Control 2000;11:721-30.
204. Ballard-Barbash R. Anthropometry and breast cancer. Body size: a moving target. Cancer 1994;74:1090-100.
205. Sala E, Warren R, McCann J, Duffy S, Luben R, Day N. High-risk mammographic parenchymal patterns and anthropometric measures: a case-control study. Br J Cancer 1999;81:1257-61.
206. Crandall C, Palla S, Reboussin BA, Ursin G, Greendale GA. Positive association between mammographic breast density and bone mineral density in the Postmenopausal Estrogen/Progestin Interventions Study. Breast Cancer Res 2005;7:R922-8.
207. Thurfjell E, Hsieh CC, Lipworth L, Ekbom A, Adami HO, Trichopoulos D. Breast size and mammographic pattern in relation to breast cancer risk. Eur J Cancer

Prev 1996;5:37-41.
208. Adams C, Burke V, Beilin LJ. Accuracy of blood pressure measurement and anthropometry among volunteer observers in a large community survey. J Clin Epidemiol 2002;55:338-44.
209. Gordon C, Bradtmiller B. Interobserver error in a large scale anthropometric survey. Am J Hum Biol 1992;4:253-63.
210. Maylia E, Fairclough JA, Nokes LD, Jones MD. Can thigh girth be measured accurately? a preliminary investigation. J Sport Rehabil 1999;8:43-9.
211. Fairclough JA, Mintowt-Czyz WJ, Mackie I, Nokes L. Abdominal girth: an unreliable measure of intra-abdominal bleeding. Injury 1984;16:85-7.
212. Gibson R. Principles of Nutritional Assessment. New York: Oxford University Press, USA, 2005:233-72.
213. Sonnenschein EG, Kim MY, Pasternack BS, Toniolo PG. Sources of variability in waist and hip measurements in middle-aged women. Am J Epidemiol 1993;138:301-9.
214. Schreiner PJ, Pitkäniemi J, Pekkanen J, Salomaa VV. Reliability of near-infrared interactance body fat assessment relative to standard anthropometric techniques. J Clin Epidemiol 1995;48:1361-7.
215. Soderberg GL, Ballantyne BT, Kestel LL. Reliability of lower extremity girth measurements after anterior cruciate ligament reconstruction. Physiother Res Int 1996;1:7-16.
216. Wells JC, Treleaven P, Cole TJ. BMI compared with 3-dimensional body shape: the UK National Sizing Survey. Am J Clin Nutr 2007;85:419-25.
217. Heuberger R, Domina T, MacGillivray M. Body scanning as a new anthropometric measurement tool for health-risk assessment. Int J Consum Stud 2008;32:34-40.
218. Meunier P, Yin S. Performance of a 2D image-based anthropometric measurement and clothing sizing system. Appl Ergon 2000;31:445-51.
219. Robinette KM, Daanen H, Paquet EI. The Caesar Project: a 3-D surface anthropometry survey in Proc 2nd Int Conf 3D Digital Imaging and Modeling. Otfawa, Ont., Canada, 1999:380-6.
220. Rimm EB, Stampfer MJ, Colditz GA, Chute CG, Litin LB, Willett WC. Validity of self-reported waist and hip circumferences in men and women. Epidemiology 1990;1:466-73.
221. Shahraki T, Shahraki M, Roudbari M, Gargari BP. Determination of the leading central obesity index among cardiovascular risk factors in Iranian women. Food Nutr Bull 2008;29:43-8.
222. Turcato E, Bosello O, Di Francesco V, Harris TB, Zoico E, Bissoli L, Fracassi E, Zamboni M. Waist circumference and abdominal sagittal diameter as surrogates of body fat distribution in the elderly: their relation with cardiovascular risk factors. Int J Obes Relat Metab Disord 2000;24:1005-10.
223. Maffeis C, Pietrobelli A, Grezzani A, Provera S, Tatò L. Waist circumference and cardiovascular risk factors in prepubertal children. Obes Res 2001;9:179-87.
224. Sharp TA, Grunwald GK, Giltinan KE, King DL, Jatkauskas CJ, Hill JO. Association of anthropometric measures with risk of diabetes and cardiovascular disease in Hispanic and Caucasian adolescents. Prev Med 2003;37:611-6.
225. Rezende FA, Rosado LE, Ribeiro Rde C, Vidigal Fde C, Vasques AC, Bonard IS, de Carvalho CR. Body mass index and waist circumference: association with cardiovascular risk factors. Arq Bras Cardiol 2006;87:728-34.
226. Botton J, Heude B, Kettaneh A, Borys JM, Lommez A, Bresson JL, Ducimetiere P, Charles MA; FLVS Study Group. Cardiovascular risk factor levels and their relationships with overweight and fat distribution in children: the Fleurbaix Laventie Ville Santé II study. Metabolism 2007;56:614-22.
227. Hara M, Saitou E, Iwata F, Okada T, Harada K. Waist-to-height ratio is the best predictor of cardiovascular disease risk factors in Japanese schoolchildren. J Atheroscler Thromb 2002;9:127-32.
228. Clarke G, Whittemore AS. Prostate cancer risk in relation to anthropometry and physical activity: The National Health and Nutrition Examination Survey I Epidemiological Follow-Up Study. Cancer Epidemiol Biomarkers Prev 2000;9:875-81.
229. MacInnis RJ, English DR, Gertig DM, Hopper JL, Giles GG. Body size and composition and prostate cancer risk. Cancer Epidemiol Biomarkers Prev 2003;12:1417-21.
230. Galanis DJ, Kolonel LN, Lee J, Le Marchand L. Anthropometric predictors of breast cancer incidence and survival in a multi-ethnic cohort of female residents of Hawaii, United States. Cancer Causes Control 1998;9:217-24.
231. Tung HT, Tsukuma H, Tanaka H, Kinoshita N, Koyama Y, Ajiki W, Oshima A, Koyama H. Risk factors for breast cancer in Japan, with special attention to anthropometric measurements and reproductive history. Jpn J Clin Oncol 1999;29:137-46.
232. Li CI, Stanford JL, Daling JR. Anthropometric variables in relation to risk of breast cancer in middle-aged women. Int J Epidemiol 2000;29:208-13.
233. Tian YF, Chu CH, Wu MH, Chang CL, Yang T, Chou YC, Hsu GC, Yu CP, Yu JC, Sun CA. Anthropometric measures, plasma adiponectin, and breast cancer risk. Endocr Relat Cancer 2007;14:669-77.
234. Nemesure B, Wu SY, Hennis A, Leske MC; Barbados National Cancer Study Group. Body size and breast cancer in a black population: the Barbados National Cancer Study. Cancer Causes Control 2009;20:387-94.
235. Friedenreich CM, Courneya KS, Bryant HE. Case-control study of anthropometric measures and breast cancer risk. Int J Cancer 2002;99:445-52.
236. Shin A, Matthews CE, Shu XO, Gao YT, Lu W, Gu K,

Zheng W. Joint effects of body size, energy intake, and physical activity on breast cancer risk. Breast Cancer Res Treat 2009;113:153-61.
237. Montazeri A, Sadighi J, Farzadi F, Maftoon F, Vahdaninia M, Ansari M, Sajadian A, Ebrahimi M, Haghighat S, Harirchi I. Weight, height, body mass index and risk of breast cancer in postmenopausal women: a case-control study. BMC Cancer 2008;8:278.
238. Lahmann PH, Hoffmann K, Allen N, van Gils CH, Khaw KT, Tehard B, Berrino F, Tjønneland A, Bigaard J, Olsen A, Overvad K, Clavel-Chapelon F, Nagel G, Boeing H, Trichopoulos D, Economou G, Bellos G, Palli D, Tumino R, Panico S, Sacerdote C, Krogh V, Peeters PH, Bueno-de-Mesquita HB, Lund E, Ardanaz E, Amiano P, Pera G, Quirós JR, Martínez C, Tormo MJ, Wirfölt E, Berglund G, Hallmans G, Key TJ, Reeves G, Bingham S, Norat T, Biessy C, Kaaks R, Riboli E. Body size and breast cancer risk: findings from the European prospective investigation into cancer and nutrition (EPIC). Int J Cancer 2004;111:762-71.
239. Lahmann PH, Lissner L, Gullberg B, Olsson H, Berglund G. A prospective study of adiposity and postmenopausal breast cancer risk: the Malmö Diet and Cancer Study. Int J Cancer 2003;103:246-52.
240. Verla-Tebit E, Chang-Claude J. Anthropometric factors and the risk of premenopausal breast cancer in Germany. Eur J Cancer Prev 2005;14:419-26.
241. Riza E, Remoundos DD, Bakali E, Karadedou-Zafiriadou E, Linos D, Linos A. Anthropometric characteristics and mammographic parenchymal patterns in post-menopausal women: a population-based study in Northern Greece. Cancer Causes Control 2009;20:181-91.
242. Ferrario M, Carpenter MA, Chambless LE. Reliability of body fat distribution measurements. The ARIC Study baseline cohort results. Atherosclerosis Risk in Communities Study. Int J Obes Relat Metab Disord 1995;19:449-57.

肥胖相關代謝疾病及癌症的體表計測指數

楊朝陽 彭茜瑜 劉英傑 陳文誌 邱文科

代謝症候群、心血管疾病及部份癌症（如：結腸癌，攝護腺癌及乳癌）被認定爲肥胖相關之疾病，肥胖形成期間多餘脂肪被儲存於人體不同部位並改變人體代謝及賀爾蒙狀態。體表計測指數有助於該疾病的早期篩檢，其應用性、可信度及趨勢也被大量的討論，然而過去的研究並未有共識，例如：研究顯示腹圍尺寸，已廣爲用於心血管疾病及結腸癌風險評量，但腹圍與代謝症候群卻需要更多證據，來證實與攝護腺癌及乳癌的關連性；經常被用來判斷肥胖的身體質量指數，對於男性及年輕女性結腸癌發生率有高度關連性，但在乳癌的發生率尚無一致發現。交叉比對各體表計測指數，發現腰身高比及腰臀比可提高與這些疾病的聯結性，如：腰身高比於心血管疾病、腰臀比於結腸癌，此概念被更進一步應用在複合指數探討，如腰身高比與腰臀比間，有著對於亞洲人發生代謝症候群風險的關連性。最後，測量的準確度（包括工具及技巧）是影響疾病預測的重要因素，高精度的三次元人體測量技術，已逐步發展爲預防醫學的輔助工具。(長庚醫誌 2011;34:1-22)

關鍵詞：肥胖，體表計測指數，代謝症候群，心血管疾病，癌症，量測誤差

長庚大學 工業設計學系
受文日期：民國99年5月3日；接受刊載：民國99年9月8日
通訊作者：邱文科教授，長庚大學 工業設計學系。桃園縣333龜山鄉文化一路259號。Tel.: (03)2118800轉5422;
Fax: (03)2118500; E-mail: wkchiu@mail.cgu.edu.tw